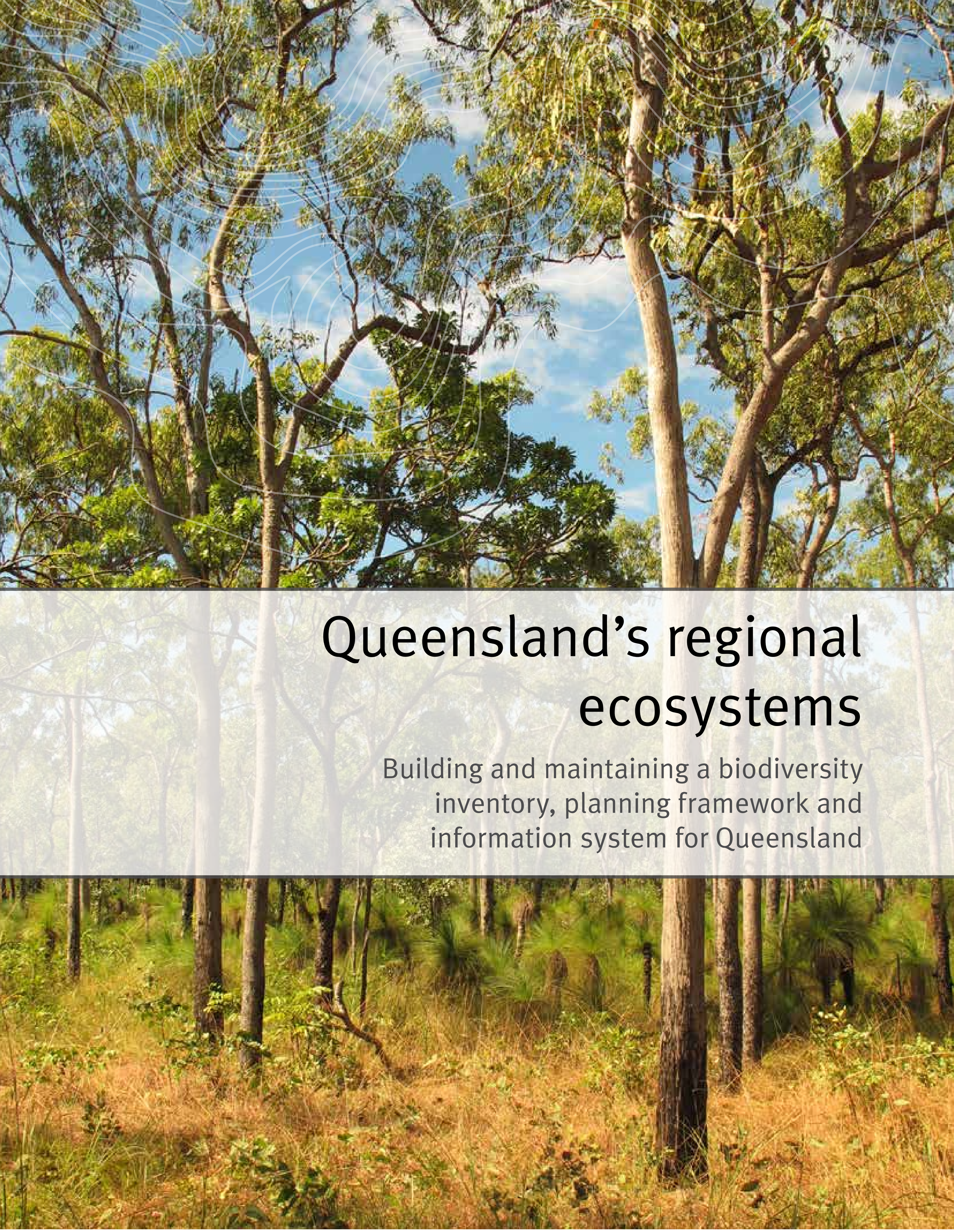

Queensland's regional ecosystems

Building and maintaining a biodiversity inventory, planning framework and information system for Queensland

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Queensland Government

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Cover image:
Eucalyptus tetrodonta, *Corymbia nesophila* woodland with *Xanthorrhoea johnsonii*, RE 3.5.36a, south of Pascoe River, Cape York Peninsula bioregion (V.J. Neldner, Queensland Herbarium, Queensland Government)

April 2019

Foreword

Early history of the development and use of the regional ecosystem classification

In late 1989, the new Queensland Government had, as its premier environmental policy, to double the National Park estate and for it to be representative of biodiversity. This policy was based on Paul Sattler's presidential address to the Royal Society of Queensland in 1983 (Sattler 1986, Comben 1999). Implementation of this policy was based on securing a representative park system across each of Queensland's 13 bioregions.

Two approaches were adopted (Sattler 1993). Where extensive land system mapping was available, viz. the Mulga Lands and the Channel Country, quantitative selection techniques were used for the first time to select parks to achieve comprehensive representation of land systems (Purdie 1986, Young 1991).

For all other bioregions where mapping had not been fully carried out, regional ecosystems were identified for each bioregion through extensive technical workshops across the state, by specialist staff and the Queensland Herbarium.

Park proposals were assessed against their contribution in achieving representation of these non-spatially identified regional ecosystems in each bioregion—as well as other criteria.

After ten years of work this classification system, The Conservation Status of Queensland's Bioregional Ecosystems (Sattler and Williams 1999), was published. This work provided a means to identify important conservation areas whilst mapping was completed.

The early development of a regional ecosystem classification system was based on work by Gethin Morgan which commenced in 1989 where he stressed the need for a comprehensive classification system involving landscape elements such as geology and geomorphology as well as vegetation. This design provided a robust classification centred on reflecting various ecological factors that determined ecosystem occurrence. The identification of regional ecosystems has been progressively refined through work by the Queensland Herbarium which embarked on the most successful ecosystem mapping program in Australia and is the envy of other states.

The regional ecosystem classification and mapping is an essential tool and data base for conservation planning including the building of a representative National Park System across all bioregions in Queensland, and for natural resource management. I congratulate the Queensland Herbarium for achieving this state-wide coverage.

Paul S. Sattler OAM
13 December 2016

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Introduction

The Queensland Herbarium has a long history of vegetation survey and mapping dating back to 1946 with botanical involvement in multi-disciplinary land system surveys, and then leading systematic vegetation surveys across Queensland since 1971. The history and development of vegetation survey and mapping in Queensland up until 1993 has been summarised in Neldner (1993). The Herbarium survey and vegetation mapping up to this time used classifications based on structure, floristics and environment.

The Queensland Environmental Protection Agency developed the unique regional ecosystem (RE) framework in the 1990s (Sattler and Williams 1999). The aim of this report is to document the development of the regional ecosystem classification from the base provided by Sattler and Williams (1999), including the many steps and processes taken to develop a consistent, seamless and robust 1:100 000 scale regional ecosystem coverage of the state of Queensland.

The regional ecosystem mapping is a significant achievement and represents several decades of investment and effort with many lessons learnt along the way. The state of Queensland covers 1.73 million square kilometres, which is five times the size of Germany, larger than Alaska, and greater in area than all but 17 countries in the world. It encompasses a wide variety of landscapes across temperate, wet and dry tropics, and semi-arid to arid climatic zones (Neldner et al. 2019a).

Technical Officer Mark Newton recording ground layer data for CORVEG site 27050 in a *Melaleuca stenostachya*, *M. viridiflora* low woodland RE 3.5.40, north of Cooktown (V.J. Neldner, Queensland Herbarium, Queensland Government)

The Queensland regional ecosystem framework

The regional ecosystem framework was developed to provide a systematic means of describing biodiversity across the variable environments of Queensland (Sattler 1999). The framework has its origins in the 1974 study that led to the description of bioregions and their major vegetation communities (Stanton and Morgan 1977). At that time the knowledge of Queensland's ecosystem biodiversity was limited with variable spatial mapping of geology at 1:250 000 scale over all of the state, land system mapping at 1:500 000 for some areas in the west of the state, and very limited systematic vegetation or soils mapping which was either associated with the land system studies or small areas on the coast (Neldner 1993). This patchwork of available mapping allowed Stanton and Morgan (1977) to develop their bioregional framework.

In the classification of Queensland's regional ecosystems, three major attributes are combined in a hierarchical manner:

1. Broad-scale landscape patterns as described by bioregion
2. Geology, soils and landforms which are described as land zones
3. Vegetation which is described in terms of structure and floristics (Sattler 1999).

The bioregions of Queensland initially described in Stanton and Morgan (1977) at a scale of approximately 1:1 m – 1:2.5 m, were used as a template to develop and apply the bioregional concept across the whole of Australia in the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway and Cresswell 1995). Although refined progressively over the last 20 years, the Australia-wide classification is still referred to as 'interim' IBRA.

Within bioregions, there are generally significant difference in landscape patterns usually associated with geology and geomorphology or climatic differences. While these distinctive sub-regions with the bioregion were called 'provinces' by Morgan and Terrey (1990) and Sattler (1999), the term 'subregion' has been adopted by the Queensland Herbarium to reinforce the hierarchical relationship.

Land zones represent significant differences in geology and associated landforms, soils and physical processes (Sattler 1999). Land zones generally corresponded to broad geological categories or groupings of these, and were related to units on the geological maps (Sattler 1999). The geology maps covered the state of Queensland in a series of 1:250 000 scale individual maps that did not always edge-match to the adjoining map, and sometimes offered different interpretation of certain geology types. Geology maps focus on the below surface hard rock materials, with varying levels of detail in regard to overlying regolith and depositional surfaces. Over time the geology and soils mapping has improved, and the concepts of land zones tested and refined, leading to the more consistent definitions and descriptions (Wilson and Taylor 2012).

The third level is the vegetation community which under the modified Specht (1970) classification system is defined in terms of the structure and floristics of the ecologically dominant layer, with the landscape position and characteristics as further attributes to define communities (Neldner et al. 2019b).

A regional ecosystem is defined as a vegetation community in a bioregion that is consistently associated with a particular combination of geology, landform and soil (Sattler 1999).

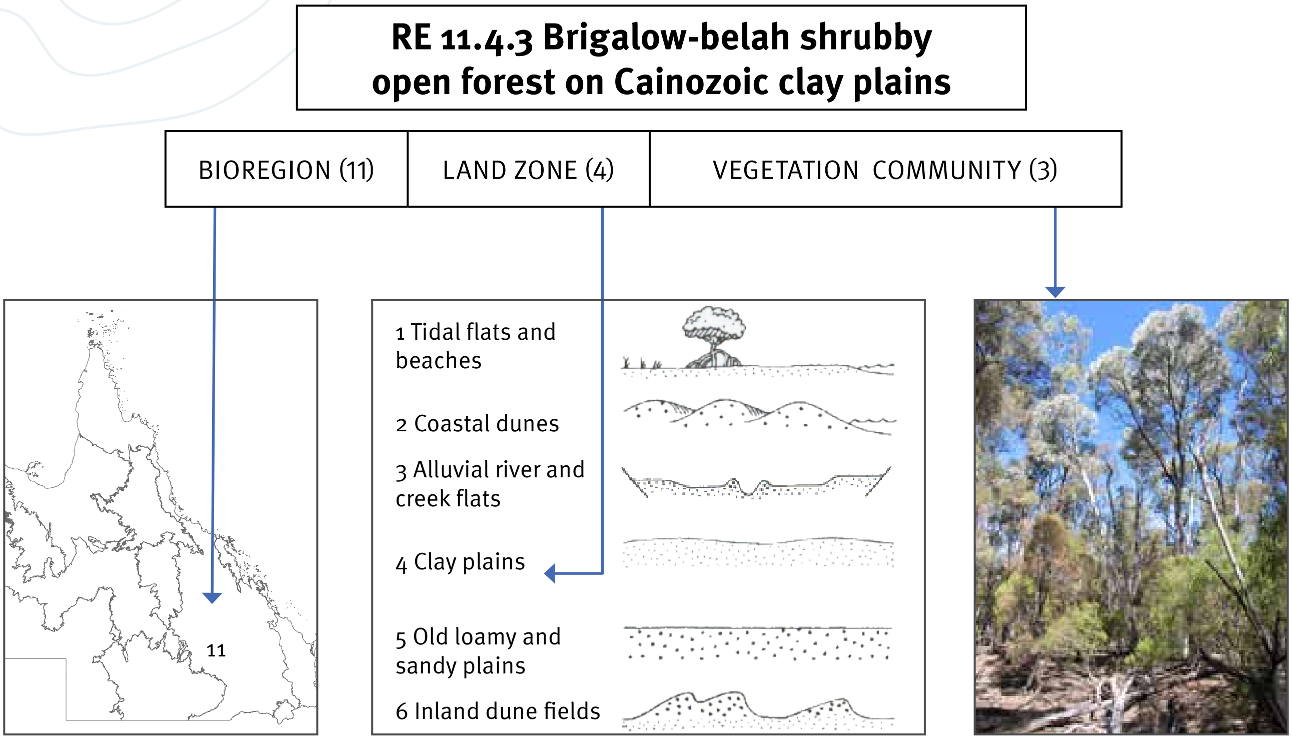


Figure 1 Example of regional ecosystem classification

Botanists Eda Addicott and John Neldner use a global positioning system (GPS) to relocate CORVEG site 3936 in RE 3.5.4 notophyll vine forest near Heathlands on northern Cape York Peninsula (M.R. Newton, Queensland Herbarium, Queensland Government)

Why the need for the regional ecosystem framework?

Vegetation communities and vegetation maps have been and continue to be used as surrogates for total biodiversity. However research has shown vegetation communities are better surrogates for certain groups of biodiversity, for example, forest ecosystems were most effective for plants and mammals, but are least effective for some other important groups such as frogs and reptiles (Grantham et al. 2010). Both the regional ecosystem and vegetation community classification use biophysical attributes such as landforms, soils and geology, and vegetation characteristics such the height and cover of structural layers and the dominant species present in these layers to define recognisable ecological entities. However, the hierarchy of applying these characteristics is more consistent in the regional ecosystem approach than for vegetation communities. The elevated importance of biophysical attributes has also been used by the Victoria state-wide biodiversity classifications of Ecological Vegetation Classes (EVCs) (Sun et al. 1997).

The underlying premise is that different biophysical environments, represented by land zones and bioregions in the RE structure, will enable regional ecosystems to provide more effective surrogacy for the full scope of biodiversity, including unique and distinct biodiversity (maybe in the lower plants, fungi or invertebrates) than classifications based only on vegetation communities. This premise is still a topic of further research, although for some ecosystems, for example, semi-evergreen vine thickets, different substrates do not appear to significantly change the structure and floristics of the vascular plants present (Fensham 1995, McDonald 1998). There is also clear evidence of the biophysical attributes being a primary driver for the types of plant and other species that occur at a site.

The other factor that led to the adoption of the regional ecosystem mapping for the official biodiversity planning classification for Queensland was that knowledge of biophysical environments across the state was sufficient to enable rapid development of a state-wide regional ecosystem coverage, that could support tree clearing legislation, by utilising existing mapping products. The biophysical geology coverage at 1:250 000 scale, complemented by the Western Arid Region Land Use Study (WARLUS) and CSIRO land research series land system mapping, provided a relatively consistent framework to develop a state-wide environmental coverage that focused initially on biophysical characters.

The development of proposed legislation, which eventually become the *Vegetation Management Act 1999* (VMA), and the desire to link this to a spatial mapping framework and Information system for implementation and regulation, led to the decision of the Environmental Protection Agency in 1995 to adopt the regional ecosystem framework as the biodiversity framework for Queensland. The Queensland Herbarium Regional Ecosystem Survey and Mapping (QHRESM) program was developed to produce a consistent, seamless, versatile, best-practice and legally-defensible 1:100 000 scale regional ecosystem coverage of the state of Queensland.

Significant publications and programs that have contributed to the QHRESM and broader vegetation surveying and mapping projects are shown as a timeline in Appendix 3.

How the regional ecosystem framework operates with the *Vegetation Management Act 1999*

Prior to the 1990s, there was little regulation of vegetation clearing in Queensland. In late 1997, a system to regulate vegetation clearing on the 70% of Queensland held as leasehold and other state lands commenced under the *Land Act 1994* (McGrath 2011). The *Vegetation Management Act 1999* (VMA) was implemented in September 2000 to regulate clearing on freehold and freeholding leases.

The RE system of classifying land provides the basis for vegetation management in Queensland (McGrath 2011).

Initially, the regional ecosystem maps were legal documents certified by the Director-General of the Department of Natural Resources and Mines (DNRM) that determined the areas that were regulated by the VMA. In 2004, the system of clearing laws for state lands in the *Land Act 1994* were integrated into the VMA (McGrath 2011). Property Maps of Assessable Vegetation (PMAVs) were introduced as part of the same round of legislative changes and allowed non-remnant areas to be 'locked in' on these property scale maps which were approved by DNRM. PMAVs and subsequent other legislative changes mean that the area regulated by the VMA no longer equates to remnant on regional ecosystem maps, and the map of assessable vegetation applicable under the VMA is constructed by DNRM from the RE maps, PMAVs and other sources. This shift is partly also because the range of vegetation regulated under the VMA has expanded beyond only remnant vegetation, for example it now includes vegetation within buffers of watercourses in some reef catchments as well as high-value regrowth. However, the regional ecosystem classification and mapping continues to be the foundation that determines what activities may occur in specific areas within the various classes of regulated vegetation.

The regional ecosystem maps are used to calculate the extent remaining and the appropriate vegetation management class for each RE. For land holders to apply the various VMA codes, for example, fodder harvesting, managing encroachment, managing weeds they must refer to the appropriate mapped regional ecosystem.

Eucalyptus robusta, *E. pilularis*, and *Syncarpia glomulifera* open forest with *Livistona australis* subcanopy, Tewantin National Park, Southeast Queenslan bioregion (V.J. Neldner, Queensland Herbarium, Queensland Government)

Challenges faced and lessons learned in building a robust Queensland-wide classification and information system

Strong scientific leadership and coordination

The QHRESM program has benefited from strong and stable long-term leadership at director and higher levels that were able to obtain essential resources and convince the government of the need and benefits of the regional ecosystem framework. The regional ecosystem framework was delivered by a single agency, the Queensland Herbarium, which had built up a reputation of delivering high-quality science in a timely manner. In some other states where the responsibility for vegetation mapping was dispersed across agencies, coordinated outcomes have been hard to achieve.

Long-term scientific leadership from officers with practical field experience was also important in guiding the development of best practice ecological skills and methods. Leadership was required to ensure coordination and training of staff to ensure adherence to the established techniques. Cooperative working with other departments, particularly Natural Resources and Mines, at both the policy and operational levels was essential in implementing the RE mapping program and the VMA operations. The close cooperative relationship with the Remote Sensing Centre and SLATS project was essential in facilitating the success of the RE survey and mapping program.

Resourcing and skilling teams

As discussed by Neldner (1993), the Queensland Herbarium has developed small teams with vegetation survey and mapping expertise through being involved in the CSIRO land research series land system mapping projects in Queensland intermittently from 1945 to 1974, and then being part of the multi-disciplinary teams that produced the Western Arid Region Land Use Study (WARLUS) from 1969 to 1980 (some reports were published as late as 1990, e.g. Boyland 1974, 1980, Purdie 1990, Purdie and McDonald 1990). The funding for WARLUS was a government response to the disastrous drought of 1964–66. The Moreton Region Non-Urban Land Suitability Study provided additional funding that allowed an ecology section of five officers to be set up at the Queensland Herbarium from 1971.

Commonwealth money through the National Estate program partly funded the Moreton Region series in 1975 (McDonald and Elsol 1984), and also the Vegetation Survey of Queensland (VSQ) which commenced in 1978. The VSQ planned nine 1:1 m map sheets to cover Queensland, and was subsequently co-funded through the Australian Biological Resource Survey (ABRS). Only three map sheets were completed and published (Boyland 1984, Neldner 1984, Neldner 1991).

The Cape York Peninsula Land Use Study (CYPLUS) delivered additional funding to the vegetation survey and mapping program from 1990–94, and added three temporary staff to the two permanent staff in Mareeba (Neldner and Clarkson 1994). The Southeast Queensland Comprehensive Regional Assessment (SEQCRA) commenced in 1994 in preparation for a Regional Forest Agreement and provided funding for six temporary staff in Brisbane.

The largest expansion of staff occurred from 1996 as the Queensland government invested funding in the regional ecosystem mapping program. At its largest size in 2000, the vegetation survey and mapping and associated vegetation management groups consisted of 21 botanists, eight technicians and seven Geographic Information Officers, with five staff based in Mareeba, five in Townsville, one in Longreach, one in Gladstone, and 24 in Brisbane. Regular communication and yearly workshops and training were essential to coordinate this large distributed team.

In 2018, four additional staff were employed in a two-year project to produce an initial vegetation condition map for Queensland. This QUEG project was part of a broader eSLATS project funded by the Queensland Government.

The well-funded projects that sustained the survey and mapping program were jointly Commonwealth and Queensland Government funded with the aim of informing land use planning decisions, and then the Queensland Government initiatives to support the VMA policies.

Other smaller project funding has come through the Cooperative Research Centre for Tropical Savannas, which allowed the Queensland Herbarium to produce a vegetation map and classification similar to regional ecosystems across the whole of northern Australia (Fox et al. 2001); the National Vegetation Information System (NVIS) provided funding for a pilot project to attempt to map condition states in the mulga lands (Buck et al. 2009); the Advanced Ecological Knowledge and Observation System (ÆKOS) which is part of the Terrestrial Ecosystem Research Network (TERN) provided funding for entering the ecological site data into CORVEG and AEKOS, and southeast Queensland local governments (Brisbane, Gold Coast and Logan City Councils) funded regional ecosystem mapping to 1:25 000 scale.

Herbarium botanists were responsible for the interpretation of imagery, mapping of vegetation and field data collection, which ensured the laboratory interpretation mirrored the reality of the field. This differed from some organisations, for example, Forestry Tasmania, where the specialities of aerial photointerpretation and field data collection where kept separate. The development of specialist Geographic Information System skills was also essential to the success of the QHRESM program. These GIS officers developed efficient and best practice routines for processing and storing satellite imagery, capturing line work from imagery, building coverages and analysing the spatial data. The GIS officers also trained the botanists in GIS skills and were available to resolve issues with the mapping coverages and the site data underpinning it.

Defining pre-clearing and remnant vegetation

Pre-clearing vegetation or regional ecosystem is defined as the vegetation or regional ecosystem present before clearing. This generally equates to terms such as 'pre-1750' or 'pre-European' used elsewhere (e.g. AUSLIG 1990). Pre-1750 or pre-European vegetation is a widely used standard for recording vegetation prior to major impacts from non-indigenous people, such as extensive clearing, altered fire regimes, the introduction of grazing animals, etc.

Since 1996, the Queensland Herbarium has used the term pre-clearing as a more accurate and defendable standard to map. Ecosystem composition and the boundaries between ecosystem types are dynamic, and some ecosystems may have changed or moved since 1750 (e.g. Butler et al. 2014). Since no consistent imagery exists for Queensland before the early 1960s and no reliable comprehensive sample points exist for the period before 1970, it is difficult to map 'pre-1750' or 'pre-European' extent throughout much of the state with any authority (Neldner et al. 2019b).

While vegetation boundaries can change, comparisons of modern vegetation patterns with records of early explorers and historical survey plans (e.g. Fensham 2008, Fensham et al. 2011) suggests that substantial change is the exception rather than the rule, hence pre-clearing generally equates to pre-European.

Change in extent is an important indicator of threat for conservation assessment of ecosystems. Pre-clearing extent provides a baseline, but the assessment of change requires definition of ‘extent remaining’. Historically, mapping programs tended to refer to natural vegetation, without clear or practical definition. For example, the Moreton region vegetation map series mapped ‘natural vegetation’ (Dowling and McDonald 1976) which included some vegetation that had disturbed by thinning (Elsol and Dowling 1978). The mapping for the SEQCRA (Bean et al. 1998) also mapped natural vegetation without providing a definition of what ‘natural vegetation’ was or the thresholds for when it was ‘not natural’, apart from when it was obviously completely removed by clearing. Vegetation maps produced in New South Wales from the same era, for example, Keith and Benson (1988) mapped ‘present day natural vegetation’ which was also not defined apart from specification that it was ‘not cleared’.

In part, the vagueness of definition around what constitutes the current, or remnant, extent of ecosystem classes was related to the low frequency of image capture, which precluded regular updates and necessitated temporal fuzziness in estimates of extent. For Herbarium mapping projects prior to 1990, satellite imagery was too expensive to be used, however with the start of the SLATS project in 1998 contemporary Landsat imagery was made available, making it feasible to map present-day natural vegetation using a consistent image base across the entire state.

A clear definition of ‘not natural’ or similar is required for a robust analysis of extent. Differences in definition cause problems when jurisdictions try to edgematch across borders, for example, New South Wales and Queensland NVIS trials, or when ecologically communities are defined with different definitions, for example, the EPBC listing of White Box—Yellow Box—Blakely’s Red Gum Woodland and Derived Native Grassland does not require any trees to be present.

The definition of ‘remnant vegetation’ utilised in the regional ecosystem mapping was developed in concert with the policy development for the VMA. A robust definition was required to ensure that all botanists were consistent in their approach, and stakeholders clearly understood the concept.

It also needed to permit previous disturbance, for example, logging or clearing, to have occurred provided the vegetation now exhibited the characteristics of remnant vegetation. In addition it was likely that the definition would need to be robust enough to withstand legal challenges.

Woody vegetation is vegetation for which the predominant stratum is composed mainly of woody vegetation such as trees or shrubs. The Queensland Herbarium assesses and maps woody dominated vegetation as remnant if it meets the definition used in the VMA 1999, which is:
‘vegetation, part of which forms the predominant canopy of the vegetation—
(a) covering more than 50% of the undisturbed predominant canopy; and
(b) averaging more than 70% of the vegetation’s undisturbed height; and
(c) composed of species characteristic of the vegetation’s undisturbed predominant canopy.’

The undisturbed predominant canopy, for vegetation, is defined in the VMA as the predominant canopy the vegetation normally has, while the undisturbed height, for vegetation, means the height to which the vegetation normally grows. Sites that have not been cleared are considered to support normal vegetation and are therefore classified as remnant (Neldner et al. 2019b).

The above definition of remnant vegetation is straightforward in many cases and includes vegetation that is commonly referred to as ‘intact’, ‘natural’, ‘virgin’, ‘never cleared’ or ‘pre-clearing’. However, it also includes vegetation that may have been lightly thinned, or cleared, or heavily thinned but substantially regrown (Wilson et al. 2002).

Vegetation that has undergone considerable changes in structure and composition may still be classified as remnant. Anything that has not been cleared by human intervention is also remnant by definition, so that drought or fire cannot render vegetation non-remnant. Essentially the remnant definition encompasses native vegetation that is in its undisturbed state, or that with sympathetic management could return to a natural state within five years. Hence, for woody vegetation, it was important to have the majority of the long lived canopy intact, as this would take a long time to restore, while sympathetic management could result in a more rapid change in ground and shrub layers.

For non-woody vegetation, for example, grasslands, the dominant layer is highly variable according to seasonal conditions, and can be rapidly modified through the use of grazing, fire or mechanical mowing. Remnant non-woody vegetation is defined as an area that:

- has not been cultivated for 15 years
- contains native species normally found in the regional ecosystem
- is not dominated by non-native perennial species.

The assessment of remnant status of non-woody vegetation follows a two-step process: mapping extent according to time since cultivation, and then making a site assessment based on the composition of the vegetation.

The time since cultivation is based on ecological research, which has shown that the native species composition generally requires 15 years to return in ploughed grasslands (Fensham et al. 2019b).

The native and exotic species assessment is based on the principal that areas that do not meet these criteria are unlikely to return to 'good native condition' within 15 years even with sympathetic management (Neldner et al. 2012).

The definition of high-value regrowth was amended on 8 March 2018 to apply to native vegetation that has not been cleared for at least 15 years. The mapping of high-value regrowth (HVR) is described in Appendix 8 in Neldner et al. (2019b).

The SLATS project provided state-wide analysis of the amount of woody vegetation clearing occurring in Queensland. 'Woody vegetation clearing' refers to the anthropogenic removal or destruction of woody vegetation (DES 2018) included both clearing of remnant and non-remnant vegetation. Hence, the statistics for vegetation change and woody vegetation cover quoted in the SLATS reports include all woody vegetation. This includes remaining areas of native vegetation, disturbed areas of native vegetation, regrowth, plantations of native and exotic species and domestic woody vegetation (DNRM 2004).

The SLATS project also calculated areas based on counts of 'cleared' Landsat pixels (30m pixels which were resampled to 25 m from SLATS inception until 2012). These two factors caused significant differences in clearing rates between the Herbarium mapping and SLATS. These differences in mapping entities had to be clearly explained to politicians and stakeholders to create understanding.

From 2000, the SLATS reports started segregating the remnant clearing derived through intersecting the Herbarium remnant RE mapping, and the remaining non-remnant woody clearing.

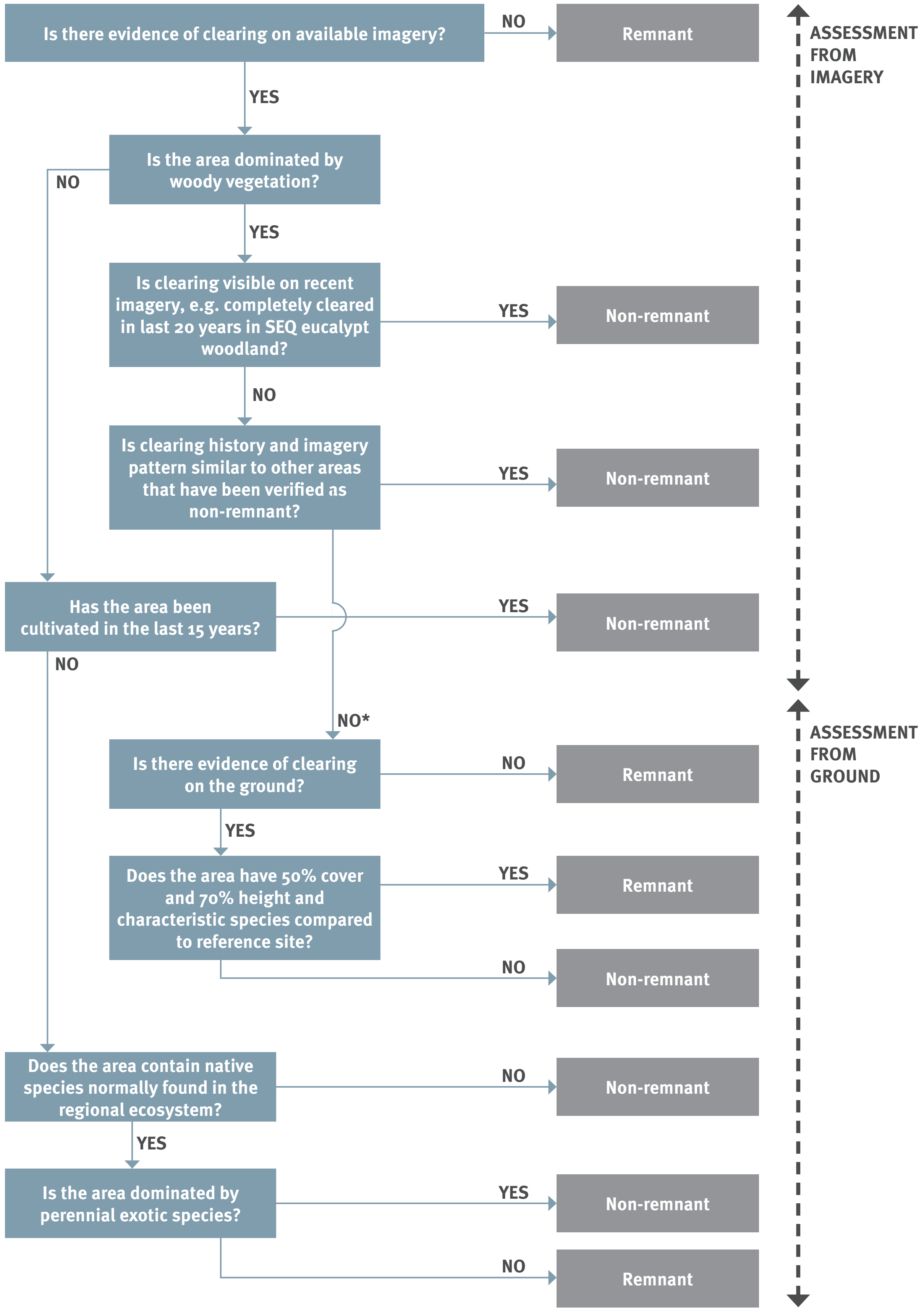


Figure 2 Flowchart showing assessment sequence for mapping vegetation cover

* Areas mapped as remnant until ground assessment is carried out

Clay pans in reticulated dune fields, Channel Country, South-West Queensland, part of the Channel Country bioregion (Nick Cuff, Queensland Herbarium, Queensland Government)

Defining land zones

Land zones are a unique landscape classification used in the regional ecosystem framework. Land zones were broadly defined by Sattler (1999) as representing significant differences in geology and associated landforms, soils and physical processes. Land zones were operationalised for bioregions by relating mapped geological units to land zones in Table 2 in the bioregion chapters in Sattler and Williams (1999).

For the most part, classifying the landscape into one of the 12 state-wide land zones is uncomplicated and would simply involve reference to a geology map and the land zone definition. In other circumstances a basic knowledge of geology and landscape processes (geomorphology and soil formation) is necessary (Wilson and Taylor 2012).

However with any new classification system, there were a number of issues with the small number of complicated or exceptional situations and these needed to be resolved in developing, implementing and communicating the land zone system. All this took time, discussion and some considerable re-working and remapping to be resolved. Examples of issues in the definition that caused discussion were the influence of geological ages in defining land zones, e.g. LZ 8 and 12, the definition and depth thresholds for deep weathering to define a land zone, e.g. LZ5 and 7, the frequency of flooding (water surface movement) required for land zone 3. There was also some tension between those wanting the regional ecosystem classification to be a comprehensive land use and land capability planning tool, and those who saw that it is primary purpose was a surrogate for biodiversity and that the important function of the biophysical components was how it influenced biodiversity.

While the botanists employed in the survey and mapping program were skilled in photointerpretation and mapping, and flora and vegetation survey, they were not specialised in landscape, geomorphology, geology or soils skills. Hence the geological mapping at 1:250 000 scale across the State was used as the default land zone coverage initially. Expert guidance was sort from specialist geologists, geomorphologists and soil scientists to help resolve issues, but as the classification was still maturing a number of opinions were canvassed and gradually resolved to a consensus. There was a clear need to document the land zone classification for Queensland, and particularly to explain clearly how the exceptional or borderline circumstances, some of which could legitimately have been assigned to either of two land zones, were assigned.

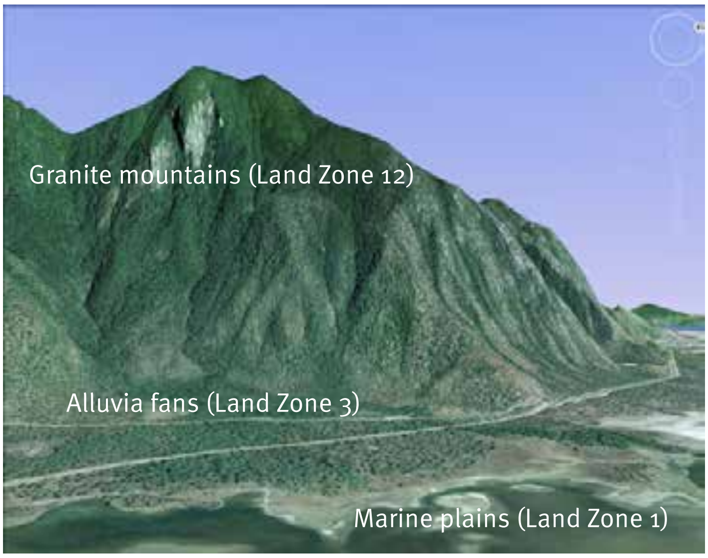


Figure 3 Quaternary alluvial fans of Mt Elliott, south of Townsville with streams and gullies from Mt Elliott aggrading fans onto the coastal marine plains. (Google Earth)

Many of the disputed regional ecosystems mapping enquiries were caused by a misunderstanding of the land zones. Wayne Harris, a geologist with botanical skills, produced a draft land zone document in 2005, and this was re-worked and made more comprehensive by Peter Wilson and Peter Taylor and published in 2012 (Wilson and Taylor 2012). Land zone recognition and definition was an integral part of the regional ecosystem training program provided for government officers and consultants by Peter Taylor at the Queensland Herbarium.

Consistent classification concepts

Most vegetation classification systems in Australia use floristics and structure as the two primary elements in classifying vegetation, and all use growth form (physiognomy) to distinguish and describe vegetation units (Sun et al. 1991).

The Queensland Herbarium adopted a modified Specht (1970) vegetation classification system (Neldner 1984, Neldner 1993) which defines communities on the basis of the ecologically dominant layer (EDL)) rather than the tallest layer (Neldner et al. 2019b).

The concept of the EDL has been used as the basis of classification by the National Vegetation Information System (NVIS) (ESCAVI 2003). However to ensure consistency in the application of the strata concept, prescriptive definitions were required and documented (Neldner et al. 2019b).

The initial forest classification system used for the SEQCRA was using height ranges rather than a definitive measure of height and range, and without the consistent hierarchy of Tree 1 (canopy), Trees 2 (subcanopy) etc. This was addressed and documented in the first Queensland Herbarium survey and mapping methodology document (Neldner et al. 1999), with further additions and refinement to the methodology documented in Neldner et al. (2004, 2005, 2017, 2019b).

The established rainforest classification devised by Webb (1978) was adopted by the Queensland Herbarium as the standard for rainforests. Walker and Hopkins (1990) and Hnatiuk et al. (2009) use most of the elements of this classification, which has its origins in Webb (1959a) and is further developed in subsequent publications by that author.

The Webb (1978) system classifies rainforest by

- complexity (of life forms)
- size of leaves of dominant plants
- complexity of dominant species
- leaf-fall characteristics (not used by Walker and Hopkins (1990) and Hnatiuk et al. (2009))
- indicator growth forms.

The Webb (1978) schema discriminates more structural variants for rainforest than the broad closed forest category of Specht (1970).

Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid to arid climatic zones (Neldner et al. 2019a). In order to provide an overview and/or map vegetation across the state or a bioregion and allow comparison with other states, the vegetation units and regional ecosystems are amalgamated into the higher-level classification of Broad Vegetation Groups (BVGs).

The Queensland Herbarium amalgamates ecosystems on an ecological basis to form BVGs (Neldner et al. 2019a). Some BVGs encompass vegetation types that are generally dominated by a single species, such as *Melaleuca viridiflora*, or a suite of species, such as *Acacia* spp. on residuals. Other groups are dominated by a distinct structural formation (such as tussock and closed tussock grasslands) or by a combination of a structural formation and habitat (such as dry woodlands, primarily on coastal sandplains and dunes). Specialised habitats such as coral islands and intertidal areas form other groups. The digital map layers allow the user to easily produce maps based on the structural formation, the map unit or the BVG (Neldner and Clarkson 1995). There are three levels of broad vegetation groups which reflect the approximate scale at which they are designed to be used: the 1:5 000 000 (national), 1:2 000 000 (state) and 1:1 000 000 (regional).

BVGs make the regional ecosystem classification part of a nested hierarchy. Below regional ecosystems, at larger scales, the Herbarium recognises vegetation associations, which are differentiated with an alphabetical suffix to the regional ecosystem code. Vegetation associations can be useful to explicitly acknowledge some of the common variations on the core theme encompassed within a regional ecosystem.

Defining scale of mapping and classification

Mapping scale has traditionally been determined and specified by the cartographic standards that dictate what can be practically depicted on a map at a specified scale. Thus at a scale of 1:100 000 the traditional minimum recommended area for polygons is about 5 mm width on the map, which equates to a ground area of 20 ha, or 3 mm width on the map for an elongated polygon, which equates to 300 m on the ground. Geographic Information Systems and digital mapping interfaces allow maps to be enlarged to any scale.

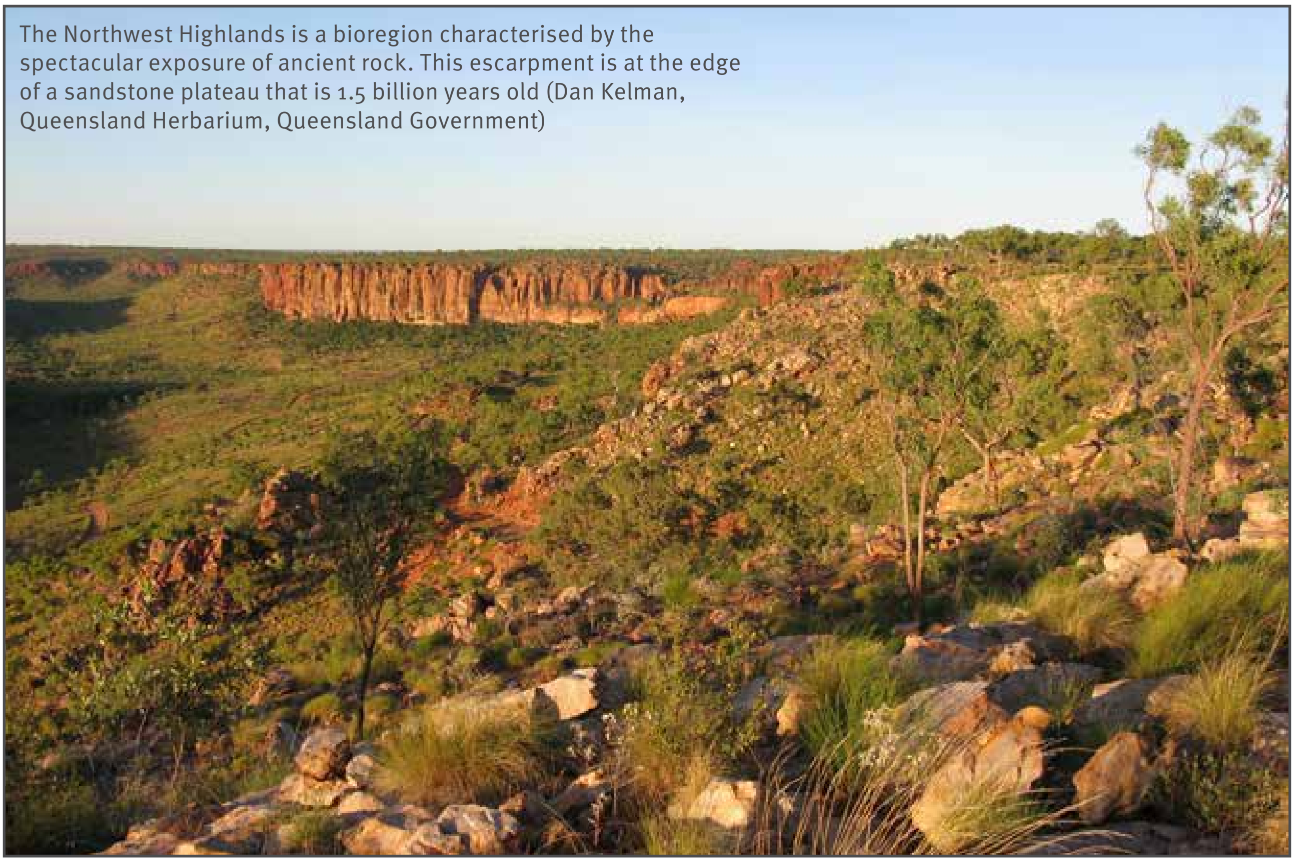
For consistency across map sheets (different mappers) and for defining the limits of precision (e.g. minimum polygon size mapped), the definition of regional ecosystems and remnant vegetation for survey and mapping must specify a scale. In general Queensland Herbarium remnant vegetation cover and regional ecosystems are defined at a scale of 1:100 000, which delineates a minimum area for remnant vegetation of 5 ha and 75 m width limit for linear features.

Within a team of vegetation mappers, there are invariably splitters (frequently driven by the complexity detected at the site level) and lumpers (driven by the patterns shown on imagery). As the scale and detail of imagery improves more features can be seen and potentially delineated. To foster a consistent level of mapping, a preferred mapping protocol is specified in Neldner et al. (2019b) which uses the patterns detected on imagery as primary source of the delineated polygons. Numerical classification can be used as a tool to ensure consistency in the level of classification based on the floristics and structure recorded in the CORVEG sites (Neldner and Howitt 1991, Addicott et al. 2018). The vegetation survey and mapping and classification processes used in Australia are summarised in Figure 1 in Neldner et al. (2019b).

Natural variation within vegetation

Vegetation is the spatial and temporal expression of the flora of an area, expressed as plant assemblages (communities) which consist of individual species with varied life-forms (Raunkiaer 1934). The Beadle and Costin (1952) Australian vegetation classification scheme was based on the principle that vegetation should be described objectively in terms of its present structure and floristics without reference to its successional status. They considered that the mapping of vegetation units was an integral part of ecological description.

The Herbarium attempts to describe the central or nodal concept of the regional ecosystem by stratifying CORVEG sampling to most typical expression of the vegetation assemblage for the biophysical conditions. Adequate site sampling needs to occur to pick up the major expressions of variation through the range of the regional ecosystem, for example, different sub-dominant trees or shrubs in different parts of the geographic range. However sites are intentionally placed to avoid ecotones and mixed units.



The Northwest Highlands is a bioregion characterised by the spectacular exposure of ancient rock. This escarpment is at the edge of a sandstone plateau that is 1.5 billion years old (Dan Kelman, Queensland Herbarium, Queensland Government)

Natural or anthropogenic disturbance

Vegetation is dynamic and uncleared vegetation can undergo structural and floristic composition changes associated with climate and/or other environmental factors (Neldner et al. 2019b). With the influence of climate change and increased incidence of extreme events, resilient native ecosystems are likely to undergo change and novel ecosystems may evolve.

Natural extreme events such as cyclones and floods can have similar destructive impacts on biodiversity as land clearing. Similarly, fires (both natural and human-ignited) and droughts can cause death of plants and animals. The challenge was define which of these events disqualify vegetation from being remnant without providing a legal loophole or perverse incentive to clear, and also for the classification to allow natural evolution in the response to environmental dynamism. Appendix 3 in Neldner et al. (2019b) provides principals for the regional ecosystem classification to deal with changing vegetation and some examples of how these situations are dealt with.

The pressure for more detailed (larger scale) mapping

While the RE mapping was designed to be used at the regional scale of 1:100 000, the ready availability and high-quality of the mapping led to RE mapping being used for planning for local government authorities, landholder properties and even individual developments. Despite the caveats and limits to use statements on the map coverages, there were many occasions where the GIS technology allowed the mapping to be pushed beyond its intended scale of use.

This pressure for more detailed mapping has increased with better quality and more affordable imagery (both aerial photographs and satellite imagery have become available through coordinated state government acquisition programs), cheaper products, and more users from a variety of sectors (see Appendix 1).

The requirement for homogeneous polygons (single RE only in each polygon) for ease of use and clarity also is a strong driver from stakeholders. Improvements in the scale and quality of geology mapping also generated the requirement to revise land zones and subsequently REs in some areas.

The demand for more detailed mapping required the definition of sub-regional ecosystem units. These are defined as vegetation communities and criteria provided for recognising new vegetation communities (Neldner et al. 2019b).

A number of local governments have funded larger scale mapping for their LGAs and would then request this larger scale mapping being incorporated into the state government RE coverage. Stitching in larger scale mapping raises a number of technical issues, and can be impossible if the classification concepts of remnant vegetation and REs are inconsistent. Some LGA mapping had to be rejected in the past because of quality or definitional issues. Some LGAs, for example, Brisbane City Council, Gold Coast City Council, contracted the Queensland Herbarium to conduct the large scale mapping projects so that these issues with inconsistency or quality are avoided.

A defensible standardised site sampling method

Australian vegetation scientists have developed a wide variety of vegetation survey, classification and mapping systems since the late 1940s (Benson 1995, Sun et al. 1997). There are a large number of issues involved in designing a standardised site sampling protocol that can be practical and efficient in the field and still scientifically robust in the broad range of vegetation and landscapes that occur in Queensland.

The Queensland Herbarium RE survey and mapping methodology (Neldner et al. 1999, 2004, 2005, 2017, 2019b) was developed over many years through the experience, learnings and input of many staff, together with external research. The 500 square metre CORVEG plots were shown to be an adequate size to capture most of the diversity present at a site (Alpha diversity), apart from for rainforests (Neldner and Butler 2008). A plotless sampling protocol was developed from the best practice for rainforest sampling (Appendix 9 in Neldner et al. 2019b). The effect of timing of sampling and seasonal influence was studied (Neldner et al. 2004) providing guidance on the completeness of floristic data in different seasons.

With the resource and time limits on the state-wide RE mapping program, a stratified sampling approach was developed, as randomized or grid based sampling was found to be impractical with the accessibility issues in much of Queensland. Techniques for exploring the adequacy of sampling were developed (Neldner et al. 1995) and reliability codes for mapping on a polygon basis (in terms of both spatial position and attribution for each polygon) was added to the map coverages. While the minimum field data required for ground truthing for mapping purposes is limited to the ecologically dominant layer, for example in wooded communities the tree layer (Neldner and Howitt 1991, Thackway et al. 2008), the QHRESM program has always been seen as an opportunity to obtain a comprehensive and systematic survey of the vegetation of Queensland, providing detailed floristic and structural data that can be used for a number of purposes (Neldner 2015).

Training and education needs

There was a clear need to train government officers, land holders and consultants involved in the implementation of the VMA, as well as policy officers and stakeholders, in understanding the RE framework. Special training courses involving laboratory and field work were developed and delivered by Peter Taylor, a Herbarium botanist and trained teacher. In addition Herbarium staff provided seminars on the RE framework to stakeholders and politicians, and guest lectures as part of University courses. To meet the demand for RE training, a four part Regional Ecosystem Framework training and educational package was developed and is hosted on the Queensland government website and is freely available (Queensland Herbarium 2016) https://publications.qld.gov.au/dataset/training-regional-ecosystem-fwork. The competencies have been written to meet Certificate IV level standards and the training materials have been produced to meet the National Training Standards. Some consultants are using these materials to offer training to clients involved in environmental assessment and management in Queensland.

Objective review and stakeholder involvement

The State Land and Tree Study (SLATS) advisory panel involved stakeholders and academics to govern and advise on this Queensland-wide project. The Herbarium Director was a member of this advisory panel. Although focused on the SLATS project, the RE framework was also regularly discussed. Frequently bioregions had a number of botanists involved in mapping projects, and a bioregional coordinator was appointed to facilitate consistency across the bioregion. A state-wide technical reference panel involving Herbarium bioregional coordinators and technical experts from other government departments was set up to oversee standards in the framework across the state. As new information was gathered through new mapping projects, a process of assigning new REs (post Sattler and Williams 1999) was developed and thresholds and requirements for new REs needed to be set. These criteria for new REs and vegetation communities were established by the state-wide reference panel and documented in Appendix 5 in Neldner et al. (2019b).

The list of regional ecosystems in Queensland documented in the Vegetation Management regulation. Updating this is not a rapid process so an alternative naming protocol needed to be developed for approved new regional ecosystems, not yet incorporated into the VM regulation. This is documented in section 2.3.1.4 in Neldner et al. (2019b).

Once the survey and mapping was approaching completion in a bioregion, the bioregional coordinator would convene a Bioregion Technical Committee, composed of government and industry officers with technical knowledge of the bioregion. The meeting would refine bioregion and subregion boundaries, and review the evidence and approve new regional ecosystems.

Accuracy and perception of accuracy

All maps are prone to some errors either through misinterpretation of patterns on imagery or human errors in the transcription process. However because the RE maps are important regulatory tools that affect landholders abilities to manage their vegetation the regional ecosystem maps are scrutinized heavily and where errors are found or perception of errors noted, there is frequently attention given in the rural media.

The QHRESM aims to achieve accuracy of greater than 80% across Queensland (Neldner et al. 2019b). With no reliable independent data sets for comparison, and the prohibitive cost of obtaining such data, various in-house accuracy assessments were conducted. The most robust examined the amount of RE mapping changed through the map modification process. These were areas where stakeholders had perceived errors in the mapping, and hence biased to 'problem' areas rather than areas where stakeholders had no issues. The results indicated an accuracy of greater than 90% (Wilson unpublished).

Elizabeth Springs (Galilee Basin) RE 10.3.31, like all Great Artesian Basin springs, is threatened by water extraction and feral animals. Elizabeth Springs is in the heart of the Desert Uplands bioregion (photo© Adam Kereszy)

Providing stakeholders with up-to-date and timely information

As the RE maps through the VMA have considerable impact on management and development options on land, it was imperative that user-friendly and cheap mapping products were developed and delivered efficiently to stakeholders. The development of various maps online https://apps.des.qld.gov.au/map-request/re-broad-veg-group/ by Spatial Information Services from 2004 was imperative to meeting this need, whereby stakeholders were emailed a free, tailor-made RE map for their requested area of interest.

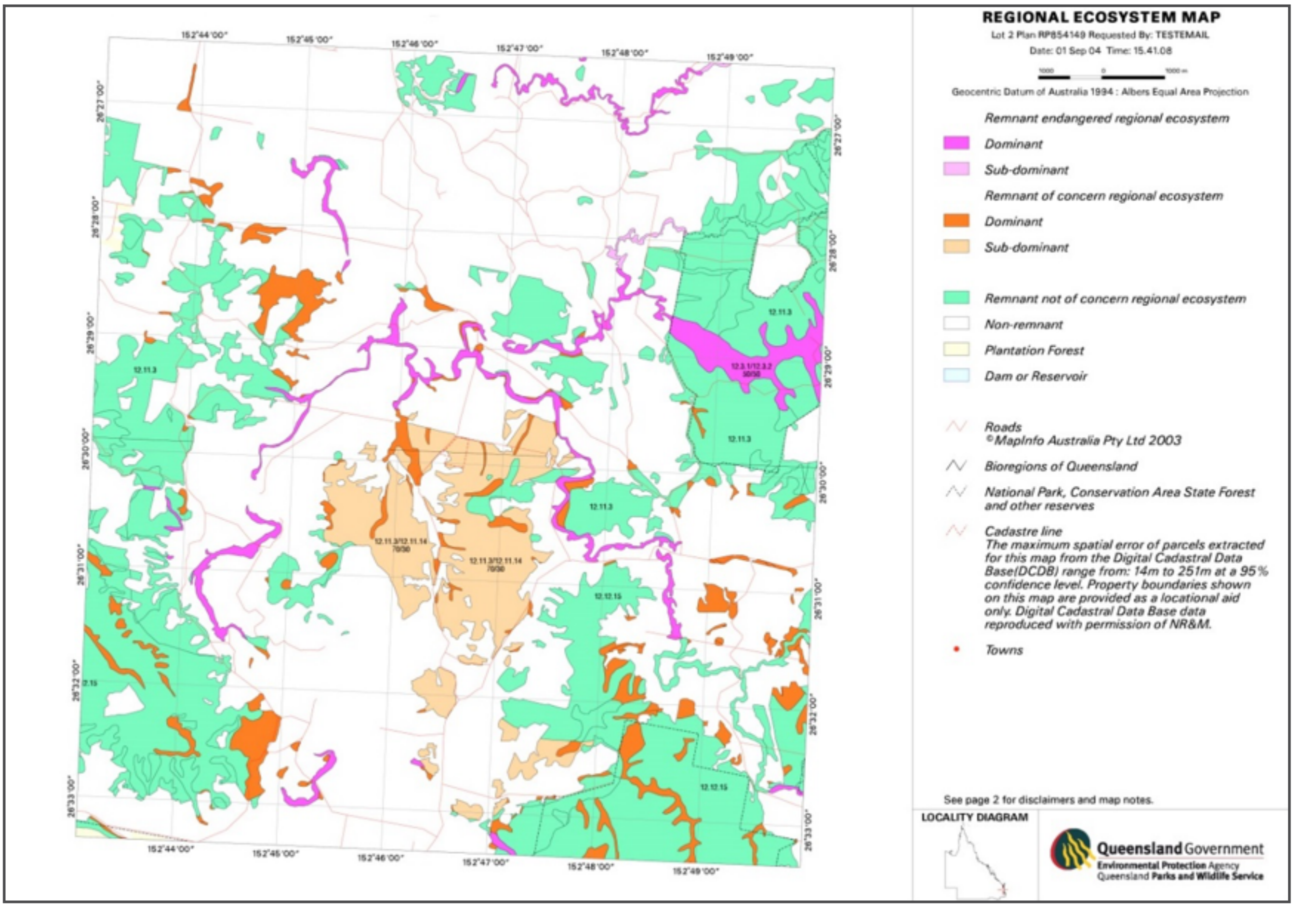


Figure 4 Customised free regional ecosystems maps have been produced online since 2004.

Comprehensive property reports with explanatory tables and analysis are now available through https://apps.des.qld.gov.au/map-request/re-broad-veg-group/.

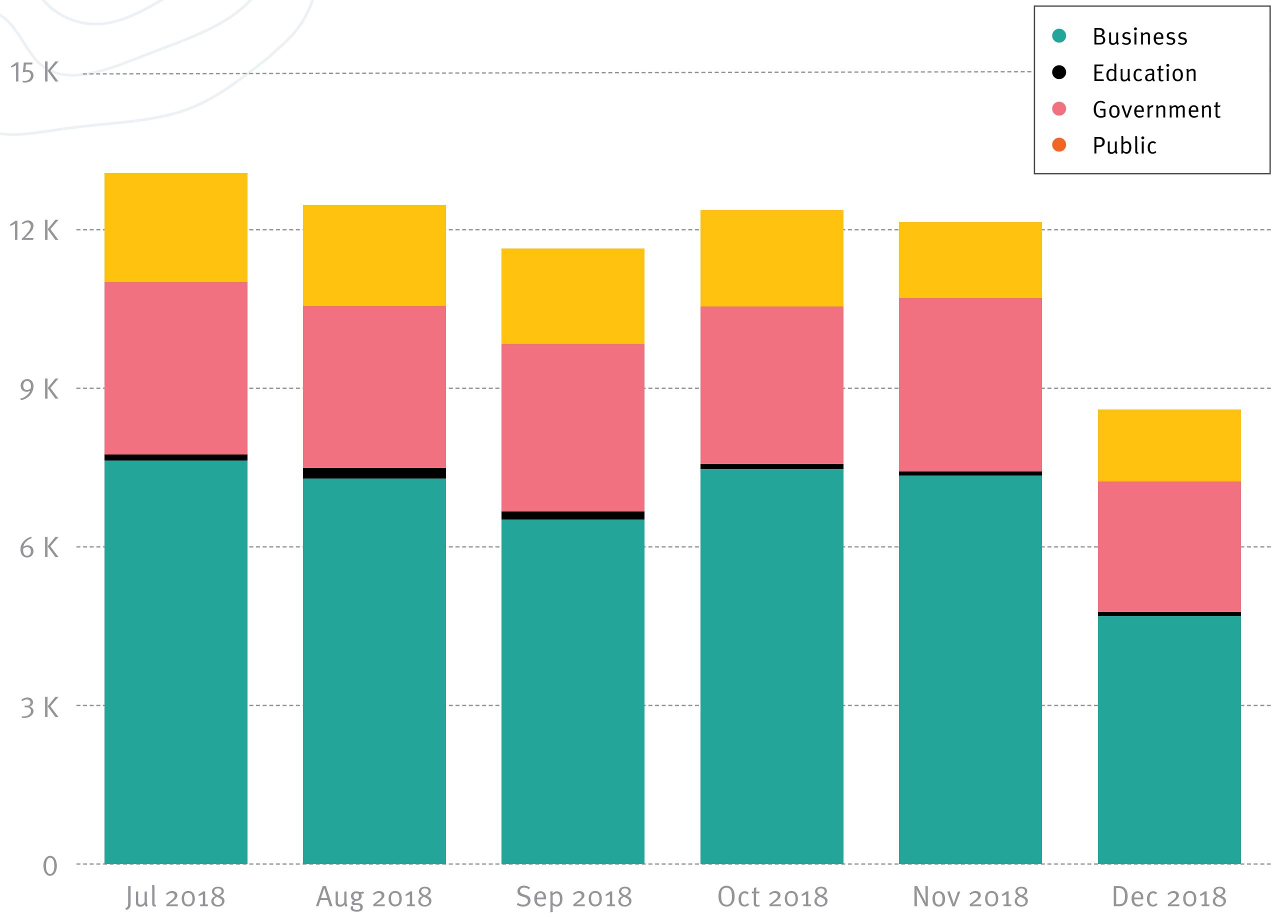


Figure 5 Requests over time by sector—monthly number of regional ecosystem maps produced for stakeholders from July 2018

Spreading buttress roots of *Heritiera littoralis*, Daintree National Park, Wet Tropics bioregion (V.J. Neldner, Queensland Herbarium, Queensland Government)

The RE mapping is also freely available to government, the public and industry using Queensland Globe: https://qldglobe.information.qld.gov.au. The RE digital coverages are also available for free in shapefile format through the Queensland Government data website https://data.qld.gov.au/ for individuals or organisation that wishes to conduct analyses on the coverages, search for 'regional ecosystems'.

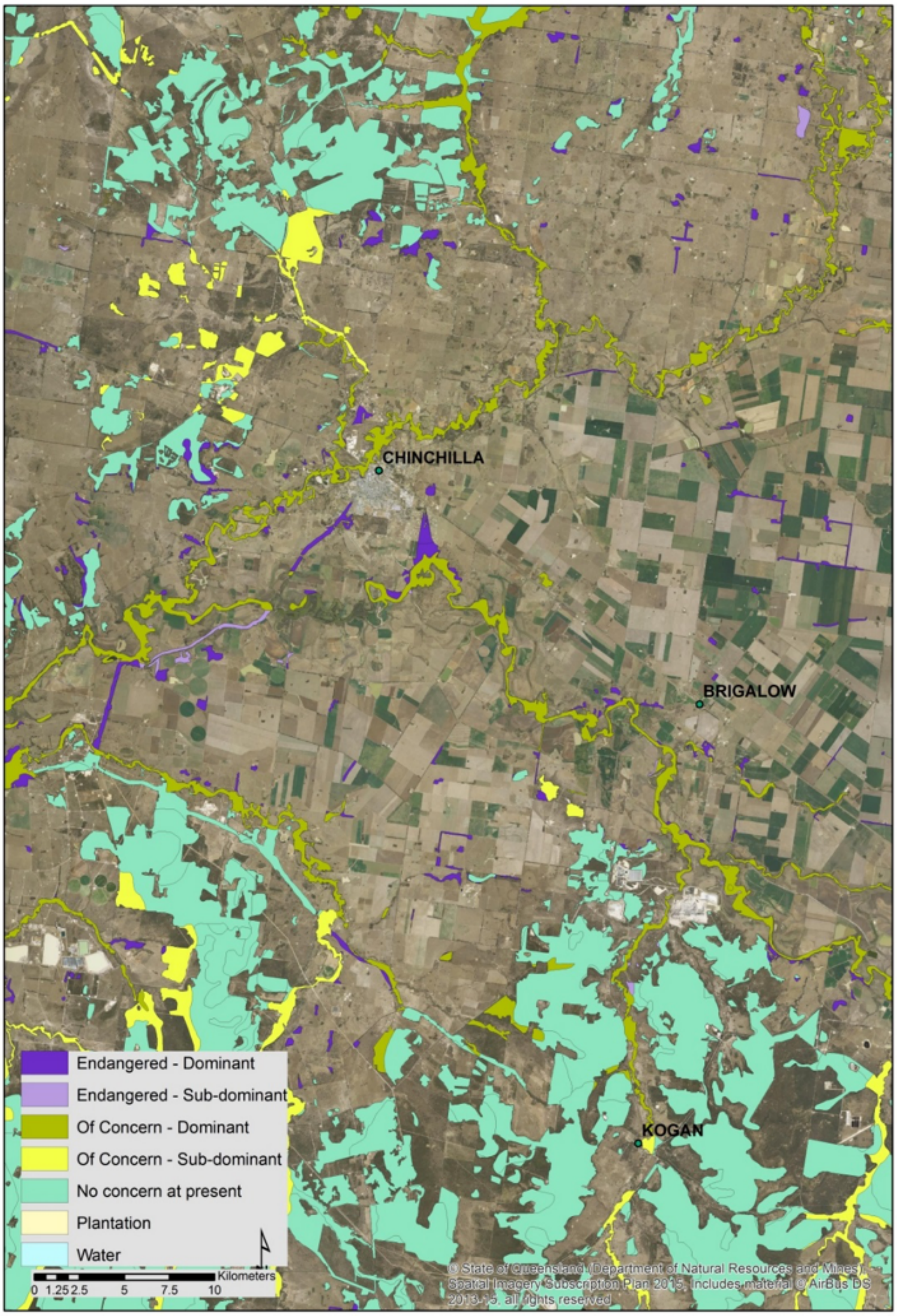


Figure 6 **Fragmented remnant 2013 vegetation coloured by biodiversity status for the area near Chinchilla where cropping and grazing are the main land uses. Queensland Globe, State of Queensland 2016**

The Regional Ecosystems Description Database (REDD) https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/ was developed to provide up-to-date information on the current list of regional ecosystems, which has been added to and enhanced since Sattler and Williams (1999). Comprehensive technical descriptions and benchmarks based on CORVEG sites have also been produced to describe the characteristics of individual REs. https://publications.qld.gov.au/dataset/re-technical-descriptions, https://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/.

While the CORVEG data that underpins the RE mapping is currently only available online to state government workers, it is available to general public through AEKOS https://www.ecoinformatics.org.au/access-data or by request to the Herbarium.

Defending the regional ecosystem maps and information in court

With the RE maps being certified legal documents in the first years of the implementation of the VMA, version control and secure archiving (both digital and paper copy) were required (https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/about/). The rigorous certified map modification process was also developed, and tool kit of data requirements and processes for input into the map modification process were developed.

Invariably some mapping decisions were disputed in court, which provided particular challenges in explaining ecological concepts and data in the legal arena. For example, while it is recognised by ecologists that vegetation boundaries may be abrupt, e.g. rainforest and savanna based on geological or fire boundary, or diffuse eucalypt woodland merging progressively to another eucalypt woodland, so a vegetation boundary (line on a map) may represent up to 200 metres in reality on the ground. Field inspections to disputed sites, or sites of alleged clearing breaches under the VMA, were required to collect adequate data and prepare expert witness statements. On occasions, staff were required to provide evidence in court, so expert witness training was provided.

The acceptance of the QHRESM by government and stakeholders is largely based on the scientific reputation, transparent documentation of processes and the delivery of user-friendly and accessible map products. Amongst many attributes, accurate plant identification is imperative in identifying REs, and with botanists having access to the curated Herbarium collection and botanical specialists, the identification of plants is generally not disputed. The QHRESM contributed nearly 90 000 specimens to the Herbarium collections between 1970 and 2011 (Neldner 2015). The remote sensing expertise of the SLATS team is widely accepted by stakeholders and other states and territories, and provides confidence in the spatial accuracy and rectification of satellite imagery on which the RE coverages are based.

A definitive analysis of regional ecosystem extent

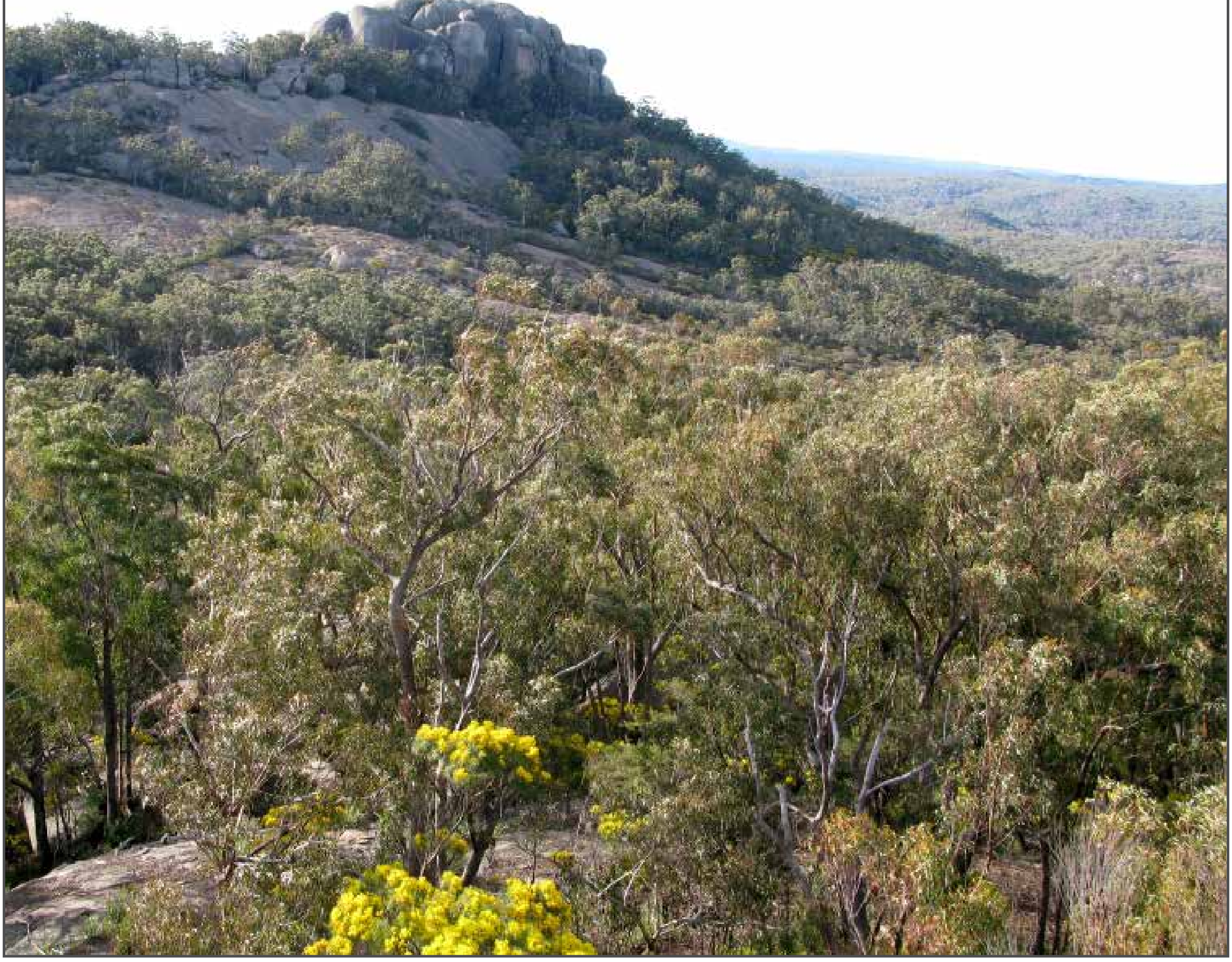
There was a need to produce a definitive analysis of the pre clearing and remnant extent of regional ecosystems to assess the status of the REs under the VMA and EP Act, but also because the land clearing issue continues to be highly political. It was also imperative that for each analysis all coverages, e.g. pre clearing, remnant 1997, remnant 1999, etc. were updated to accommodate corrections or improvements that were made, so that the comparison between years and rates of clearing was made on the most accurate mapping.

The analysis of mosaic polygons requires a more sophisticated analysis of area be conducted than on homogeneous polygons, and this has not been understood or accounted for in some GIS analysis of the RE coverages. Hence, the Queensland Herbarium has produced definitive analyses of the extent of remnant vegetation and REs in Queensland since 2001 with each new release of the RE mapping (Accad et al. 2001, 2003, 2006, 2008, 2012, 2017, 2019, Accad and Neldner 2015, Wilson et al. 2002).

Increasing maintenance load on staff

As the QHRESM program mapped more areas and the field surveys gathered more ecological site data, plant specimens and photographs, the administrative cost of maintaining these data increases. These improved data sources also become in greater demand for a variety of applications and uses, so efficient data and map distribution methods are essential. Plant nomenclature changes regularly so there are always scientific name changes (some simple, and others more complex) that need to adjusted, and generally in a multiple of products, e.g. a plant name change could affect a number of CORVEG sites, photograph captions, technical descriptions and benchmarks. To reduce this maintenance cost, there is a need to structure databases so that a fundamental change of a plant name can flow through automatically to all relevant products. Significant investment in scoping and designing an integrated ecological database has occurred through the Biodiversity Systems Modernisation program. However, more work is required to implement a new improved database.

Eucalyptus andrewsii, *E. prava*, and *E. youmanii* woodland , RE 13.12.2, looking to Mt Norman from Mallee Ridge, Girraween National Park (Queensland Government)



Current uses of regional ecosystem mapping

The QHRESM program has been labour intensive with photointerpretation, coverage building and maintaining, plant identification and curation, and database entry and maintenance being time-consuming but essential technical tasks completed in the office. In addition, the fundamental field work which provides the scientific rigour to the QHRESM program is both labour and resources intensive. However the QHRESM program has provided rigorous scientific and objective data that can and has been used by a large variety of stakeholders and clients in both industry and government, so like soil and resource surveys in Australia and the USA, the benefit-cost ratios are in the order of 40:1 to 50:1 (Dent and Young 1981). Some of the current uses for the QHRESM program are listed below, with quotes from some users documented in Appendix 1.

Legislation and regulation

The RE maps are a key input into the assessable vegetation map (regulated vegetation management map) under the VMA, and the underlying RE maps are also used to calculate the extent remaining and the appropriate VM class.

For land holders to apply the various VM codes, for example, fodder harvesting, managing weeds, managing encroachment, they must refer to the appropriate regional ecosystem. The data for the structural and floristic characteristics come from the CORVEG database, augmented by observation sites, and are summarised into regional ecosystem descriptions in REDD.

The mapping is also freely available to government, the public and industry through the Queensland Globe or through maps online, which produces tailor made make products of defined areas, e.g. lot on plans, or specific locations in the landscape. REs are also central to the identification of essential habitat as defined in the VMA for threatened species listed under the Nature Conservation Act.

The RE maps are also fundamental to the implementation and regulation of the Environmental Protection Act (EP) as it pertains to developments such as mining.

Environmental planning—the RE mapping is one of the main spatial inputs into the Biodiversity Assessment and Planning Methodologies (BAMM) which are conducted on a bioregional basis around the state. The RE mapping is also used exhaustively by NPWS to evaluate the effectiveness of their protected area estate to conserve the state's biodiversity at the ecosystem level and to evaluate new areas for acquisition and addition to the protected area estate. It is essential for evaluating Nature Refuge proposals, and then the fire management guidelines in REDD are used to help formulate management plans.

Governments at all levels (national, state and local) use the RE mapping in their planning and regulation, and regional NRM groups for the planning of conservation investment in on-ground works. The RE mapping is also used by the real estate industry to search for possible limitations on the use of the land because of the VMA, EP or NC Acts.

Protected area management

The RE is a primary layer in planning for the placement of infrastructure and access trails, and for fire management on the QPWS managed estate. The fire guidelines assist in developing fire management activities for individual regional ecosystems.

Derived mapping/classification products

The Broad vegetation Groups (BVGs) are an amalgamation of the regional ecosystem mapping to produce mapping and classification of vegetation communities based primarily on structural and floristic attributes at scales ranging from 1:1 m to 1:5 m. The BVG classification is used to simplify the vegetation into distinct more readily undertook groupings.

The Wetlands mapping is nested within the RE framework and as well as mapping natural wetlands, includes human made wetlands. The Groundwater Dependent Ecosystems (GDE) mapping is derived directly from the RE mapping using a number of decision rules.

For threatened ecological communities listed under the Environment Protection and Biodiversity Conservation (EPBC) Act, the Commonwealth uses the RE mapping in Queensland to illustrate the distribution of these communities within Queensland, and also in the assessment of nominations for listing of National threatened ecological communities.

The Rural Fire Service in the Department of Fire and Emergency Services use the RE mapping as a primary input into their state-wide mapping of Bushfire hazards. The remnant mapping and the site data (particularly structure and biomass attributes) have been interrogated to develop bushfire hazard classes. The pre-clearing mapping and woody vegetation coverages produced by SLATS, together with terrain inputs, are interrogated to produce mapping of fire hazard for the non-remnant woody vegetation.

The pre-clearing mapping is also widely used for planning offsets and providing guidance on the vegetation that should be suited to grow on a site. This is also used to calculate the potential carbon that can grow on a site through the regrowth benefits tool.

The Great Barrier Reef Marine Park Authority (GRMPA) have used the RE coverage to develop 'Blue' maps of the vegetation of the various catchments to the reef, to assist with planning and developing conceptual models of how the catchment functions.

The use of the CORVEG site data

The CORVEG site data collected from standard sized plots using consistent methods (Neldner et. al. 2019b) is a key data source for defining and describing regional ecosystems. The descriptions of regional ecosystems in REDD descriptions, benchmarks and RE technical descriptions are all derived from the CORVEG site data. These data have been provided to TERN and AEKOS for access to users across the world. Currently there are 20,000 CORVEG secondary sites for Queensland. The location and species information from the CORVEG database are provided to WildNet and the Atlas of Living Australia to ensure accessibility of these data to the world.

The CORVEG data and RE mapping is also widely used for academic research (e.g. Lawson 2006, 2007, McCarthy et al. 2016) and for modelling of species and ecosystems distributions (Laidlaw et al. 2019).

Future improvements and challenges

Full documentation of Regional Ecosystems

There is a need to database and check all CORVEG data, and use it to produce comprehensive RE Technical Descriptions, Benchmarks and REDD descriptions. By producing these products, these will also show inadequacies in the representation of the site data, and point to REs that require strategic site sampling.

As the RE coverages have become more comprehensive, the relationship between closely related REs has become more difficult to communicate in written publications. There is a need to develop digital keys to REs (e.g. LUCID keys) and digital applications (apps) to improve the ease of identifying the correct RE, both in the office and in the field.

The fire management guidelines https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/fire-management/ and habitat suitability for threatened fauna and flora sections for each RE in REDD can be greatly expanded using tools such as species habitat modelling (Laidlaw et al. in prep.). This also assists in more accurate mapping of essential habitat under the VMA, and may improve the comprehensiveness of the flora trigger map under the Nature Conservation Act 1992.

More detailed (larger scale) mapping

There will continue to be a demand for larger scale mapping in areas of competing land use demands, particular urban areas, coastal areas and mining areas. Currently all of the Wet Tropics and much of Southeast Queensland bioregions are mapped at 1:50 000 scale (some parts such as Brisbane City Council at 1:25 000 scale). It is likely more LGAs will require larger scale mapping of homogeneous polygons (which is simpler for users) in the future as tools for their various planning schemes and development approvals.

Mapping the condition of regional ecosystems

Vegetation and regional ecosystems in different condition states retain different levels of biodiversity. Currently the RE framework only maps three broad condition states—remnant, high-value regrowth and and non-remnant. Within these states there can be considerable variation, particularly in the ground and shrub layers.

The BioCondition assessment tool (Eyre et al. 2015) has proven to be a robust assessment of site condition for natural vegetation and rehabilitation (Neldner and Ngugi 2014), however attempts to spatially map condition states have had very limited success (Buck et al. 2009). The QVEG project is researching a method for reliable mapping of vegetation condition across Queensland.

Immediate applications would include identifying non-remnant vegetation that has now reached remnant condition, monitoring of mining or illegal clearing rehabilitation, and the monitoring of condition of offset areas.

Monitoring changes in regional ecosystems

As well the need to monitor changes in condition of REs, there will be continuing need to monitor ecological sites for subtle changes in either the flora or fauna. Permanently marked sites re-located on previous CORVEG sites will provide a measure of the effectiveness of the present management and the impacts of threatening processes such as climate change, myrtle rust or feral species is having on the biodiversity of an area, e.g. Neldner and Butler (in press). Presently, apart from the Southeast Queensland horse trail site monitoring program (Ngugi et al. 2017) and the Moreton Bay Mangrove Monitoring project (Accad et al. 2016) there are no funded projects to provide this long-term monitoring.

Adopt new technologies to continuously improve regional ecosystem mapping

New sources of satellite imagery, digital aerial photography, LIDAR, and radar continue to improve the resolution and precision, the QHRESM program must continuously evaluate the utility of these new data sources to improve the mapping. Drones offer the potential to capture data cheaply for inaccessible areas. Improvements in GIS software and modelling also offer opportunities to enhance the RE mapping.

Conclusions

Regional ecosystems provide a robust and systematic biodiversity inventory, planning framework and information system for Queensland. The development and refinement of the regional ecosystem classification and mapping has required the investment of substantial resources and staff expertise over a number of decades.

The delivery of Queensland-wide products has required continued leadership, commitment and ownership by the Queensland Herbarium, and a determination to deliver high quality products that can meet a large number of client's needs.

While the regional ecosystem program has already delivered significant knowledge and benefits, continued innovation and improvements are expected over the coming years.

References

Accad, A., Neldner, V.J., Wilson, B. A. and Niehus, R.E. (2001) Remnant Vegetation in Queensland: Analysis of Pre-clearing, Remnant 1997–1999 Regional Ecosystem Information. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Accad, A., Neldner, V.J., Wilson, B. A. and Niehus, R.E. (2003) Remnant Vegetation in Queensland: Analysis of Remnant Vegetation 1997—1999—2000—2001, including Regional Ecosystem Information. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Accad, A., Neldner, V.J., Wilson, B. A. and Niehus, R.E. (2006) Remnant Vegetation in Queensland: Analysis of Remnant Vegetation 1997—1999—2000—2001—2003, including Regional Ecosystem Information. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Accad, A., Neldner, V.J., Wilson, B. A. and Niehus, R.E. (2008) Remnant Vegetation in Queensland: Analysis of Remnant Vegetation 1997—1999—2000—2001—2003—2005, including Regional Ecosystem Information. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Accad, A. and Neldner, V.J. (2015) Remnant Regional Ecosystem Vegetation in Queensland, Analysis 1997–2013. (Queensland Department of Science, Information Technology and Innovation: Brisbane).

Accad, A., Li, J., Dowling, R. and Guymer, G.P. 2016, Mangrove and associated communities of Moreton Bay, Queensland, Australia: change in extent 1955–1997–2012. Queensland Herbarium, Department of Science, Information Technology and Innovation. https://publications.qld.gov.au/dataset/mangrove-and-associated-communities-of-moreton-bay

Accad, A., Neldner, V.J., Kelley, J.A.R. and Li, J. 2017, Remnant Regional Ecosystem Vegetation in Queensland, Analysis 1997-2015. Queensland Department of Science, Information Technology and Innovation: Brisbane. https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/remnant-vegetation/

Accad, A., Neldner, V.J., Kelley, J.A.R., Li, J. and Richter, D. 2019, Remnant Regional Ecosystem Vegetation in Queensland, Analysis 1997-2017. Queensland Department of Environment and Science: Brisbane. https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/remnant-vegetation/

Addicott, E., Laurance, S. and Lyons, M., Butler D. and Neldner, J. (2018a) When rare species are not important: linking plot-based vegetation classifications and landscape-scale mapping in Australian savanna vegetation. *Community Ecology 19*, 67–76.

AUSLIG (1990) Vegetation. Atlas of Australian Resources. Third Series, Volume 6. Australian Survey and Land Information Group, Canberra.

Beadle, N.C.W. and Costin, A.B. (1952) Ecological classification and nomenclature. Proceedings of the Linnean Society of New South Wales 77:61–82.

Bean, A.R., Sparshott, K.M., McDonald, W.J.F. and Neldner, V.J. (Eds) (1998) Forest Ecosystem Mapping and Analysis of South-Eastern Queensland Biogeographic Region. A. Vegetation Survey and Mapping. Report for Queensland CRA/RFA Steering Committee. Queensland Herbarium, Queensland Department of Environment and Heritage, and Environment Australia, Commonwealth Department of the Environment, Sport and Territories, Brisbane.

Benson, J. (1995) Sampling, strategies and costs of regional vegetation mapping strategies. The Globe number 43. Journal of the Australian Map Circle 43:18–27.

Bohnet I.C., Roebeling P.C., Williams K.J., Holzworth D., van Grieken M.E., Pert P.L., Kroon F.J., Westcott D.A. and Brodie, J. (2011) Landscapes Toolkit—an integrated modelling framework to assist stakeholders in exploring options for sustainable landscape development. Landscape Ecology 26, 1179–1198. DOI: 10.1007/s10980-011-9640-0.

Boyland, D.E. (1974) Vegetation (maps included). In Western Arid Region Land Use Study—Part 1, Technical Bulletin No. 12, Division of Land Utilisation, Department of Primary Industries, Brisbane, pp. 47–70.

Boyland, D.E. (1980) Vegetation (maps included). In Western Arid Region Land Use Study—Part II, Technical Bulletin No. 22, Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane, pp. 36–67.

Boyland, D.E. (1984) South Western Queensland. Vegetation Survey of Queensland. Queensland Department of Primary Industries Botany Bulletin No. 4.

Buck, R., Armston, J., Eyre, T., Neldner, J., Kelly, A. and Kitchen, J. (2009) Queensland Vegetation Condition Mapping Trial. Department of Environment and Resource Management, Brisbane.

Butler D.W. (2005) Recovery plan for the Bluegrass (*Dichanthium* spp.) dominant grasslands in the Brigalow Belt bioregions in Queensland endangered ecological community 2006-2010. Report to Department of Environment and Heritage, Canberra. Queensland Parks and Wildlife Service, Brisbane.

Butler D.W., Fensham, R.J., Murphy, B. P., Haberle, S. G., Bury, S. J. and Bowman, D.M. J.S. (2014) Aborigine-managed forest, savanna and grassland: biome switching in montane eastern Australia. Journal of Biogeography 41:1492–1505.

Comben, P. (1999) Riversleigh—Pasture to Park. How a fossil field was preserved for science, pp.4–6. In Riversleigh Notes—The Newsletter of the Riversleigh Society (Riversleigh Society, P O Box 868, Kensington NSW 1465).

Dent, D. and Young, A. (1981). Soil Survey and Land Evaluation. George Allen and Unwin, London.

DEWR (2006) Metadata: Australia—Estimated Pre-1750 Major Vegetation Subgroups—NVIS Stage 1, Version 3.1—Albers. Australian Government Department of the Environment and Water Resources, Canberra.

DSEWPaC (2012) Australia—Estimated Pre-1750 Major Vegetation Subgroups—NVIS Version 4.1 (Albers 100 m analysis product) (Metadata identifier: c9136118-a054-4835-b4d6-1645cba33e10). Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Department of Natural Resources and Mines (2000) Land cover change in Queensland 1997–1999: a Statewide Landcover and Trees Study SLATS) Report, Dec, 2004. Department of Natural Resources, Brisbane.

Department of Natural Resources and Mines (2004) Land cover change in Queensland 1988–1991: a Statewide Landcover and Trees Study SLATS) Report, Dec, 2004. Department of Natural Resources, Brisbane.

DES (2018) Land cover change in Queensland State-wide Landcover and Trees Study Summary Report: 2016–17 and 2017–18, Department of Environment and Science. https://www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/slats/slats-report#most-recent-reports

Dowling, R.M. and McDonald, W.J.F. (1976) Moreton Region Vegetation Map Series: Brisbane. Botany Branch, Queensland Department of Primary Industries, Brisbane.

Elsol, J.A. and Dowling, R.M. (1978) Moreton Region Vegetation Map Series: Beenleigh. Botany Branch, Queensland Department of Primary Industries, Brisbane.

Executive Steering Committee for Australian Vegetation Information (ESCAVI) (2003) Australian Vegetation Attribute Manual: National Vegetation Information System, Version 6.0. Department of the Environment and Heritage, Canberra.

Eyre, T.J., Kelly, A.L., Neldner, V.J., Wilson, B.A., Ferguson, D.J., Laidlaw, M.J. and Franks, A.J. (2015) BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Methodology Manual. Version 2.2. Department of Science, Information Technology and Innovation http://www.qld.gov.au/environment/plants-animals/plants/herbarium/publications/

Fensham, R.J. (1995) Floristics and environmental relations of inland dry rainforest in north Queensland, Australia. Journal of Biogeography 22:1047–1063.

Fensham, R.J. (2008) Leichhardt's maps: 100 years of change in vegetation structure in inland Queensland. Journal of Biogeography 35:141–56.

Fensham, R.J., Powell, O. and Horne, J. (2011) Rail survey plans to remote sensing: vegetation change in the Mulga Lands of eastern Australia and its implications for land use. The Rangeland Journal 33:229–238.

Fensham, R.J., Wang, J. and Kilgour, C. (2015) The relative impacts of grazing, fire and invasion by buffel grass (*Cenchrus ciliaris*) on the floristic composition of a rangeland savanna ecosystem. The Rangeland Journal 37:227–237.

Fox, I.D., Neldner, V.J., Wilson, G.W. and Bannink, P.J. (2001) Vegetation of Northern Australia. Brisbane: Queensland Herbarium, Environmental Protection Agency.

Grantham, H. S., Pressey, R.L., Wells, J.A. and Beattie, A.J. (2010) Effectiveness of Biodiversity Surrogates for Conservation Planning: Different Measures of Effectiveness Generate a Kaleidoscope of Variation. PLoS ONE 5(7): e11430. doi:10.1371/journal.pone.0011430

Harwood T.D., Donohue R.J., Williams K.J., Ferrier S., McVicar T.R., Newell G. and White M. (2016) HCAS: A new way to assess the condition of natural habitats for terrestrial biodiversity across whole regions using remote sensing data. Methods in Ecology and Evolution 7, 1050-1059. DOI: 10.1111/2041–210X.12579.

Hill R., Grace R., O'Malley T., Williams K.J., Pert P.L. and Jenkins S. (2010a) Mission Beach Habitat Network Action Plan. CSIRO and Terrain NRM, Cairns.

Hill R., Williams K., Pert P. and Harding E. (2009) Cassowary conservation through adaptive, collaborative planning at Mission Beach. In: Taylor R. and Long S. (eds) Proceedings of the 2008 Marine and Tropical Sciences Research Facility Annual Conference, 28 April - 1 May 2008. Reef and Rainforest Research Centre Ltd., 51–63.

Hill R., Williams K.J., Pert P.L., Robinson C.J., Dale A.P., Westcott D.A., Grace R.A. and O'Malley T. (2010b) Adaptive community-based biodiversity conservation in Australia's tropical rainforests. Environmental Conservation 37(1), 73-82. DOI: doi:10.1017/S0376892910000330.

Hnatiuk, R.J., Thackway, R. and Walker, J., M.S. (2009) Vegetation. In: The National Committee on Soil and Terrain (Eds) Australian Soil and Land Survey. Field Handbook. 3rd edn. Melbourne: CSIRO publishing, pg. 73–126.

Keith, D.A. and Benson, D.H. (1988) The natural vegetation of the Katoomba 1:100 000 map sheet. Cunninghamia 2:107–143.

Laidlaw, M.J. (2019) Threatened flora habitat. https://www.stateoftheenvironment.des.qld.gov.au/biodiversity/species-and-habitation#topic-flora

Laidlaw, M.J., Guymer, G.P., Butler, D.W. and Halford, D.A. (in prep.) Quantifying the impact of land clearing on threatened species habitat in Queensland, Australia.

Lawson, B. E. (2006) Delving into the Datasets I: Trends in Regional Ecosystem Mapping in Queensland, Australasian Journal of Environmental Management 13: 28–35.

Lawson, B. E. (2007) The utility of site-based datasets and regional ecosystem mapping for biodiversity conservation in the South-east Queensland Bioregion: past, present, future. PhD Thesis, School of Natural and Rural Systems Management, University of Queensland.

Leonard, J., Opie, K., Newnham, G. and Blanchi, R. (2014) A new methodology for State-wide mapping of Bushfire Prone Areas in Queensland. Melbourne, CSIRO report for the Public Safety Business Agency.

McCarthy, J. K., Mokany, K. and Dwyer, J.M. (2016) Estimating plant abundances from crown cover and forest structure data reveals size-dependent patterns of rarity in subtropical Australia. Applied vegetation Science 19:700–710. DOI: 10.1111/avsc.12261

McDonald, W.J.F. (1998) Spatial and temporal patterns in the dry seasonal subtropical rainforests of eastern Australia, with particular reference to the vine thickets of central and southern Queensland. PhD. Thesis, University of New England.

McDonald, W.J.F. and Dillewaard, H.A. (1994) CORVEG (Version 2.0) Vegetation and Flora Data Base for Queensland. Queensland Herbarium, Queensland Department of Environment and Heritage, Brisbane.

McDonald, W.J.F. and Elsol, J.A. (1984) Summary Report for Caloundra, Brisbane, Beenleigh and Murwillumbah Sheets. Moreton Region Vegetation Map Series, Queensland Department of Primary Industries, Brisbane.

McGrath, C. (2011) Synopsis of the Queensland Legal System. 5th edition. Environmental Law Publishing, Brisbane.

Morgan, M.G. and Terrey, J. (1990) Natural regions of western New South Wales and their use for environmental management. Proceedings of Ecological Society of Australia 16:67–73.

Neldner, V.J. (1984) South Central Queensland. Vegetation Survey of Queensland. Queensland Department of Primary Industries Botany Bulletin No. 3.

Neldner, V.J. (1991) Central Western Queensland. Vegetation Survey of Queensland. Queensland Department of Primary Industries Botany Bulletin No. 9.

Neldner, V.J. (1993) Vegetation Survey and Mapping in Queensland. Queensland Botany Bulletin No. 12.

Neldner, V.J. (2014). The contribution of vegetation survey and mapping to Herbarium collections and botanical knowledge: a case study from Queensland. Cunninghamia 14: 77–87.

Neldner V.J. and Butler D.W. (2008) Is 500 m² an effective plot size to sample floristic diversity of Queensland vegetation? *Cunninghamia*, 10: 513–520.

Neldner, V.J. and Butler, D.W. (in press) Dynamics of the ground layer communities of tropical eucalypt woodlands of northern Queensland

Neldner V.J. and Clarkson J.R. (1995) Vegetation Survey and Mapping of Cape York Peninsula. Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General and Queensland Department of Environment of Heritage, Brisbane.

Neldner V.J., Crossley D.C. and Cofinas M. (1995) Using Geographical Information Systems (GIS) to determine the adequacy of sampling in vegetation surveys. Biological Conservation 73:1–17

Neldner, V.J. and Howitt, C.J. (1991) Comparison of an intuitive mapping classification and numerical classifications of vegetation in south-east Queensland, Australia. Vegetation 94:141–152.

Neldner, V.J., Kirkwood, A.B. and Collyer, B.S. (2004) Optimum time for sampling floristic diversity in tropical eucalypt woodlands of northern Queensland. The Rangeland Journal 26: 190–203.

Neldner, V.J. and Ngugi, M.R. (2014) Application of the BioCondition assessment framework to mine vegetation rehabilitation. Ecological Management and Restoration 15:158–161.

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F. and Ford, A.J. (2015) The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 2.0. Queensland Herbarium, Department of Science, Information Technology and Innovation, Brisbane.

Neldner, V.J., Thompson, E.J., Bean, A.R and Dillewaard H.A. (1999) Methodology for Survey and Mapping of Vegetation Communities and Regional Ecosystems in Queensland. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Neldner, V.J., Wilson, B.A., Thompson, E.J. and Dillewaard H.A. (2004) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.0. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Neldner, V.J., Wilson, B.A., Thompson, E.J. and Dillewaard H.A. (2005) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.1. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Neldner, V.J., Wilson, B.A., Thompson, E.J. and Dillewaard H.A. (2012) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.2.Updated August 2012. Queensland Herbarium, Queensland Department of Science, Information Technology, Innovation and the Arts, Brisbane.

Neldner, V.J., Wilson, B.A., Dillewaard H.A., Ryan, T.S. and Butler, D. W. (2017) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 4.0. Queensland Herbarium, Queensland Department of Science, Information Technology and Innovation, Brisbane. https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4

Neldner, V.J., Wilson, B.A., Dillewaard H.A., Ryan, T.S., Butler, D. W., McDonald, W.J.F., Addicott, E.P. and Appelman, C.N. 2019b, Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 5.0. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane. https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4

Ngugi, M.R., Neldner, V.J. and Dowling, R. 2014, Non-native plant species richness adjacent to a horse trail network in seven National Parks in southeast Queensland, Australia. *Australasian Journal of Environmental Management* DOI: 10.1080/14486563.2014.952788

Queensland Department of Science, Information Technology and Innovation. (2016) Land cover change in Queensland 2014–15: a Statewide Landcover and Trees Study (SLATS) report. DSITI, Brisbane.

Queensland Herbarium (2016) Regional Ecosystem Framework Training. Prerequisites, Competencies and Assessment. https://publications.qld.gov.au/dataset/training-regional-ecosystem-fwork

Prober S.M., Gosper C.R., Gilfedder L., Thiele K.R., Williams K.J. and Yates C.J. (2017, in press) Temperate eucalypt woodlands. In: Keith D (ed.) Australian Vegetation, Third Edition.

Prober S.M., Williams K.J., Harwood T.D., Doerr V.A.J., Jeanneret T., Manion G. and Ferrier S. (2015) Helping Biodiversity Adapt: Supporting climate-adaptation planning using a community-level modelling approach. CSIRO Land and Water Flagship, Canberra.

Purdie, R.W. (1986) Development of a National Park System for Queensland's Mulga Region, pp 122–127, in Sattler, P.S. (ed.), The Mulga Lands. Symposium Proceedings. (Royal Society of Queensland, Brisbane).

Purdie, R.W. (1990) Vegetation (Maps included). In Western Arid Region Land Use Study—Part VI, Technical Bulletin No.28, Division of Land Utilisation, Department of Primary Industries, Brisbane, pp. 49–92.

Purdie, R.W. and McDonald, W.J.F. (1990) Vegetation. (Maps included). In Western Arid Region Land Use Study - Part III, Technical Bulletin No. 29. Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane, pp. 69–103.

Raunkiaer, C. (1934) The Life Forms of Plants and Statistical Plant Geography. Clarendon Press, Oxford.

Reeson A.F., Rodriguez L.C., Whitten S.M., Williams K., Nolles K., Windle J. and Rolfe J. (2011) Adapting auctions for the provision of ecosystem services at the landscape scale. Ecological Economics 70(9), 1621-1627. DOI: 10.1016/j.ecolecon.2011.03.022.

Sattler, P.S. (1986) Nature Conservation in Queensland: Planning the Matrix, Presidential Address, 7 April 1986. Proceedings of the Royal Society of Queensland, 97: 1–21. (Royal Society of Queensland, Brisbane).

Sattler, P.S. (1993) Towards a Nationwide Biodiversity Strategy—The Queensland Contribution, pp 313–325. In Moritz, C. & Kikkawa, J. (eds), Conservation Biology in Australia and Oceania. (Surrey Beatty and Sons, Chipping Norton).

Sattler, P.S. (1999) Introduction. In: Sattler P.S. and Williams R.D. (eds), The Conservation Status of Queensland Bioregional Ecosystems. Environmental Protection Agency, Brisbane.

Sattler P.S. and Williams R.D. (eds) (1999), The Conservation Status of Queensland Bioregional Ecosystems. Environmental Protection Agency, Brisbane.

Specht, R.L. (1970) 'Vegetation', in G.W. Leeper (ed.), The Australian Environment, 4th edition, CSIRO and Melbourne University Press, pp. 44–67.

Stanton, J.P. and Morgan, M. G. (1977) Project RAKES—The Rapid Selection and Appraisal of Key and Endangered Sites: The Queensland Case Study. A report to the Department of Environment, Housing and Community Development, University of New England, Armidale.

Sun, D., Hnatiuk, R.J. and Neldner, V.J. (1997) Review of vegetation classification and mapping systems undertaken by major forested land management agencies in Australia. Australian Journal of Botany 45: 929–948.

Thackway, R. and Cresswell, I.D. (eds) (1995) An Interim Biogeographic Regionalisation for Australia: a framework for establishing a national system of reserve, version 4.0. Australian, Nature Conservation Agency, Canberra.

Thackway R. and Lesslie R. (2005) Vegetation Assets, States, and Transitions: accounting for vegetation condition in the Australian landscape. BRS Technical Report, Bureau of Rural Sciences, Canberra.

Thackway, R., Neldner, V. J. and Bolton, M.P. (2008) Vegetation. In McKenzie. N.J., Grundy, M.J., Webster, R. and Ringrose-Voase, A.J. (Eds) Australian soil and land survey handbook: guidelines for surveying soil and land resources (2nd edn). CSIRO Publishing: Melbourne.

Walker, J. and Hopkins, M.S. (1990) Vegetation. In: McDonald, R.C., R.F., Isbell, J.G., Speight, J., Walker and Hopkins, M.S. (Eds) Australian Soil and Land Survey. Field Handbook. 2nd edn. Melbourne: Inkata Press.

Webb, L.J. (1978) A general classification of Australian rainforests. Australian Plants 9:349–363.

Webb, L.J., Tracey, J.G., Williams, W.T. and Lance, G.N. (1970) Studies in the numerical analysis of complex rainforest communities. V. A comparison of the properties of floristic and physiognomic - structural data. Journal of Ecology 58:203–232.

Williams K.J., Belbin L., Austin M.P., Stein J. and Ferrier S. (2012a) Which environmental variables should I use in my biodiversity model? International Journal of Geographic Information Sciences 26(11), 2009–2047. DOI: 10.1080/13658816.2012.698015.

Williams K.J., Faith D.P., Ferrier S., Hill R. and Pert P. (2009a) Potential gaps in the complementary representation of regional ecosystems within protected areas of the Wet Tropics natural resource management planning region. In: Taylor R and Long S (eds) Proceedings of the 2008 Marine and Tropical Sciences Research Facility Annual Conference, 28 April – 1 May 2008. Reef and Rainforest Research Centre Ltd, Cairns.

Williams K.J., Ferrier S., Rosauer D., Yeates D., Manion G., Harwood T., Stein J., Faith D.P., Laity T. and Whalen, A. (2010) Harnessing Continent-Wide Biodiversity Datasets for Prioritising National Conservation Investment. A report prepared for the Department of Sustainability, Environment, Water, Population and Communities, Australian Government, Canberra, by CSIRO Ecosystem Sciences, Canberra, https://publications.csiro.au/rpr/pub?list=BRO&pid=csiro:EP102983.

Williams, K.J., Hill, R., Pert, P.L., Harding, E.K. and O'Malley, T. (2009b) Current, pre-clearing and 2025 scenarios of vegetation cover and cassowary habitat in Mission Beach and surrounds. In: Taylor R. and Long S. (eds) Proceedings of the 2008 Marine and Tropical Sciences Research Facility Annual Conference, 28 April – 1 May 2008. Reef and Rainforest Research Centre Ltd, Cairns.

Williams, K.J., Reeson, A.F., Drielsma M.J. and Love, J. (2012b) Optimised whole-landscape ecological metrics for effective delivery of connectivity-focused conservation incentive payments. Ecological Economics 81, 48-59. DOI: 10.1016/j.ecolecon.2012.07.005.

Wilson, B.A. (2000) Queensland Herbarium vegetation and regional ecosystem mapping program, in Boulter, S.L., Wilson, B.A., Westrup, J., Anderson, E.R., Turner, E.J. and Scanlan, J.C. (eds), Native Vegetation Management in Queensland. Background, Science and Values. Department of Natural Resources, Brisbane.

Wilson, B. A., Neldner, V.J. and Accad, A. (2002) The extent and status of remnant vegetation in Queensland and its implications for statewide vegetation management and legislation. The Rangeland Journal 24:6–35.

Wilson, P.R. and Taylor, P.M. (2012) Land Zones of Queensland. Queensland Herbarium, Queensland Department of Science, Information Technology, Innovation and the Arts, Brisbane, p 79. http://www.ehp.qld.gov.au/assets/documents/plants-animals/ecosystems/land-zones-queensland.pdf

Young, P. (1991) Summary Report on Channel Country Complex Biogeographic Survey. Unpublished report. (Queensland Dept of Environment and Heritage, Brisbane).

Appendix 1

Users/clients comments on the utility of the RE mapping and importance for their work

Government

Never underestimate the power of a map. Policies and laws to manage and conserve biodiversity depend on simple words and tools to represent complex ecological concepts. The 'regional ecosystem' unit, and the maps created to show these, are superlative examples. Queensland was uniquely blessed that they came into existence just when the State started to get serious about nature conservation.

Policy makers value them exactly because they gave us, for the first time, a practical way to interpret the natural environment at a landscape scale. Vague assertions were replaced with visually tangible lines, colours, numbers and statistics which transformed the conversation with decision-makers and the wider community forever. Regional ecosystem mapping has given us an enduring tool that has (thankfully) improved with age.

Adrian Jeffreys
Executive Director, Environment Policy
Department of the Premier and Cabinet
19 December 2016

The regional ecosystem mapping framework in Queensland is from our perspective the most comprehensive ecosystem-level mapping and classification system for any state in Australia, particularly now that version 10 is available. It provides critical information for determining the Queensland range of threatened ecological communities for potential national protection under national environment law. In particular, the pre-clearing and current estimated extent data for remnant vegetation and regional descriptions is crucial to define and assess national ecological communities within Queensland.

Matt White
Director, Ecological Communities
Commonwealth Department of Environment and Energy
9 December 2016

The regional ecosystem mapping is a critical tool for the work of my team. We use it to: inform the selection of sites for flora and fauna survey and monitoring; evaluate habitat suitability for significant species; examine land use suitability; and to inform and review management practices such as the application of planned burning for conservation purposes. The comprehensive coverage of the mapping and its ongoing maintenance and refinement is fundamental to building knowledge and understanding of the values conserved on QPWS estate and to their effective management.

Dr Rhonda Melzer
Manager Ecological Assessment Unit, QPWS
19 December 2016

> As an environmental professional working for the Queensland Government (Transport and Main Roads) the use of regional ecosystem information is critical for my day to day operations. I use regional ecosystem information in the assessment of a range of scenarios, from adjoining property owners wanting to clear small amounts of vegetation for fence lines, research projects within the road reserve, burning of the road reserve to the multibillion dollar green field project such as the Toowoomba Second Range Project currently under construction to name just a few. I have always found the information very accurate within the scale limitations and look forward to having state wide coverage with the release of version 10.

Peter Sparshott
Environmental Officer
Department of Transport and Main Roads
6 December 2016

> The regional ecosystem (RE) mapping has been the foundation of our coastal ecosystems work program. By grouping the REs into functional groups, we are able to show pre-clear and present day vegetation cover, and relate these changes to impacts in the receiving waters of the Great Barrier Reef. By mapping the functional RE groups, we were able to use maps to show the changes that have occurred. These maps have been a powerful tool in our work in showing people how the catchments have changed, and are fundamental in our way forward to focus restoration efforts of ecosystem services and the ecological processes that underpin them.

Paul Groves
Project Manager, Coastal Ecosystems
Great Barrier Reef Marine Park Authority
9 December 2016

> Regional Ecosystem (RE) mapping is a primary layer in planning for fire on the QPWS managed estate and is a fundamental element guiding much of the fire management activities. As an example, RE mapping contributes to reserve fire management plans by enabling appropriate fire regimes to be spatially assigned to fire regime groups, and by predicting potential fire hazard for community risk mitigation planning. QPWS's bioregional planned burn guidelines are built around RE mapping, and these guidelines identify appropriate objectives when preparing individual burn plans. RE mapping is also key to preparing operational mapping for fire management operations and wildfire response. A good vegetation layer in operational mapping is a safety element for fire personnel, to identify potential fuel hazards and predict planned burn and wildfire behaviour, as well as identifying natural barriers such as riparian rainforest for wildfire containment.

Peter Leeson
A/Team Leader (Fire Management)
Queensland Parks and Wildlife Service
13 December 2016

The regional ecosystem mapping is a critical foundation data set for the Biodiversity Planning Assessments. These BPAs, and derived products, feed into a wide range of planning, policy and legislation for example Matters of State Environmental Significance and the Vegetation Management Act Essential Habitat. Due to these legislative links it is important for the assessments to be based on robust, consistent and scale appropriate vegetation mapping that has the right attributes. In the past the RE mapping has provided this base where available. It is very exciting that the RE mapping is now a seamless statewide coverage, and we are looking forward to integrating the mapping into our assessments. We have worked closely with the Herbarium on a number of projects and they have always provided professional and timely advice and should be congratulated on addressing the challenges of completing a consistent and seamless statewide vegetation coverage.

Steven Howell
Manager, Biodiversity Assessment
Department of Environment and Heritage Protection
6 January 2017

The evolution of the regional ecosystem framework has provided demonstrable proof of the value of developing a robust, integrated system of ecosystem classification for the planning of conservation and land management actions. The successful implementation of this framework and the associated mapping at the jurisdictional scale is an achievement largely unmatched to date elsewhere in Australia. The system has provided a model on which to advance classification and mapping at the continental scale with a view to providing a more compatible, national level approach.

The availability of accurate, consistently attributed, information rich and uniformly scaled ecosystem mapping has provided a robust base for the further development of natural resource management products such as wetland habitat mapping and fuel characterisation mapping. These types of base ecosystem layers are fundamental assets to land managers in not only the sustainable development of land but the generation of alternative incomes from natural ecosystems.

Nick Cuff
Senior Botanist, NT Herbarium
Flora and Fauna Division
Department of Environment and Natural Resources
8 December 2016

A new state-wide mapping methodology has been developed to identify bushfire-prone areas in support of bushfire hazard provisions of Queensland's State Planning Policy. The mapping of bushfire-prone areas in Queensland is reliant on the estimation of three spatial components—fire weather severity, maximum landscape slope and potential fuel load (Leonard et al. 2014). Potential fuel load across Queensland has been mapped by applying fuel volume estimates to 20 vegetation hazard classes formed from a combination of the regional ecosystem types (Queensland Herbarium) and other state-wide mapping products such as foliage projective cover (Remote Sensing Centre) and land use.

Rosalie Buck, Rural Fire Service Queensland
Queensland Fire and Emergency Services
5 January 2017

The regional ecosystem mapping is a world class product and is the envy of many states within Australia. Because it takes a landscape perspective it has a very holistic framework for looking at not just the vegetation but the surrounding landforms and landscapes. It is a critical input to wetlands and groundwater dependent ecosystem mapping and the latter would not be much diminished without the RE framework. The ability to update the mapping and provide statistics of change over time, which does not confuse improvements in mapping with genuine changes in vegetation coverage is a critically important product for reporting on change in wetlands extent over time and an essential input to all monitoring programs and state of environment reporting.

In summary the RE mapping framework is the best in Australia and we would not have a wetlands programs without it.

Mike Ronan
Manager, Wetlands Biodiversity Assessment
Department of Environment and Heritage Protection
21 December 2016

The Regional Ecosystem mapping has been, and is, a critical resource for my environmental planning work since its inception in 1999. Over the last 5 years I have used to it for:

- conservation area planning with the Cape York Peninsula Tenure Resolution group both in planning new National Park (CYPAL) areas and in creating priority activities in existing protected areas.
- identifying the nationally and likely internationally significant areas on Cape York Peninsula associated with AICS program (Areas of International Conservation Significance). The dataset was crucial in the development of the publication The natural attributes for World Heritage nomination of Cape York Peninsula (Valentine et al. 2013).
- stratifying field survey work in protected areas, potential protected areas (Delbessie program) and with Traditional Owners on Aboriginal freehold land.

Dr Bruce Wannan, Senior Planning Officer
Cape York Peninsula Tenure Resolution
Department of Aboriginal and Torres Strait Islander Partnerships
16 January 2017

Industry

Quality regional ecosystem mapping across Queensland is a foundation asset for the state's land use planning and natural resource management system. Without it, there would be uncertainty both for development interests and for those with an interest in the protection and enhancement of biodiversity. As Chair of Regional Development Australia, Far North Queensland and Torres Strait, I need the state government to have state-of the-art tools to support planning and decision making. These easy to use products both support the development approval process, while at the same time help efforts in protecting the key assets for our tourism and emerging ecosystem service industries.

Allan Dale (Chairperson)
Regional Development Australia Far North Queensland and Torres Strait Inc
7 December 2016

Savanna-burning projects provide income to assist Indigenous ranger groups maintain their connection to country and enhance the profitability of pastoral enterprises. There are currently 40 Savanna Burning projects across north Queensland. To enable an accurate assessment of how fire management is reducing greenhouse gas emissions, the Australian Clean Energy Regulator requires these projects to provide fuel loads maps with an accuracy of at least 80%. Firescape Science has used RE mapping to produce fuel maps for several of these projects. For most projects, fuel maps could be directly derived by a simple allocation of REs to a fuel type. In other projects, only minor adjustments have been needed to achieve the required level of accuracy. Using RE mapping, a verified fuel map can be produced in about 5 days, one of which is spent in a helicopter checking the accuracy of mapping at around 500 sample sites. Without RE mapping, the process would require substantially more investment, and the cost involved would affect the project's financial viability.

Dr Gabriel Crowley and Dr Leasie Felderhof
Firescape Science, Atherton
8 December 2016

At Greencollar we use Queensland's regional ecosystem mapping dataset in our Ground Truthing and Biomass field surveys for Human Induced Regeneration Projects. To meet the requirements of this Carbon Farming Initiative methodology, we must ensure that regenerating forest consists of only native plant communities. The regional ecosystem mapping provides us with reliable evidence that our projects fall within regions consisting of native vegetation communities. This prior knowledge also helps guide our ground truthing surveys. The dataset is easy to use and analyse within a GIS environment and is an important component of the spatial data required for each project's field survey.

Laura Watts
Geospatial Analyst, GreenCollar Group
20 December 2016

The regional ecosystem mapping and associated classification framework is an invaluable tool for the assessment and management of biodiversity values across Queensland. The mapping and associated information allows rapid and precise assessments to be undertaken across the state for a wide range of users including Commonwealth, state and local governments, and community and catchment groups, NGOs, mining, agriculture and urban developers.

Bruce Wilson, Principal Ecologist (Technical)
Eco Logical Australia Pty Ltd
7 December 2016

The Queensland Herbarium's regional ecosystem mapping is an essential tool for carrying out my work as an ecological consultant. Logistical planning for flora and fauna surveys requires knowledge of the on-ground vegetation communities likely to be encountered. Without the mapping this would require extended time in the field inspecting the site before surveys can be carried out. The state-wide coverage and ease of use and access through the Queensland Globe portal make it far superior to the vegetation mapping I have used from other states in Australia.

Brett Taylor, Senior Ecologist
CDM Smith Australia
23 December 2016

The Queensland Trust for Nature enjoys the privilege of using the Regional Ecosystem Mapping on an almost daily basis. The mapping is an essential tool to help the Trust identify, enhance and protect private land with high conservation values. The mapping is used for a range of assessment, planning and management applications including Nature Refuge certifications and to determine environmentally sensitive areas that the Trust wishes to acquire and protect. The comprehensive range of attributes for each regional ecosystem including its description, vegetation and biodiversity status, ecological values and distribution provides consistent and accurate information that assists in establishing the Trust's priorities for biodiversity conservation.

Tanya Pritchard
Queensland Trust for Nature
6 December 2016

When I started work in the Brigalow Scheme in the 1960s we relied on a compass and chain traverse to calculate the area being cleared, now I simply measure the White area on the RE map with the GIS. It often took a week to measure a patch of pulling on a Brigalow Block being developed under the scheme; springing over the pulled tree trunks, eight-foot deep on the ground, carrying the equipment, a tin of sardines and water-bottle, if you slipped you got staked.

About 80% of the state was leasehold with the rent calculation based on carrying capacity; each rental assessment was argued in the Land Court using air photo interpretation to classify the land types based on perceived changes in vegetation, referenced to a field inspection of the property; this resulted in a lot of grey areas in the evidence. Now the description of the RE tells at a glance, the extent and composition of each vegetation type, based on expert botanical and spatial analysis.

The RE mapping is relied upon to determine the changes in vegetation resulting from grazing and weather factors, such as encroachment of gidgee seedlings on the Mitchell Grass Downs and the sparse Boree woodlands; as well as showing areas that can potentially be developed under the Vegetation Act. The RE also indicates where Rare and Threatened plants may occur that will be affected by mining proposals, also useful for indicating habitats suited to particular fauna species, such as Koala. The Pre-clearing layer can be used to work out Offset areas for mining proposals, and also indicate the productive potential of the land for farming and grazing.

I am involved in beekeeping, recently our beekeeping organisation mapped the sites where the Leptospermum plants occurred using the search feature in the RE description. The Industry is analysing honey from these plants, which have potential to produce honey that can be sold into the lucrative medi-honey market known as the Manuka Factor.

Neville Hunt
Environmental and land use consultant
7 December 2016

As a comprehensive spatially explicit surrogate for biodiversity, Queensland's ground-truthed regional ecosystem mapping forms the backbone of our ecological impact assessment and offset work throughout the state. As the foundation of the Biodiversity Planning Assessment framework it is essential to our forward ecological planning.

The integrated nature of the classification system that incorporates surficial geology, soils and vegetation communities within a bioregion, combined with its comprehensive coverage of the state makes regional ecosystem mapping indispensable to our work as consultants. I think it is a marvellous achievement that the Herbarium should be immensely proud of.

Dr Andrew Daniel, Principal Ecologist
Terrestria Pty Ltd
21 December 2016

The Queensland Herbarium's regional ecosystem mapping provides an essential and practical vegetation classification system. By documenting the extent of vegetation types across the state, it allows the determination of habitats with limited distributions.

I use the regional ecosystem mapping in my research into fire and weed management, as it provides a logical vegetation classification on which to base the evaluation of fire responses of different vegetation communities and the patterns of weed invasions. The regional ecosystem framework is also of particular value for making assessments of the progress of mine site rehabilitation.

The Queensland Herbarium have put considerable work and effort into refining the regional ecosystem descriptions, which will further enhance the accuracy and value of the ecosystem.

Dr Paul Williams
Vegetation Management Science
10 January 2017

Research

As a basis for conservation planning, the Queensland mapping of regional ecosystems is one of the most valuable spatial coverages in the world. The combination of very large extent, high thematic resolution, explicit methodology, expert interpretation, and consistency across an entire large jurisdiction make the RE mapping unique and immensely important for conservation science and policy. My research group has already used earlier versions of the RE mapping to produce scientific papers on the state and future of nature conservation in Queensland, and also to test and disseminate novel methods and ideas that are applicable to other study regions. Our planned applications for the 2017 coverage include: a time-series analysis of Queensland-protected areas, including allocating ratings to REs for suitability for cropping and grazing; and evaluation of the conservation impact of protected areas in avoiding loss of biodiversity. The RE mapping, with its utility for conservation research and its critical policy role in underpinning vegetation policy in the state, has played, and will continue to play, a key role in promoting nature conservation in Queensland.

Bob Pressey FAA, Distinguished Professor
Australian Research Council Centre of Excellence for Coral Reef Studies
James Cook University
8 December 2016

The regional ecosystem mapping is the most comprehensive, state-wide spatial information on vegetation and landscape ecosystems ever produced in Australia. This approach developed for classifying and mapping ecosystems provides a valuable source of information for researchers, planners and land managers that is scientifically reliable and robust. I have used the regional ecosystem mapping in assessing the natural heritage value of Cape York Peninsular. I also use the mapping as a source of habitat information for species distribution modelling and projecting the impacts of future climate on both species and ecosystems.

Prof Brendan Mackey, PhD
Director, Griffith Climate Change Response Program
Griffith University, Gold Coast
8 December 2016

The RE mapping dataset provides an invaluable source of data and information on vegetation types across Queensland. Underpinned by peer reviewed methods of field survey, classification and mapping, users can have high level confidence in using the RE mapping for regional scale applications. Access to the RE mapping via online spatial mapping and query tools makes this a 'dataset of first choice' for practitioners who need to query the extent of RE types within other regional geographies, e.g. land use, tenure and catchments. By combining RE mapping with change detection cover datasets, derived from remote sensing, e.g. ground cover, bare ground and persistent green vegetation cover, this gives land use policy and planning decision makers powerful and robust surveillance information on areas of vegetation types where environmental change may need to be further investigated.

Richard Thackway, Adjunct Associate Professor
The University of Queensland
6 December 2016

I have used regional ecosystems mapping and descriptions extensively to ascertain habitat preferences of plant and animal species especially threatened and localised species. This has permitted targeted searches and improved efficiency with my time. It has also enabled location of previously unknown populations of perceived restricted species.

Identification of threats within mapped REs has enabled better management especially of threatened REs.

Keith R. McDonald
Independent researcher
13 December 2016

The regional ecosystem mapping has been, and will be, an invaluable tool for anyone who (like me), is involved in developing the scientific understanding needed to underpin sound decision-making for managing biodiversity and ecosystems. Working with a range of students and colleagues, I have used this mapping for assessments of the current status and trends in natural ecosystems and to help choose survey sites for research in ecology and conservation.

Carla Catterall, Professor (Ecology)
Griffith University
13 December 2016

Over the past couple of years I have been involved in finalising a manuscript on the Vegetation of Fraser Island. During this process, I used the Broad Vegetation Groups (BVG) to identify how the structural vegetation classification I used, related to the broad vegetation groups identified by the Herbarium, even if the scale was 1:1 000 000. This is a higher level grouping of vegetation communities and regional ecosystems, but even at this scale we were able to match most of the groupings, which were designed as a state-wide classification to account for a greater diversity of vegetation communities than just occur on Fraser Island. Now that the regional ecosystem framework is at a scale of 1:100,000, it will provide a better scale for looking at major ecological patterns and relationships across Queensland, including places such as Fraser Island and facilitate comparisons across regions.

Grahame Applegate, Associate Professor
Tropical Forests and People Research Centre
University of the Sunshine Coast
10 December 2016

The systematic characterisation of vegetation at relatively fine scales and across broad regions of Queensland is a significant undertaking and achievement of science, and a necessary first step toward evidence-based decision making for sustainable management of natural resources. Queensland is to be congratulated for having accomplished a state-wide program of vegetation survey and mapping, which has added considerably to the knowledge of flora and fauna distribution and the status of habitats.

I have been using regional ecosystems in assessments and models since I joined the Queensland government in 1998 and subsequently with CSIRO since 2003. For example, in 2009, I used my knowledge of regional ecosystem mapping to updated assessments of suitable habitat for the southern cassowary and presented these in the context of future clearing scenarios (Williams et al., 2009b). This work supported a process of adaptive collaborative management (Hill et al., 2009), resulting in the development of a community plan for maintaining habitat in the Mission Beach region (Hill et al., 2010a), and contributed to the new concept of collaborative focal species (Hill et al., 2010b).

The detail with which information about mosaic vegetation types is included in the regional ecosystem mapping enables flexible and novel conservation assessments. An example of how full use of the available data was made is presented in an analysis of gaps in the complementary representation of vegetation types within parks and reserves (Williams et al., 2009a). The vegetation disturbance information in the RE data, along with other sources of land use and management information, also enabled the transition states to be mapped based on the VAST conceptual framework (Thackway and Lesslie, 2005), converted into a habitat condition score and incorporated into integrated modelling tools for assessing sustainable land use options (Bohnet et al., 2011).

The remnant RE data was also used in an assessment of spatial habitat configurations to show how complementarity and connectivity amongst ecosystems can be used together to improve priority-setting in conservation incentive programs (Reeson et al., 2011; Williams et al., 2012b).

I have also used the RE data in its integrated form in the NVIS major vegetation subgroup dataset (DEWR, 2006; DSEWPaC, 2012) to generate biotic habitat attributes as predictors in biodiversity models by disaggregating the structure and composition description fields to generate continuous variables (Williams et al., 2012a; Williams et al., 2010); and project the fate of vegetation types into the future (Prober et al., 2017, in press; Prober et al., 2015).

We are now considering using RE remnant mapping, along with other datasets indicating the anthropogenic modifications of vegetation, to train a national model of habitat condition (Harwood et al., 2016).

Dr Kristen Williams
CSIRO
26 December 2016

Stakeholders

I have observed the evolution of the Queensland regional ecosystem mapping since its inception, and the sophisticated, detailed and dedicated teamwork involved in completing this nationally significant data set. I have used the mapping extensively in survey site selection, conservation planning, property significance assessments, species distribution models and the identification of threatened species habitat. It is a remarkable and valuable source of biodiversity information.

Dr Alex Kutt
Bush Heritage Australia
9 December 2016

Since regional ecosystem mapping was introduced in the late 1990s it has proven its worth time and time again. With the essential components of the regional ecosystem classification relating the various vegetation communities within the particular bioregion to landform, the importance of understanding vegetation associations for a variety of reasons cannot be overstated.

The regional ecosystem mapping has proved useful in planning fauna surveys, advocating for the expansion of the protected area estate, opposing inappropriate and non-essential developments and justifying grant applications to various funding bodies.

With mapping now available state-wide at a scale of 1: 100 000 or at 1:50 000 in certain regions and its ready access through the government's Open Data portal, regional ecosystem mapping is an essential component of Wildlife Queensland's tool kit for cost-effective and efficient operations.

Des Boyland
Wildlife Queensland
8 December 2016

The Night Parrot (*Pezoporus occidentalis*) is an endangered species that was once found right throughout Australia's arid zone. Nowadays, the only reliable population occurs in western Queensland. One of the challenges in saving Night Parrots from extinction is that very little is known about their biology. This includes information about survey techniques, habitat use, movements, diet and breeding.

Over the past three years, the Night Parrot Recovery Team has been leading research efforts to fill these knowledge gaps. A fundamental aspect of the research program has been to identify and describe Night Parrot habitats. Queensland regional ecosystem mapping is the main tool we use to define habitats at a regional level in western Queensland. Its value lies in its consistency across a large area, coupled with detailed floristic descriptions and accurate line-work.

We have relied on RE mapping as a cornerstone of our research and management, and at times have been extremely grateful to staff at Queensland Herbarium for making available pre-release versions of the mapping for high priority, urgent habitat assessments. It has made a significant contribution to a more secure future for Night Parrots.

Steve Murphy, Ecologist
Bush Heritage Australia
6 December 2016

Queensland is the world leader in development of a robust system for defining, for systematically mapping and assigning a conservation status to regional-scaled ecosystems based on evidence of loss or degradation. How revolutionary that idea still is!

It was only a couple of years ago that the IUCN finally settled on a red list for ecosystems, establishing criteria for assigning a conservation status. Of course when Sattler and Williams regional ecosystems of Queensland came out in 1999, there were decades of prior work by ecologists in devising various classification schemes for terrestrial and marine habitats, vegetation types and ecosystems. But none of it rose to the level of state policy except in Queensland. The RE framework was developed primarily as the underpinning for a science based reserve system growth plan, based on principles of comprehensive, adequate and representative sampling of natural ecosystems.

However, the Queensland RE map came into its own as the foundation of the Vegetation Management Act, which in 2006 included a ban on broadscale clearing of remnant forests.

I have tried to develop a national equivalent with limited success, to be able to derive ecosystem sampling performance measures for the reserve system (Building Nature's Safety Net reports) and also to attempt to apply the new IUCN redlist criteria at a national scale

(Changing land use to save Australian wildlife report). The Queensland RE system remains the benchmark and the model.

In the Changing land use report (2014) I made the following observation:

> *Nearly half of 5,815 terrestrial ecosystems, covering an area of approximately 257 million hectares, meet IUCN Redlist criteria for threatened ecosystems as a result of land clearing and degradation. This contrasts with just 66 ecological communities recognised as threatened under national legislation, but compares well with Queensland, which has a comprehensive system for mapping and assessing the conservation status of ecosystems.*

Queensland is far ahead of the Commonwealth on this important issue of assigning conservation status. We sincerely hope the federal government will adopt the systematic Queensland model and so implement much more effective protection of Australia's natural ecosystems.

Dr Martin Taylor
World Wildlife Fund Australia
6 December 2016

Appendix 2

Staff involved in the Queensland Herbarium Regional Ecosystem Survey and Mapping program 1975–2019

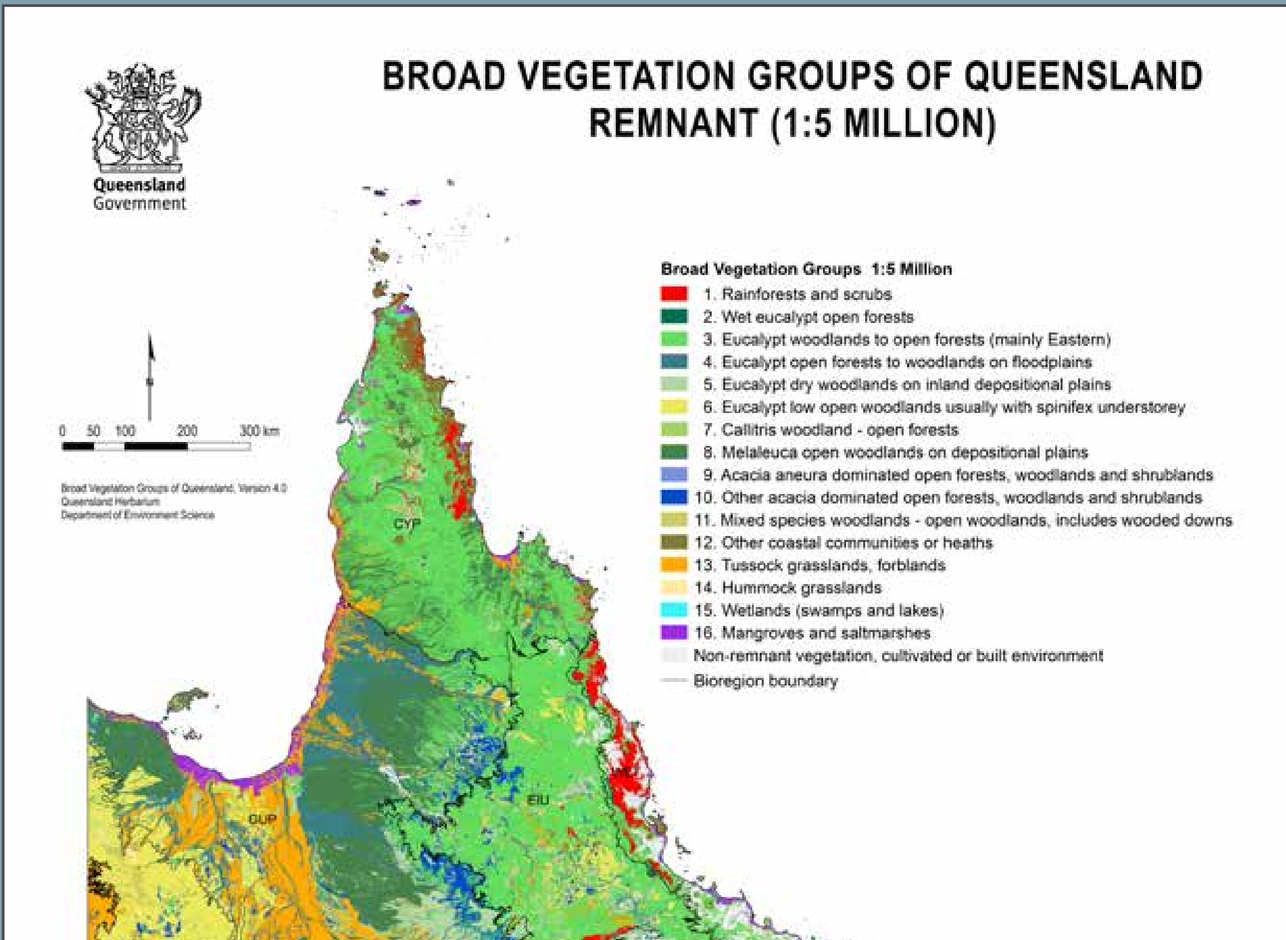
Arnon Accad, Eda Addicott, Chris Appelman, Julie Bahr, Lynne Bailey#, Birte Balle-Hosking, Peter Bannink, George Batianoff*, Darryl Baumgartner, Tony Bean, Greg Beeston, Ron Booth, Des Boyland, Joy Brushe, Don Butler, Helen Cartan, John Clarkson, Ben Collyer, Nick Cuff, Russell Cumming, Andrew Daniel, Lori Dean, Hans Dillewaard, Ralph Dowling, Lorraine Durrington, Mark Edginton, Brad Ellis, James Elsol, Teresa Eyre, Russell Fairfax, Sam Farina, Rod Fensham, Dan Ferguson, Andrew Franks,Ian Fox, Katherine Glanville, Ashleigh Gorring, Leigh Gould, Paul Grimshaw, Gordon Guymer, Val Halbert, David Halford, Luke Hogan, James Holman, Troy Honeman, Merrilyn Hosking, Shannon Hudson, Roger Jaensch, Bob Johnson*, Derek Johnson, Peter Johnson, Kerstin Jones*, Chris Kahler, Evanthia Karpouzli, Jack Kelley, Annie Kelly, Dan Kelman, Jeanette Kemp, Jacob Kirk, Andrew Kirkwood, Melinda Laidlaw, Alison Lawrence, Jiaorong Li, Rosemary Lovatt, Bill McDonald, John McDonald, Mike Mathieson, Damian Milne, Chris Mitchell, John Neldner, Mark Newton, Michaell Ngugi, Rosemary Niehus, Shelley Novello, Les Pedley*, Chris Pennay, Sandy Pollock, Robbie Price, Rosemary Purdie, Dale Richter, Tim Ryan, Paul Sattler, Jessica Scanlon*, Miriam Schmeider, Christine Shewell, Matt Skett, Geoff Smith, Kym Sparshott, Kathy Stephens, Trevor Stanley, Shelley Sullivan, Peter Taylor*, Megan Thomas, Simon Thompson, John Thompson, Gerry Turpin, Kaori van Baalen, Melanie Venz, Alicia Wain, Jian Wang, Hayley Warlich, Bruce Wilson, Gary Wilson and Peter Young.

*Deceased

Palustrine wetland near South Yaamba (Rockhampton) in the Brigalow Belt bioregion (Christopher Pennay, Queensland Herbarium, Queensland Government)

Appendix 3

Timeline for Queensland Herbarium vegetation surveying and mapping 1970 to present



BROAD VEGETATION GROUPS OF QUEENSLAND
REMNANT (1:5 MILLION)
Queensland
Government
0 50 100 200 300 km
Broad Vegetation Groups of Queensland, Version 4.0
Queensland Herbarium
Department of Environment Science
Broad Vegetation Groups 1:5 Million
1. Rainforests and scrubs
2. Wet eucalypt open forests
3. Eucalypt woodlands to open forests (mainly Eastern)
4. Eucalypt open forests to woodlands on floodplains
5. Eucalypt dry woodlands on inland depositional plains
6. Eucalypt low open woodlands usually with spinifex understorey
7. Callitris woodland - open forests
8. Melaleuca open woodlands on depositional plains
9. Acacia aneura dominated open forests, woodlands and shrublands
10. Other acacia dominated open forests, woodlands and shrublands
11. Mixed species woodlands - open woodlands, includes wooded downs
12. Other coastal communities or heaths
13. Tussock grasslands, forblands
14. Hummock grasslands
15. Wetlands (swamps and lakes)
16. Mangroves and saltmarshes
Non-remnant vegetation, cultivated or built environment
Bioregion boundary
CYP
EIU
GUP
NWH
BRB
CQC
SEQ
NET
CHC