Submission No. 504

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Research Director
Agriculture and Environment Committee
Parliament House, BRISBANE QLD 4000

To: Agriculture and Environment Committee

Re: Vegetation Management (Reinstatement) and Other Legislation Amendment Bill 2016

From: Concerned group of senior Queensland environmental scientists

We are a group of 28 expert independent environmental scientists based at Universities and research institutions across Queensland. Collectively, our expertise covers biodiversity and ecology (land and water), land degradation, climate change, carbon accounting, remote sensing, environmental policy and resource management. Each of us has a distinguished scholarly reputation, and holds a senior position of responsibility in our organisations.

We make this submission to demonstrate the strong scientific consensus about the multiple important ecological functions of retained native vegetation, and the wide range of adverse undesirable and long-term consequences for land, water, climate and biodiversity that result from increased land clearing.

Attempts to reverse these consequences after clearing has occurred are not only expensive, but often of limited effectiveness. It is far more cost-effective to avoid land clearing in the first instance, rather than later to attempt repair of the resulting environmental damage.

The purpose of the Vegetation Management Act 1999 (henceforth "VMA") is to regulate the clearing of vegetation in order to achieve specified ecological outcomes, including: preventing loss of remnant regional ecosystems, avoiding land degradation, preventing loss of biodiversity, maintaining ecological processes, reducing greenhouse gas emissions and allowing for ecologically sustainable land use (VMA Section 3[1]). This Section of the Act also specifies application of the precautionary principle: "*lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment if there are threats of serious or irreversible environmental damage*"[1].

We submit that increased clearing of native woody vegetation enabled by the current VMA (as amended in 2013) has outcomes that are contrary to the Act's purpose. Re-strengthening Queensland's ability to regulate the clearing of native vegetation across all land tenures, through legal mechanisms, is a crucial component of any effective policy framework for ensuring future environmental and economic sustainability.

We support the currently proposed amendments outlined in the Bill, but note they are unlikely to address fully the recently-observed very large increases in clearing of native vegetation.

We also request an opportunity to provide evidence in person at the Committee's public hearing on this matter. If invited to attend the hearing, selected representatives will attend.

The following section provides a summary of relevant specific issues, with reference to key scientific sources.

Specific issues related to vegetation clearing and the Queensland VMA

Below we explain the basis of our submission. The current form of the Act is referred to as "VMA 2013". Details of the scientific publications and data supporting each point are provided at the end of this submission, cross-referenced to the relevant section. These documents are available on request; most are provided at: https://drive.google.com/folderview?id=0BxprmX5WkYonTllxT01xdzd1am8&usp=sharing_eid&ts=5719739b.

First, we consider the evidence that VMA 2013 has enabled a substantial increase in vegetation clearing.

Second, we outline different ecological functions of native vegetation cover: for terrestrial biodiversity and ecosystems, streambank stability and stream quality, coastal waters and biodiversity (including the Great Barrier Reef), regional climate, atmospheric carbon and climate change. For these functions, we also outline the adverse consequences of increased vegetation loss.

Third, we explain the significance of regrowth vegetation for various functions, and **finally we comment on achieving sustainable land use**. We also highlight the high **costs of repairing the damage** caused by broadscale vegetation clearing.

Evidence that the 2013 VMA amendments increased vegetation clearing

The Statewide Land and Trees Survey (SLATS) monitors change in woody vegetation extent in Queensland[2a]. The recent SLATS report[2b] for the years 2012-13 and 2013-2014 showed that, while annual rates of land clearing had steadily reduced over the decade 2000-2010, they are now increasing steeply. For example, 296,000 ha of native vegetation were cleared in 2013-14 compared with 78,000 ha in 2009-10.

This report[2b] also shows that:

- this recent clearing was of both remnant vegetation and regrowth, including mature regrowth of threatened ecosystems. The cleared remnant vegetation included all threat categories ('Least Concern', 'Of Concern' and 'Endangered'; and
- clearing was spread across the state, being particularly high in the Brigalow Belt, which is a national biodiversity hotspot.

Recent independent analysis[2c] of the Queensland government's data has shown that, between 2011-12 and 2013-14, annual clearing increased by:

- 270% for 'Least Concern' Regional Ecosystems (REs);
- 309% for 'Of Concern' REs; and
- 58% for 'Endangered' REs.

Such high clearing rates have not been seen since prior to the phasing out of broadscale clearing in 2006[2d].

Much of the native vegetation cleared after VMA 2013 was in areas mapped as potential habitat for threatened species[2e].

This evidence indicates a **failure of the VMA in its current form to meet two of its stated purposes** – conserving regional ecosystems that are "Endangered" and "Of Concern"; and preventing the loss of biodiversity.

Ecological functions and current status of Queensland's native woody vegetation

Native woody vegetation supports the health of Queensland's environment through a diverse range of ecological functions, all of which are placed at risk by increased land clearing. Below we outline the scientific basis of, and evidence for, the need to strengthen the VMA's ability to meet its stated purposes of: ensuring that clearing does not cause land degradation; preventing the loss of biodiversity; and maintaining ecological processes.

We do this for five important ecological functions.

1. Terrestrial biodiversity and ecosystems

The total extent of native vegetation in a landscape is the most important factor in determining how many species that the landscape can support[3a].

Native vegetation also contributes to species' ability to move or disperse through the landscape; without this movement threatened species in Australia are at much greater risk of extinction[3b]. Movement capacity will become even more crucial as climate change forces species to shift their ranges[3c].

Old-growth vegetation has especially high biodiversity values because regrowth vegetation after clearing lacks certain important habitat features that are essential to sustain some species (for example, tree hollows, which can take centuries to form)[3d].

Additionally, increased cover of native vegetation reduces the impact of invasive predators (such as feral cats) on threatened fauna, and is likely to be crucial in enabling native fauna to escape cat predation. This reduces the amount (and financial cost) of predator control[3e].

Queensland has a lower percentage of its land in protected areas (conservation reserves) than any other Australian State or Territory[3f]. Therefore, Queensland's vegetation outside of these reserves is especially important to biodiversity and ecosystem function. However, the Brigalow Belt and Mulga Lands bioregions, both of which have less than 5% of land in protected areas, had the greatest clearing rates in 2012-2014[3g].

2. Catchment erosion, water security and aquatic ecosystem health

Riparian condition (the amount and quality of forest vegetation cover along the margins of watercourses) is the main factor that influences the water quality and ecosystem heath of Queensland's rivers[4a]. Vegetation clearing is a major cause of riparian land degradation (loss of condition), and therefore the single most important management preventive action is to protect (and restore) riparian vegetation[4b].

Recent research in several of Queensland's major coastal catchments has shown that most of the sediment entering water storages and coastal environments originated from erosion of stream banks and gullies[5b]. This erosion often accounts for more than 90% of the sediment[4c], and it has been caused mainly by degradation of riparian lands.

This degradation of riparian lands by vegetation clearing threatens water security. For example, during the 2011 flood, Brisbane came within 6 hours of running out of water when the Mt Crosby treatment plant was overwhelmed with sediment; the estimated cost of sedimentation to water storage capacity and treatment in SEQ is over $7M pa, and could increase by more than $32M pa by 2031 if not addressed[4d].

Road infrastructure and valuable farmland are at risk from riparian land degradation[4e]. For example, 477,670 tonnes of soil, with estimated value $14.3M, were eroded from a single 278 hectare farm during the 2011 Brisbane river flood[4f]; protecting and restoring riparian vegetation is essential to reduce the risk of such erosion during extreme weather events.

Several of Queensland's endangered freshwater species depend on protecting riparian vegetation[4g]. Riparian vegetation is also particularly important for terrestrial wildlife. For example, more than 50% of all the koalas in the nationally significant Mulga Lands population are found in the 1% of the vegetation that is along river and stream banks[4h].

3. Coastal waters and biodiversity, including the Great Barrier Reef

Pollution of rivers with sediment and nutrients resulting from riparian degradation affects both the rivers themselves (as described in the previous section) and the coastal environments into which they flow. Therefore the amount and quality of forest vegetation cover near to watercourses is also a major factor influencing Queensland's coastal environments, including Moreton Bay and the Great Barrier Reef.

A. Moreton Bay

Coastal inputs from runoff when catchment vegetation has been cleared are much greater than for the same catchment if vegetation was retained: for Moreton Bay this is estimated to be 50-200 times greater for soil; 25-60 for phosphorus and 1.6-4.1 times greater for nitrogen [5a]. Sedimentation of Moreton Bay has increased since historical vegetation clearing in its catchment[5b]. During the 2011 floods, a 3- to 10-fold increase in sediment deposition into the Bay required months of costly additional dredging works[5c].

B. Great Barrier Reef

Maintaining and improving water quality and condition of biodiversity in the coastal waters of the Great Barrier Reef (GBR) lagoon are central to the success of the Reef 2050 Plan[5d].

Retaining sufficient native vegetation cover, especially in riparian zones and steeper topography, is crucial to limiting soil erosion (see previous section) and consequent runoff to the GBR, and evidence has shown clearly the impact of soil stability in GBR catchments on reef water quality[5e].

Deterioration of water quality in the GBR lagoon resulting from loss of catchment vegetation cover threatens a wide range of GBR ecosystems. For example, increased fine sediment loads due to catchment runoff affect seagrasses and corals by increasing turbidity and reducing light penetration[5f].

However, 38% of the clearing under VMA 2013 was done in catchments that drain to the Great Barrier Reef[5g].

Such losses risk reversing the beneficial effects of recent investments in improving reef water quality; the estimated cost of counteracting the water quality decline (based on estimates included in regional Water Quality Improvement Plans) over ten years is as high as $5-10 billion[5h].

Queensland's Auditor-General recently recommended that stronger legislation would be essential to reducing harmful catchment runoff to the Great Barrier Reef[5i].

4. Atmospheric carbon and climate change

Queensland's native vegetation cover is vital to limiting Australia's greenhouse gas emissions, because retained woody vegetation can store large amounts of carbon, whereas clearing this vegetation will release the carbon into the atmosphere[6a].

Carbon emissions from land clearing in Queensland in 2013-14 were 35.8 million tonnes per year under VMA 2013: more than double the emissions rate from land clearing in 2009-10, when clearing rates were lowest (77,590 ha/year)[6b].

Note that these estimates, from Queensland's SLATS data, are more reliable than those of Australia's National Carbon Accounting System (which has produced lower emissions estimates for 2013-14)[6c].

At the average cost of $13/tonne, Emissions Reduction Fund payments required to counter just the increase in Queensland's land clearing emissions since 2009-10 would be approximately $257 million per year were the most recent rates of land clearing to continue[6d].

Retaining native vegetation provides an enormous opportunity for avoiding potential carbon emissions[6e].

5. Regional climate

The loss of native vegetation from the landscape affects not only the global climate through carbon emissions, but also regional climate and drought severity. For example, the extensive clearing of native woody vegetation for crops and improved pastures in Queensland's inland regions has been shown to cause increased temperature (especially in summer) and decreased rainfall, as well as reduced soil moisture [7a].

This has important implications for agriculture and the environment under an already warming climate, because vegetation management policies that allow the further conversion of woody vegetation will exacerbate this trend and result in more severe and more frequent droughts and heatwaves.

Roles of regrowth and restored vegetation

Older regrowth vegetation has acquired a partial range of important ecological functions and is on track to develop others over time. For restoring native vegetation, it is more cost effective to retain older regrowth than to invest in tree planting projects. Clearing of high value regrowth risks loss of biodiversity, ecological degradation, and financial waste because it then becomes necessary to invest in active restoration, as outlined below.

Values of regrowth to ecological functions

Very young regrowth vegetation typically has fewer species and a simpler structure than old-growth vegetation, and therefore supports fewer species[8a]. However, within a few decades, regrowth vegetation starts to make important contributions to biodiversity and ecological processes. For example, brigalow regrowth older than about 30 years supports similar bird diversity to old-growth brigalow, and retaining regrowth also helps to increase the number of species that a landscape can support[8a].

Allowing regrowth to mature is important to biodiversity and threatened species because some old-growth habitat features, such as hollow trees, large flowering/fruiting trees, coarse woody debris, and the functions they perform, require many more decades to develop, if the regrowth is protected[8b].

Carbon stocks also accumulate over time as regrowth matures. Older, larger trees hold more carbon than young, dense regrowth. Allowing regrowth to mature is a highly efficient way to sequester carbon, especially in Queensland[8c], because carbon stocks also accumulate over time as regrowth matures

Within a few decades, regrowth vegetation can also contribute substantially to catchment protection[8d].

Category C "high value" regrowth (as used in the VMA) is now likely to be more than 30 years old, and is therefore likely to have a range of habitat values and ecological functions partly or well-developed. However, clearing will revert these values to zero, resulting in loss of present biodiversity and function, and of the important potential for further recovery (see also next section)

Cost of replacement through active restoration

Australia spends millions of dollars each year on tree planting projects. For example, Caring for our Country and Biodiversity Fund grants reported just over 42,000 hectares of replanting since 2013[9a], yet nearly 300,000 ha of Queensland's native vegetation were cleared in 2013-14[2b]. The Commonwealth is currently investing A$50 million to replace 20 million trees over five years by 2020, as part of the '20 million trees' Program[9a]. However, at current rates, just one year of land clearing in Queensland removes more than 20 million trees.

And furthermore, the cost per hectare to successfully replant native vegetation is so large that only small areas can be restored, and even then the result after 2-3 decades is inferior in biodiversity and ecosystem function to intact remnant vegetation. For example, woodland replanting costs up to $20K per hectare, to partially restore vegetation structure and diversity[9b], and tropical rainforest replanting costs $20-30K (and up to $50k) per hectare with only partial success at recovering forest-like biodiversity and function after 2-3 decades[9c]. Smaller per hectare investments, using cheaper plantings of lower diversity and tree density, result in even poorer function and slower development [9d]. The cost of effectively stabilising river-banks following deforestation can range from A$16,000 to A$5 million per kilometre[9e].

Retaining already-established regrowth vegetation achieves a range of environmental benefits (see previous section), for a fraction of what it would cost to later compensate for vegetation clearing by funding tree-planting projects. Many Queensland ecosystems can readily regenerate passively through unassisted regrowth, and this capacity provides a significant opportunity to achieve the same restoration goals at a substantially reduced cost.

Sustainable land use

A large proportion of land suitable for intensive agricultural cropland has already been cleared, and provides a basis for Australia's food production. Regulation of the clearing of native vegetation does not restrict existing agricultural productivity, but rather it seeks to make it more sustainable. Retained trees have benefits for the amelioration of many environmental risks that hamper agricultural productivity, including animal health, long-term pasture productivity and hydrological risks[10].

Recent pastoral production has suffered from drought, but land clearing cannot be an effective quick-fix drought remedy, because such a solution leads to environmental degradation in the longer term – for example, drought risks will increase with further tree clearing, as described previously[7].

Sustainable land use requires the retention of native vegetation, not its ongoing destruction.

Signed:

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Signatories to this submission

	Name	Position	Institution	Expertise
1	**Associate Professor Martine Maron**	ARC Future Fellow and Associate Professor; Deputy Director, NESP Threatened Species Recovery Hub	The University of Queensland	Applied ecology, conservation policy, environmental offsetting
2	**Professor Carla Catterall**	Professor of Ecology, Griffith School of Environment	Griffith University	Wildlife ecology, forest restoration, environmental management
3	**Professor Marc Hockings**	Deputy Head, School of Geography, Planning and Environmental Management; Vice-Chair (Science) IUCN World Commission on Protected Areas	The University of Queensland	Protected area management, environmental policy, conservation monitoring and evaluation
4	**Associate Professor Kerrie Wilson**	ARC Future Fellow and Associate Professor; Deputy Director, Centre for Biodiversity & Conservation Science	The University of Queensland, The University of Copenhagen	Applied conservation resource allocation; biodiversity conservation and ecosystem services
5	**Professor Hugh Possingham**	ARC Laureate Fellow; Directory, ARC Centre of Excellence in Environmental Decisions & NESP Threatened Species Recovery Hub	The University of Queensland	Decision science, conservation planning, optimal monitoring, threatened species management, marine and terrestrial ecology
6	**Professor Stuart Bunn**	Director, Australian Rivers Institute	Griffith University	Freshwater ecology, water quality, flow management and aquatic ecosystem health
7	**Professor Richard G. Pearson**	Emeritus Professor, College of Science and Engineering	James Cook University	Freshwater and terrestrial ecology
8	**Professor Steven Turton**	Professor, Centre for Tropical Environmental and Sustainability Studies	James Cook University	Climate change impacts and adaptation, natural resource management, tropical rainforest disturbance ecology
9	**Professor Jean-Marc Hero**	Professor, School of Environment Environmental Futures Research Institute	Griffith University	Conservation and biodiversity, amphibian conservation, climate change, wildlife disease
10	**Professor William F. Laurance**	Distinguished Research Professor & ARC Laureate Fellow	James Cook University	Deforestation, forest fragmentation, tropical conservation biology, climate change, conservation policy
11	**Associate Professor Jonathan Rhodes**	Associate Professor, School of Geography, Planning and Environmental Management	The University of Queensland	Biodiversity and ecosystem services, wildlife spatial ecology, conservation planning
12	**Associate Professor Paul Dargusch**	Associate Professor, School of Geography, Planning and Environmental Management	The University of Queensland	Climate change mitigation, carbon and energy management
13	**Dr Diana Fisher**	Senior Lecturer & ARC Future Fellow	School of Biological Sciences	Extinction risk, mammal ecology

14	**Dr Greg Baxter**	Senior Lecturer in Wildlife Ecology; School of Geography, Planning and Environmental Management	The University of Queensland	Wildlife management, biodiversity conservation
15	**Professor Clive McAlpine**	Professor, School of Geography, Planning and Environmental Management	The University of Queensland	Landscape ecology, threatened species conservation, climate change, koala ecology
16	**Professor Stuart Phinn**	Director, Remote Sensing Research Centre, Australian Earth Observation Community Coordination Group	The University of Queensland	Application of satellite and airborne images with field data for mapping and monitoring environmental change in terrestrial and marine environments.
17	**Professor Karen Hussey**	Deputy Director, Global Change Institute	The University of Queensland	Environmental policy and economics, specifically in relation to water resource management, energy policy, waste, climate adaptation, agriculture and international trade.
18	**Professor Ove Hoegh-Guldberg**	Director, Global Change Institute	The University of Queensland	Marine scientist with expertise in the ecology of reefs, climate change science, and water quality.
19	**Professor Bob Pressey**	Distinguished Research Professor and Program Leader, Conservation Planning	James Cook University	Biodiversity, conservation science, conservation policy
20	**Mr Jon Brodie**	Chief Research Officer, TropWATER (Centre for Tropical water and Aquatic Ecosystem Research)	James Cook University	Marine and freshwater quality, coral reef health
21	**Associate Professor Andrew Le Brocque**	Associate Professor (Ecology & Sustainability), Faculty of Health, Engineering & Sciences	University of Southern Queensland	Plant ecology, vegetation management, hydrological function, conservation ecology
22	**Associate Professor Rod Fensham**	School of Biological Sciences	The University of Queensland	Ecology and Conservation of Queensland' vegetation
23	**Associate Professor James Watson**	Deputy Director, Centre for Biodiversity & Conservation Science; President, Society for Conservation Biology	The University of Queensland	Climate change adaptation, threatened species planning, protected area management and planning
24	**Associate Professor Richard Fuller**	ARC Future Fellow, School of Biological Sciences	The University of Queensland	Conservation planning, shorebird conservation, urban ecology
25	**Mr Phil Shaw**	Managing Director	ecosure	environmental management, vegetation management planning
26	**Professor Damien Burrows**	Director, TropWATER (Centre for Tropical water and Aquatic Ecosystem Research)	James Cook University	Aquatic ecology and catchment management
27	**Associate Professor Noam Levin**	Visiting Research Fellow, School of Geography, Planning and Environmental Management	The University of Queensland	Remote sensing, systematic conservation planning, landscape change
28	**Associate Professor Salit Kark**	School of Biological Sciences	The University of Queensland	Invasive species, avian ecology, conservation planning

Cited information sources (these sources match the superscript numbers in the submission's text)

1 Vegetation Management Act 1999. Current as at 11 September 2015.< www.legislation.qld.gov.au>

2. Supporting information re "Evidence that the 2013 VMA amendments increased vegetation clearing"

2a. The mapping in the SLATS process is recognised as international best practice for detecting woody vegetation removal. It is highly labour intensive and has been developed over a 15 year period, using ongoing fieldwork across the state, a growing archive of satellite image and vegetation maps now produced yearly, and gradually improved methods to reduce error levels.

The SLATS mapping process is for clearing only, and does not produce a product from which regrowth extent can be inferred as its methodology does not reliably identify young regrowth as distinct from changes in foliage density except in producing its data on clearing (total foliage removal).

2b. SLATS report 2012-14:

Department of Science Information Technology Innovation and the Arts. (2015). Land Cover Change in Queensland 2012-13and 2013-14. Statewide Landcover and Trees Study (SLATS) Report. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

This report presents details of the following information.

- From a low of less than 100,000 hectares cleared in 2009-10, 296,000 hectares of native woody vegetation were cleared in 2013-14, the most recent year for which data are available.
- These 296,000 hectares included 103,308 ha of remnant native vegetation and 27,721 hectares of high-value regrowth (mature regrowth of threatened ecosystems).
- Continued loss of mature regrowth of 'Of Concern' and 'Endangered' ecosystems has occurred, which prevents their recovery and removal from the threatened list.
- The rate of loss of 'Of Concern' remnant ecosystems has increased, further threatening the persistence of these ecosystems and preventing their recovery.
- The vegetation loss was spread across the state, with particularly high rates of clearing in the Brigalow Belt north and south bioregions, which are national biodiversity hotspots.

2c. Recent independent analysis of annual clearing (by Assoc. Prof. J. R. Rhodes) for 'Not Of Concern', 'Of Concern' and 'Endangered' Regional Ecosystems has used GIS to overlay the SLATS data on land clearing and the previously-known distribution of regional ecosystems. The results show that between 2011/12 and 2013/14 the anthropogenic clearing rate of 'Of Concern' Regional Ecosystems more than tripled (rising from 33 km^2 in 2011/12 to 102 km^2 in 2013/14) and the clearing rate of 'Endangered' Regional Ecosystems increased 58% (rising from 12 km^2 in 2011/12 to 19 km^2 in 2013/14), with clearing of 'Least Concern' Regional Ecosystems increasing 270%(rising from 310 km2 in 2011/12 to 837 km2 in 2013/14).

To perform this analysis, SLATS land clearing data and the regional ecosystem mapping version 9.0 provided by Department of Science Information Technology Innovation and the Arts were used. Raster data sets of the proportion of each VMA Class in 25m x 25m resolution cells were generated to match the resolution of the corresponding FPC data. This produced raster layers of the distribution of Least Concern, Of Concern, and Endangered vegetation communities across Queensland. Next the raster cells cleared in each year based on the SLATS woody vegetation clearing data were identified and the proportion of each cell cleared that was classified as Least Concern, Of Concern, and Endangered under the VMA was identified from the previously created raster layer. This was used to calculate the area cleared (km2) of each VMA Class (Least Concern, Of Concern and Endangered) in each year in Queensland (tree loss). To ensure only anthropogenic was considered clearing, natural disaster damage and natural tree death were excluded from these estimates.

2d. These recent clearing rates have not been seen since prior to the phasing out of broadscale clearing in 2006. There is a huge scientific literature on this subject. See for example:

Department of Science Information Technology Innovation and the Arts (2015) *Land Cover Change in Queensland 2012-13 and 2013-14. Statewide Landcover and Trees Study (SLATS) Report*.. Vegetation

clearing rates in Queensland. Supplementary report. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

2e. http://www.wwf.org.au/?15660/More-than-40000-hectares-of-koala-habitat-cleared

3. Supporting information re "Terrestrial biodiversity and ecosystems"

3a. The total extent of vegetation in a landscape is the most important factor in determining how many species that landscape can support. See:

Pimm, S.L., Raven, P. (2000) Biodiversity: extinction by numbers. Nature 304: 843-843

Fahrig, L., (2001) Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management 61: 603–610.

Radford, J.Q., Bennett, A.F., Cheers, G.J. (2005) Landscape-level thresholds of habitat cover for woodland-dependent birds. Biological Conservation 124: 317-337.

3b. Native vegetation also contributes to these species' ability to move or disperse through the landscape; without this movement, threatened species in Australia are at much greater risk of extinction. There is a very large literature on this subject; for example, see:

Brooker, L., Brooker, M., Cale, P. (1999) Animal dispersal in fragmented habitat: measuring habitat connectivity, corridor use, and dispersal mortality. Conservation Ecology [online] 3(1): 4. URL: http://www.consecol.org/vol3/iss1/art4/.

Soulé, M.E., Mackey, B.G., Recher, H.F., Williams, J.E., Woinarski, J.C.Z., Driscoll, D., Dennison, W., Jones, M., 2004. The role of connectivity in Australian conservation. Pacific Conservation Biology 10, 266-279.

3c. Movement capacity will become even more crucial as climate change forces species to shift their ranges. See:

Travis, J.M.J., Delgado, M., Bocedi, G., Baguette, M., Bartoń, K., Bonte, D., Boulangeat, I., Hodgson, J.A., Kubisch, A., Penteriani, V., Saastamoinen, M., Stevens, V.M., Bullock, J.M. (2013) Dispersal and species' responses to climate change. Oikos 122: 1532-1540

Reside, A.E., VanDerWal, J., Kutt, A.S. (2012) Projected changes in distributions of Australian tropical savanna birds under climate change using three dispersal scenarios. Ecology and Evolution 2:705-718

3d. Supporting evidence or ref(s) for "Old-growth vegetation has especially high biodiversity values, because regrowth vegetation after clearing lacks certain important habitat features that are essential to sustain some species features (for example tree hollows, which can take centuries to form). See:

Department of Sustainability and Environment (2003) Loss of hollow-bearing trees from Victorian native forests and woodlands Action Statement No. 192, State of Victoria

Remm J, Lohmus A (2011) Tree cavities in forests - The broad distribution pattern of a keystone structure for biodiversity. Forest Ecology and Management 262: 579–585.

3e. There is strong evidence that invasive predators such as cats are only able to have such severe effects on threatened fauna because clearing and vegetation degradation gives invasive species an advantage when hunting(Doherty et al. 2015). Retaining intact savanna vegetation gives threatened tropical mammals a chance against cats (Woinarski et al. 2015). See:

Doherty, T. S., Davis, R., van Etten, E., Algar, D., Collier, N., Dickman, C., Edwards, G., Masters, P., Palmer, R., & Robinson, S., 2015. A continental-scale analysis of feral cat diet in Australia. Journal of Biogeography, 42: 964-975

Woinarski, J.C.Z., Burbidge, A.A., Harrison, P.L., 2015. Ongoing unraveling of a continental fauna: Decline and extinction of Australian mammals since European settlement. Proceedings of the National Academy of Sciences. 112: 4531-4540 doi:10.1073/pnas.1417301112

3f. Only 8.16% of Queensland is in protected areas (CAPAD 2014 data). All jurisdictions in Australia have committed to establishing a comprehensive, adequate and representative system of protected areas (National Reserves System Task Group, 2009) that conserve the full diversity of biogeographic regions.

However, only four of the 18 biogeographic regions that occur in Queensland have greater than 15% of the area in reserves. See:

CAPAD (2014) Collaborative Australian Protected Areas Database . Department of the Environment, Canberra. http://www.environment.gov.au/land/nrs/science/capad.

National Reserve System Task Group (2009) Australia's Strategy for the National Reserve System 2009-2030. Canberra: Department of the Environment, Water, Heritage and the Arts.

3g. However, the Brigalow Belt and Mulga Lands bioregions, both of which have less than 5% of land in protected areas, had the greatest clearing rates in 2012-2014. See:

Department of Science Information Technology Innovation and the Arts (2015) *Land Cover Change in Queensland 2012-13 and 2013-14. Statewide Landcover and Trees Study (SLATS) Report*. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

4. Supporting information re "Catchment erosion, water security and aquatic ecosystem health"

4a. River health in Queensland (measured in terms of water quality, biodiversity and ecosystem processes) is primarily influenced by riparian condition (i.e. the extent and quality of forest vegetation cover along the margins of watercourses), especially in rural lands. See information in:

Bunn, S.E., Davies, P.M. & Mosisch, T.D. (1999). Ecosystem measures of river health and their response to riparian and catchment degradation. Freshwater Biology 41, 333-345.

Peterson, E.E., Sheldon, F., Darnell, R., Bunn, S.E. and Harch, B.D. (2011). A comparison of spatially explicit landscape representation methods and their relationship to seasonal stream conditions. Freshwater Biology 56, 590-610.

Sheldon, F., Peterson, E.E., Boone, E.L., Sippel, S., Bunn, S.E. and Harch, B.D. (2012). Identifying the spatial scale of land-use that most strongly influences overall river ecosystem health score. Ecological Applications 22, 2188–2203.

4b. protection and, where necessary, targeted rehabilitation of riparian vegetation is the single most important management action to address the threat of degradation resulting from poor riparian land management. See information in:

Allan, J.D.(2004).Landscape and riverscapes:the influence of land use on river ecosystems. Annual Review of Ecology, Evolution and Systematics 35, 257–284.

Lovett, S. & Price, P. (eds.) (2007). Principles for riparian lands management. Land and Water Australia, Canberra.

4c. Studies conducted in several catchments along the Queensland coast have confirmed that most (often exceeding 90%) of the sediment entering water storages and coastal environments comes from channel erosion (i.e. stream banks and gullies). See information in:

Caitcheon, G., Olley, J., Pantus, F., Hancock, G., and Leslie, C., (2012). The dominant erosion processes supplying fine sediment to three major rivers in tropical Australia, the Daly (NT), Mitchell (Qld) and Flinders (Qld) Rivers. Geomorphology 151, 188-195.

Olley, J.M., Brooks, A., Spencer, J.S., Pietsch, T., Borombovits, D.K., (2013a). Subsoil erosion dominates the supply of fine sediment to rivers draining into Princess Charlotte Bay, Australia. Journal of Environmental Radioactivity 124, 121-129.

Olley, J.M., Burton, J., Smolders, K., Pantus, F., Pietsch, T. (2013b) The application of fallout radionuclides to determine the dominant erosion process in water supply catchments of subtropical South-East Queensland, Australia. Hydrological Processes 27, 885-895.

Burton, J., Furuich,i T., Lewis, S., Olley, J., Wilkinson, S. (2014). Identifying Erosion Processes and Sources in the Burdekin Dry Tropics Catchment - Synthesis Report. Department of Science, Information Technology and Innovation, Brisbane.

4d. In the 2011 flood, Brisbane was within 6 hours of running out of water because the Mt Crosby treatment plant was overwhelmed with sediment. The loss of water storage capacity in SEQ from sedimentation and sediment removal at the treatment plant is estimated to cost over $7M pa, and water treatment costs could increase by in excess of $32M pa by 2031 if this is not addressed. See:

Marsden Jacob Associates (2011). The future of our bay. Report to Queensland Department of Environment and Resource Management.

4e. Road infrastructure and valuable farmland are at risk from riparian land degradation. See:

Thornton, C.M., Cowie, B.A., Freebairn, D.M. Playford, C.L. (2007) The Brigalow Catchment Study: II. Clearing brigalow (*Acacia harpophylla*) for cropping or pasture increases runoff. Australian Journal of Soil Research 45: 496-511.

4f. LiDAR analysis of a 278 hectare farm area in Tenthill by SEQ Catchments after the 2013 flood showed that 477,670 tonnes of soil were lost. Using a replacement cost of $30 per tonne, this was estimated as a loss of $14.3M of productive soil from a single event. Unpublished data. SEQ Catchments.

4g. Protection and rehabilitation of riparian lands is recognized as a key management action to reduce the threats to several endangered freshwater species in Queensland. For example:

http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=83806

4h. More than 50% of all the koalas in the nationally significant Mulga Lands population are found in the 1% of the vegetation that is along river and stream banks. See:

Sullivan, B.J., Baxter, G.S., Lisle, A.T., Pahl, L. & Norris, W.M. (2004) Low-density koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. IV. Abundance and conservation status. Wildlife Research, 31, 19-29.

5. Supporting information re "Coastal waters and biodiversity, including the Great Barrier Reef"

5a. Modelling of water quality data from Moreton Bay catchments has shown that the sediment yield per unit area from a catchment containing no remnant riparian vegetation is predicted to be between 50 and 200 times that of a fully vegetated channel network; total phosphorus between 25 and 60 times; total nitrogen between 1.6 and 4.1 times. See:

Olley, J., Burton, J., Hermoso, V., Smolders, K., McMahon, J., Thomson, B., Watkinson, A., (2015) Remnant riparian vegetation, sediment and nutrient loads, and river rehabilitation in subtropical Australia, Hydrological Processes 29, 2290-2300.

5b. The infilling of Moreton Bay with sediment has been greatly accelerated by historical clearing of catchment vegetation. See:

Coates-Marnane, J., Olley, J., Burton, J., Sharma, A. (submitted). Catchment clearing accelerates the infilling of a shallow sub-tropical bay in east coast Australia. Estuarine, Coastal and Shelf Science. Draft available to Committee on request.

5c. In an average year, 100,000-300,000 m^3 of sediment is dredged from the Port of Brisbane and Moreton Bay to ensure navigable shipping channels. However, the floods in January 2011 deposited more than 1 million m3 of additional material into the channels and berths, which added several extra months of work to the dredging schedule. See:

Marsden Jacob Associates (2011). The future of our bay. Report to Queensland Department of Environment and Resource Management.

5d. Reef 2050 Plan:

Commonwealth of Australia (2015) Reef 2050 Long-Term Sustainability Plan http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan.

5e. Evidence has shown clearly the impact of soil stability in GBR catchments on reef water quality; see:

Waters, D.K., Carroll C., Ellis, R., Hateley L., McCloskey J., Packett R., Dougall C., Fentie B. (2014) Modelling reductions of pollutant loads due to improved management practices in the Great Barrier Reef catchments – Whole of GBR, Technical Report, Volume 1, Queensland Department of Natural Resources and Mines, Toowoomba, QLD

5f. Fine sediment loads entering the lagoon cause extra turbidity and reduced light, which affect seagrasses and corals.

Fabricius, K.E., Logan, M., Weeks, S., Brodie, J. (2014) The effects of river run-off on water clarity across the central Great Barrier Reef. Marine Pollution Bulletin 84: 191-200

Fabricius, K.E., Logan, M., Weeks, S.J., Lewis, S.E., Brodie, J. (2016) Changes in water clarity in response to river discharges on the Great Barrier Reef continental shelf: 2002–2013. Estuarine, Coastal and Shelf Science http://dx.doi.org/10.1016/j.ecss.2016.03.001.

5g. Data from SLATS report to show that 38% of the clearing under VMA 2013 was done in catchments that drain to the Great Barrier Reef. See:

Department of Science Information Technology Innovation and the Arts (2015) *Land Cover Change in Queensland 2012-13 and 2013-14. Statewide Landcover and Trees Study (SLATS) Report*. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

5h. The estimated cost of investment to counteract declining GBR health is about $5-10 billion to fully solve GBR water quality issues, based on costs included in recent Water Quality Improvement Plans, available at https://www.ehp.qld.gov.au/water/policy/water_quality_improvement_plans.html

Brodie J., Pearson, R. In review. Management of ecosystem health of the Great Barrier Reef, Australia: Time for reprioritisation and action on the basis of triage. Estuarine, Coastal and Shelf Science

5i. Queensland's Auditor-General reported in 2015 that stronger legislation would be essential to reducing harmful catchment runoff to the Great Barrier Reef; see:

Queensland Audit Office (2015) Managing water quality in Great Barrier Reef catchments Report 20: 2014–15.

6. Supporting information re "Atmospheric carbon and climate change"

6a. See information in:

Johnson, I. and Coburn, R. 2010. Trees for carbon sequestration. Climate in Primary Industries, Government of New South Wales.

Butler, D.W. and Halford, J. (2015) Opportunitites for greenhouse benefits from land use change in Queensland. Department of Science, Information Technology and Innovation, Queensland Government.

6b. Land clearing was the lowest in 2009-10 (78,378 ha/year) since the SLATS program began recording clearing. In 2013-14 the annual clearing rate was 296,324 ha/year. See:

Department of Science Information Technology Innovation and the Arts (2015) *Land Cover Change in Queensland 2012-13 and 2013-14. Statewide Landcover and Trees Study (SLATS) Report*. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

6c. Estimates from Queensland's SLATS data are more reliable than those of Australia's National Accounting System (NCAS), which has produced lower emissions estimates for 2013-14. The SLATS and NCAS used different methods of estimation. SLATS methods are more reliable (and considered world's best practice – see also supporting information under (2a) above), because they incorporate background year-to-year fluctuations in satellite-sensed measurements due to changes in foliage density associated with environmental factors unrelated to land clearing or regrowth, such as the effects of wet vs dry years. Changes in foliage density have negligible influence on carbon storage, because most carbon is stored in wood (stems and branches). See information in:

Department of Science Information Technology Innovation and the Arts (2015) *Land Cover Change in Queensland 2012-13 and 2013-14. Statewide Landcover and Trees Study (SLATS) Report*. Department of Science Information Technology Innovation and the Arts, Brisbane, Australia.

Commonwealth of Australia (2016) Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2015. http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/quarterly-update-australias-national-greenhouse-gas-inventory-sep-2015

6d. http://www.cleanenergyregulator.gov.au/ERF/Auctions-results

6e. By 2050, potential carbon abatement through avoided deforestation and regrowth in Australia is estimated to be in the range of 4-50 Mt CO_2e/year, and 7-10 Mt CO_2e/year; see:

Battaglia, M. (2011) Greenhouse gas mitigation: sources and links in agriculture and forestry. In H. Cleugh, M. Stafford-Smith, M. Battaglia, P Graham (eds) Climate Change: Science and Solutions for Australia. CSIRO Publishing, Collingwood, Australia pp.97-108.

7. Supporting information re "Regional climate"

7a. Reduced native vegetation cover in eastern Australia has been shown to increase temperatures and decrease rainfall. The extensive clearing of native woody vegetation for crops and improved pastures in the inland regions of Queensland has resulted in a warming, most prominent in summer, of between 0.5 and 2.0°C. Also, modelling shows that soil moisture is reduced by 5-30% because of a reduction in convective rainfall and cloud cover. See:

McAlpine C.A., Syktus J.I., Ryan, J.G., Deo R.C., McKeon, G.M., McGowan H.A. & Phinn S.R. (2009) A continent under stress: interactions, feedbacks and risks associated with impact of modified land cover on Australia's climate. Global Change Biology. 15: 2206–2223.

Syktus J.I. and McAlpine C.A. More than carbon sequestration: Biophysical climate benefits of restored semi-arid woodlands. Nature Scientific Reports. – under review [Confidential copy of submitted draft available to Committee on request].

8. Supporting information re "Values of regrowth to ecological functions"

8a. See information in:

Bowen, M.E., McAlpine, C.A., Seabrook, L.M., House, A.P., Smith, G.C. (2009). The age and amount of regrowth forest in fragmented brigalow landscapes are both important for woodland dependent birds. *Biological Conservation* 142, 3051-3059.

Bruton, M.J., McAlpine, C.A., Maron, M. (2013). Regrowth woodlands are valuable habitat for reptile communities. *Biological Conservation* 165, 95-103.

8b. See information in:

Vesk, P.A., Nolan, R., Thomson, J.R., Dorrough, J.W., Mac Nally, R., 2008. Time lags in provision of habitat resources through revegetation. *Biological Conservation* 141, 174-186.

Shoo, L.P., Freebody, K., Kanowski, J. and Catterall, C.P. (2016) Slow recovery of tropical old field rainforest regrowth and the value and limitations of active restoration. *Conservation Biology* 30: 121–132.

8c. See information in:

Dwyer, J.M., Fensham, R.J., Butler, D.W., Buckley, Y.M. (2009). Carbon for conservation: Assessing the potential for win–win investment in an extensive Australian regrowth ecosystem. Agriculture, ecosystems & environment 134, 1-7.

Evans, M.C., Carwardine, J., Fensham, R.J., Butler, D.W., Wilson, K.A., Possingham, H.P., Martin, T.G. (2015). Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes. Environmental science & policy 50, 114-129.

Bryan, B.A., Runting, R.K., Capon, T., Perring, M.P., Cunningham, S.C., Kragt, M.E., Nolan, M., Law, E.A., Renwick, A.R., Eber, S., Christian, R., Wilson, K.A. (2016). Designer policy for carbon and biodiversity co-benefits under global change. Nature Clim. Change 6, 301-305.

8d. See information in:

Lovett, S. & Price, P. (eds.) (2007). *Principles For Riparian Lands Management*. Land and Water Australia, Canberra.

9. Supporting information re "Cost of replacement through active restoration"

9a. The Commonwealth is investing A$50 million to replace 20 million trees over five years by 2020, as part of the '20 million trees' program. However, just one year of increased land clearing in Qld removes more than 20 million trees. Caring for our Country and Biodiversity Fund grants reported just over 42,000 hectares of replanting since 2013; see:

Australian Government (2016) 20 Million Trees. http://www.nrm.gov.au/national/20-million-trees.

Australian Government (2016) Field capture https://fieldcapture.ala.org.au/home/projectExplorer.
[This website shows that in Queensland the Green Army program has revegetated 93.75 ha of land and planted up to 55,000 plants.]

9b. In woodland ecosystems, tree planting for ecosystem restoration costs can cost as much as A$20,000 per hectare, and still result in ecosystems inferior to intact native vegetation[9b]; see:

Schirmer, J. and Field, J. (2000) *The Cost of Revegetation*. Final report. ANU Forestry and Greening Australia.

Munro, N., Fischer, J., Wood, J. and Lindemayer, D.B. (2009) Revegetation in agricultural areas: the development of structural complexity and floristic diversity. *Ecological Applications* 19: 1197-1210.

9c. In the Wet Tropics, active "biodiversity plantings" of plant communities during Natural Heritage Trust projects (1997-2003) required $20- $30K/ha on average, with ecological outcomes after two decades that were significantly inferior to intact remnant vegetation in many of the measured properties; see:

Catterall, C.P. and Harrison, D.A. 2006. *Rainforest Restoration Activities in Australia's Tropics and Subtropics*. Rainforest CRC, Cairns. Online via: http://www.jcu.edu.au/rainforest/reports.htm.

Catterall, C.P., Freeman, A.N.D, Kanowski, J. and Freebody, K. (2012) Can active restoration of tropical rainforest rescue biodiversity? a case with bird community indicators. *Biological Conservation* 146: 53–61.

Shoo, L.P., Freebody, K., Kanowski, J. and Catterall, C.P. (2016) Slow recovery of tropical old field rainforest regrowth and the value and limitations of active restoration. *Conservation Biology* 30: 121–132.

9d. Smaller per hectare investments, using cheaper plantings of lower diversity and tree density, result in poorer function and slower development; see:

Catterall, C.P., Kanowski, J. and Wardell-Johnson, G.W. 2008. Biodiversity and new forests: interacting processes, prospects and pitfalls of rainforest restoration. Pp 510-525 in: Stork, N. and Turton, S. (eds.) *Living in a Dynamic Tropical Forest Landscape*. Wiley-Blackwell, Oxford.

9e. Bartley, R., Henderson, A. Wilkinson, S., Whitten, S and Rutherfurd, I. (2015) Stream Bank Management in the Great Barrier Reef Catchments: A Handbook. Report to the Department of Environment. CSIRO Land and Water, Australia.

10. Supporting information re "Sustainable land use"

See information in:

Mitchell, C.D., Harper, R.J., Keenan, R.J., 2012. Current status and future prospects for carbon forestry in Australia. *Australian Forestry* 75, 200-212.