Development of a Fine-scale Vegetation Map for the Coffs Harbour Local Government Area

VOLUME 1: PROJECT REPORT

November 2012

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Credits and Acknowledgements

This project was funded by the Coffs Harbour City Council, with financial assistance from the Northern Rivers Catchment Management Authority and the National Parks and Wildlife Service.

The vegetation classification and mapping project involved many people with varied and specialised skills. The Office of Environment and Heritage (OEH) would like to acknowledge the main contributors to this project.

OEH would like to acknowledge the contribution of Ernst Kemmerer (OEH) and Nigel Cotsell (Coffs Harbour City Council [CHCC]) for co-ordinating the project.

The main report was prepared by Ernst Kemmerer and Paul Sheringham, with assistance from Paul Houlder. OEH would like to acknowledge the technical expertise of the Biodiversity Assessment Unit; Paul Sheringham, Brendan Rennison, Karen Caves and Mark Cameron, and their contribution in compiling the Vegetation Community Profiles in Volume 2 of the report and providing the maps, figures and tables.

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List of abbreviations

2D	two-dimensional
3D	three-dimensional
ADS40	airborne digital sensor (Leica Geosystems)
API	aerial photograph interpretation
CMA	Catchment Management Authority
EEC	endangered ecological community
LPMA	Land and Property Management Authority
LGA	local government area
LiDAR	light detecting and ranging
NPWS	NSW National Parks and Wildlife Service (which now falls within Office of Environment and Heritage)
NSW	New South Wales
OEH	Office of Environment and Heritage
PATN	pattern analysis software
ROTAP	Rare or Threatened Australian Plant
SEPP	State Environmental Planning policy
UPGMA	unweighted pair-group arithmetic averaging
YETI	flora database held by OEH

Summary

A vegetation survey and mapping program was conducted for the Coffs Harbour City Council Local Government Area (Coffs Harbour LGA) using high resolution digital imagery. The main purposes of the program were to produce a fine-scale 'Class 5' vegetation map suitable for Council's planning and project requirements, and to develop a survey and mapping methodology that could be more widely used by other local governments across coastal New South Wales.

The current native vegetation map used by Council is dated and requires upgrading to show current vegetation extant and landuses. This study sought to prepare a fine-scale vegetation map and provide up-to-date information on the type and extent of vegetation in the Coffs Harbour LGA (the study area).

The study was carried out in four main stages:

- trial and select methods to map land cover and vegetation community boundaries
- map broad land cover
- develop a vegetation community classification for Coffs Harbour LGA
- map vegetation communities.

A number of techniques were trialled to determine the most efficient process for preparing the vegetation map. It was concluded that conventional aerial photography interpretation resulted in the most accurate linework and method for attributing vegetation communities. A total of 79 different vegetation communities were classified in the study area.

Land cover was divided into 13 types, including the following cover classes and features: extant vegetation cover, cleared, horticulture/cropping, plantations, remnant trees, water bodies, estuaries and beaches. Over 88 000 hectares of extant vegetation in the Coffs Harbour LGA were mapped at 1:5000 scale using API. During the API work the vegetation patterns were mapped and polygons attributed using the codes supplied for the 79 vegetation communities.

The classification and mapping program was supported by 3 754 survey sites. Data from 534 full floristic flora survey sites were used for the vegetation community classification analysis. Information on dominant plant species only was gathered at 462 rapid data sites for interpolation and mapping purposes, 279 for accuracy assessment and 2 479 API survey sites were visited to ground truth the API work.

To achieve an unbiased survey effort across all tenures, private landowners were invited to voluntarily have flora surveys conducted on their land. This resulted in a sampling rate of approximately one site per 60 hectares on Crown lands and one site per 76 hectares on freehold lands. Overall mapping accuracy was found to be 66% and with subsequent revision giving an accuracy of 77% weighted by area of each vegetation class.

Surveys conducted during this study, combined with previous work, have identified 53 significant plants and 10 endangered ecological communities within the LGA. The endangered communities are likely to occur within 24 different vegetation communities mapped in this study, and potentially cover up to 11 600 hectares in the LGA.

The new Coffs Harbour Class 5 vegetation map will underpin a range of environmental planning and vegetation management programs. The vegetation map is suitable for use at the 1:5000 scale and will support environmental planning at the whole-of-LGA level. The map may not be suitable for individual property or development plans where further flora and fauna surveys may be required to meet the requirements of the *Threatened Species*

Conservation Act 1995. However, the mapping will have direct influence on the following Council strategies, planning instruments and guidelines:

- Coffs Harbour Koala Plan of Management
- Open Space Strategy
- Biodiversity Information Sheets
- Coffs Harbour Biodiversity Action Strategy 2012 - 2013
- State of the Environment reporting
- Draft Coffs Harbour Local Environmental Plan 2012
- Draft Development Control Plan
- Bushfire Mapping.

The development of the Class 5 vegetation map has been a multi-agency initiative supported by Coffs Harbour City Council, the Office of Environment Heritage and the Northern Rivers Catchment Management Authority. It is anticipated that the fine-scale vegetation map will be adopted by a range of end-users and natural resource managers.

1. Introduction

Vegetation type and vegetation condition are widely used in combination as a surrogate for biodiversity. As such, maps of vegetation type and condition form the basis of most conservation management plans and environmental planning instruments. While vegetation mapping needs may vary between government agencies, a common theme is the need for complete and consistent maps of the area of interest.

Coffs Harbour City Council ('Council') is currently using a composite vegetation map derived from a variety of sources. The primary sources are Forest Type Mapping (Forestry Commission of NSW 1989), forest ecosystem models, vegetation type mapping by Fisher et al. (1996) — with supplementary aerial photograph interpretation (API) work by Kendall (2005) — and modelling interpretation work by Eco Logical Australia (2005).

This composite vegetation map has limitations because the various map sections use different classifications systems and map scales, resulting in edge mismatches between sections. A contiguous vegetation map and classification is therefore required to overcome these issues and provide a common reference for future environmental planning and management in the Coffs Harbour City Council Local Government Area ('Coffs Harbour LGA'). For example, Council recently released its 'Biodiversity Action Strategy' (CHCC 2012) which sets the agenda and direction for biodiversity conservation planning and management throughout the Coffs Harbour LGA from 2012 to 2030 and beyond.

The development of a contiguous, fine-scale vegetation map is fundamental to a number of major programs within the Strategy, particularly for LGA-wide assessment programs such as:

- mapping Koala habitat (to contribute to the development of Council's Koala Plan of Management)
- identifying and mapping high value habitats, including endangered ecological communities (including SEPP26 areas), over-cleared vegetation communities, significant wetlands (including SEPP14), estuaries and riparian zones
- identifying and mapping threatened and significant fauna habitat
- identifying landscape connections.

These programs will ultimately contribute to Council's strategic and operational planning, including the Local Environment Plan (2012) and associated Development Control Plan. Figure A5.1 (page 30) from the 'Biodiversity Action Strategy' (CHCC 2012) illustrates the role of the vegetation mapping in Council's planning framework and has been included here in Appendix 1.

The National Parks and Wildlife Service (NPWS) also requires a consistent, up-to-date vegetation map of the entire Coffs Coast Regional Park, an area which is jointly managed by Council and NPWS. A contiguous, fine-scale vegetation map will support improved flora, fauna and fire management of the coastal vegetation and identify potential impacts as well as opportunities for tourism in the region. The Environment Protection Authority and Northern Rivers Catchment Management Authority (CMA) also have a vested interest in improving vegetation information to support the regulation, management, conservation and rehabilitation of vegetation.

In addition, the Office of Environment and Heritage (OEH) has been seeking to improve vegetation mapping products across New South Wales and take advantage of the opportunities for fine-scale mapping presented by the airborne digital sensor (ADS40) data captured by Land and Property Information since 2007 (Taunton 2010). The ADS40 is a high resolution, airborne digital camera that captures fine-scale, multi-spectral photography that is able to be viewed in three dimensions. Council also acquired light imaging detecting and radar (LiDAR) data for the LGA in 2005. LiDAR data produces high resolution models, including digital terrain (or ground) models, and surface models (i.e. above ground) with vertical accuracies of ±15 centimetres.

This new imagery provides an opportunity to research and develop methods to provide an integrated vegetation map for coastal New South Wales using the best available technology and data. A multi-agency vegetation mapping program was therefore initiated in 2010. The aim of the program is to develop a fine-scale vegetation map to support the requirements of the various government agencies by using the latest digital products. The project aims to explore various approaches to digital API and map production in order to recommend a model or methodology to guide future vegetation mapping projects of this nature and at this scale of resolution.

The fine-scale mapping project for the Coffs Harbour LGA is presented in two separate volumes: Volume 1 (this volume) – Project Report, and Volume 2 – Vegetation Community Profiles.

1.1 Objectives of the study

The objectives of this study are to:

- produce contiguous map products at the 1:5000 scale for the Coffs Harbour LGA
- produce a land cover map for Coffs Harbour LGA
- develop a vegetation community classification for Coffs Harbour LGA
- develop a fine-scale map of vegetation communities in the Coffs Harbour LGA
- research and develop current technologies and test several approaches to fine-scale mapping

1.2 Study area

The Coffs Harbour LGA covers 117,300 hectares and is one of the few areas of coastal New South Wales where the high elevation landscapes of the Great Dividing Range are within close proximity to the coast. The diversity and extremes in landforms across the study area have produced a range of varied habitats containing a high diversity of flora and fauna. The area is within the New South Wales North Coast Bioregion and the majority of the area is within the Coffs Coast and Escarpment Subregion (Thackway & Cresswell 1995).

The overall study area can be seen as consisting of three predominant topographical landscapes: coastal plains, midland hills and escarpment ranges (see Figure 1 and Table 1).

Table 1 Landscapes of the Coffs Harbour LGA

Landscape	Area (ha)	Area (%)
Coastal plains	32 150	27
Midland hills	47 500	41
Escarpment ranges	37 650	32
Total	**117 300**	**100**

Of these three landscapes, the coastal plains landscape is home to the majority of the LGA's human population and contains the least vegetated land. Conversely the midland hills, and to a greater extent the escarpment ranges, support a much lower density of population per square kilometre because most of these areas are rural or village living. Accordingly, these landscapes — particularly the escarpment ranges — contain the highest amount of vegetated land within the study area. Major land uses in the LGA vary across the three landscapes. The coastal plains are dominated by urban and rural residential areas, with limited areas of horticulture, grazing and cropping. The midland hills and escarpment ranges are mostly rural, with some grazing and forestry, and limited areas of horticulture (primarily bananas and blueberries).

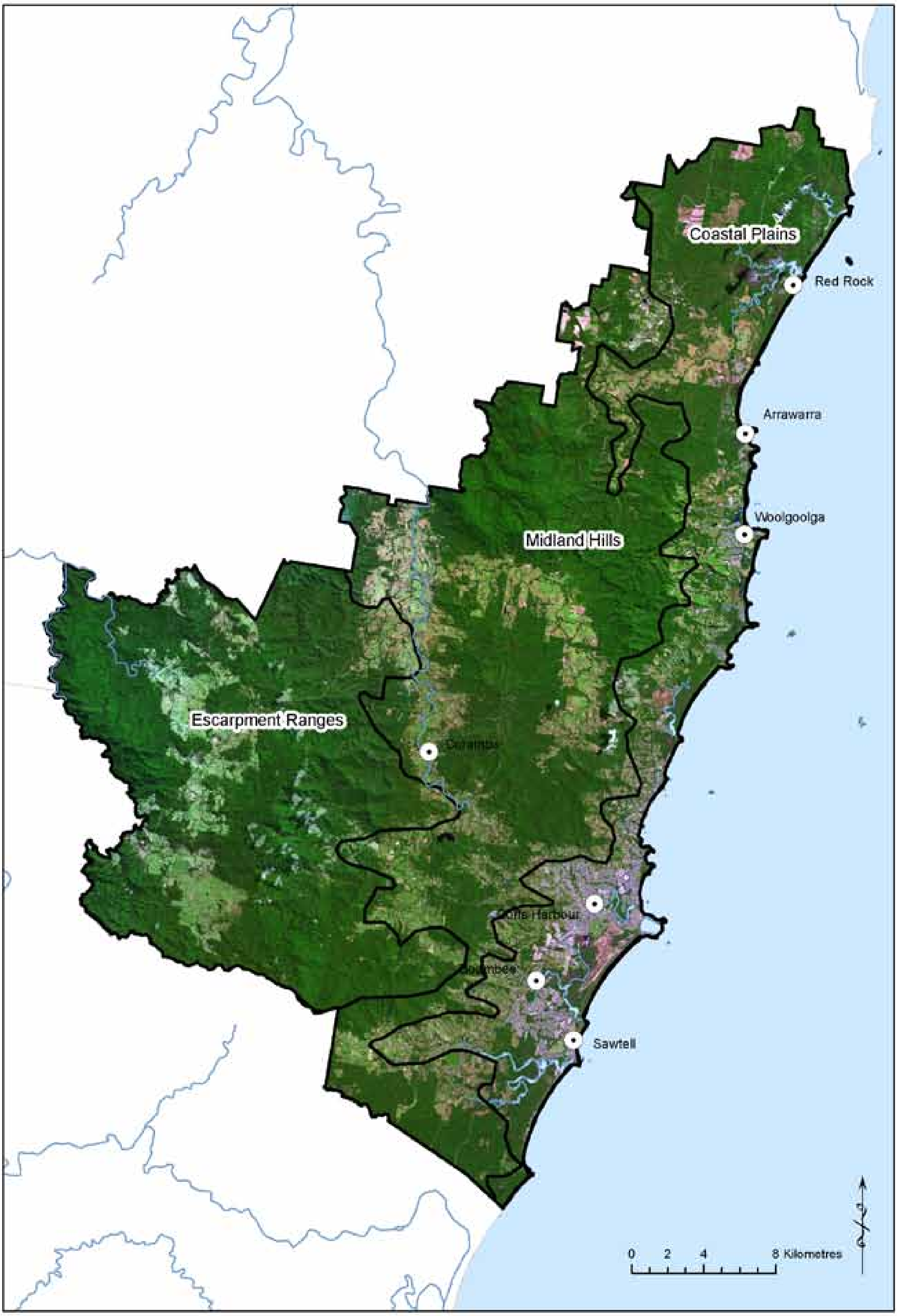

Figure 1 The study area and landscapes of Coffs Harbour LGA

1.3 Landforms

The coastal plain is a low relief landscape with little variation in altitude. It gradually rises from sea level along the shoreline to around 50 metres elevation where it transforms into the midland hills landscape, usually within 10 kilometres of the coast. Slopes are predominantly flat to gentle (0–5°) though some small hills with steeper slopes are found in this landscape. The coastline is approximately 80 kilometres in length and features a series of prominent rocky headlands and beaches.

The coastal plains landform may be divided into the Barcoongere Low Hills and Gleniffer Bonville Hills regions described by Milford (1999). These are characterised by low relief, undulating to rolling foothills and creeklines draining the coast range. Milford (1999) also names the Coffs Harbour Coast region as a landform and this contains the unconsolidated alluvial, estuarine and coastal barrier sediments.

The midland hills landscape is a moderately undulating landform and encompasses the foothills and low ranges between the coastal plains and the escarpment ranges. The western boundary roughly corresponds to the 250 metre elevation contour. Land along major river valleys is relatively flat, with associated slopes being predominantly slight to moderately steep (1–20°), though very occasional steep slopes (>40°) also occur. This landscape includes some geographic features associated with the coastal ranges, including sandstone escarpments in the north-west, and valleys, creeks and rivers draining northwards to the Clarence River.

The midland hills landscape can be further subdivided into the distinctive sandstone landforms of the Kremnos Plateau, and the steep metasedimentary and sedimentary hills of the Coast Range physiographic region. Milford (1999) also recognised the Orara, Corindi and Bellingen River Valley physiographic regions, which cross all three broad landscape classes. These regions encompass flat to gently undulating floodplains, channels and swamps. The Orara River Valley drains a large proportion of the catchment of the study area.

The escarpment ranges landscapes includes the steep hills of the Dorrigo and Orara escarpment regions as well as the flatter, more undulating terrain of the eastern Dorrigo Plateau and Bobo River Valley. The escarpment ranges extend from around the 250 metre contour in the west of the study area rising steeply to high points such as Mount Wondurrigah (820 m) and Mount Moombil (1042 m) in the south. Slopes are predominantly moderately steep to very steep (16–49°) with small areas of precipitous slopes along some cliffs associated with gorges. Some of the major gorges and canyons in this area include Wayper Creek, Shingleback Creek, Bangalore Creek, Little Nymbioda River and Urumbillum Creek.

On the elevated western fall of the escarpment range there is a combination of large and relatively flat plateaus, interspersed with slight to moderate slopes in the valleys which form the eastern Dorrigo Plateau landscape. The vegetation is influenced by the altitude and colder climate here, with significant areas of warm temperate and cool temperate rainforest. The southern boundary of the eastern Dorrigo Plateau and the LGA runs along the ridgeline of mountain ranges bordering the Gleniffer and Crossmaglen valleys.

1.4 Geology and geomorphology

The overall geological history of the study area is that of older and stable weathered Permian and Carboniferous clastic metasedimentary rocks overlain by more-recent sedimentary rocks formed in the Clarence–Moreton Basin. The only examples of volcanic or plutonic activity in the study area are intrusions of monzogranite at Diggers Point and Look-at-me-now Headland (Milford 1999). The geological history of the coast and floodplains is of recent deposition of Holocene and Pleistocene unconsolidated sediments. The rise in topography from east to west is due to uplift during the formation of the Great Escarpment which commenced about 80 million years ago (Oliver 1982).

Milford (1999) provides a more detailed account of the geology and describes the soil landscapes of the Coffs Harbour 1:100,000 map sheet. The Coffs Harbour LGA is located within three major geological divisions of sedimentary and metasedimentary rocks: the Clarence–Moreton Basin, Nambucca Block and Demon Block. Figure 2 shows the distribution of the major geological units across the landscape. Table 2 describes the main geological units of the Coffs Harbour area, and the corresponding age and geographic/geomorphic group to which they belong.

Table 2 Geological units of the Coffs Harbour LGA

Geological age	Geographic/geomorphic group	Geological unit
Holocene	Unconsolidated sediments	Dunes and beaches
		Saline tidal areas (estuarine plains)
		Floodplains (alluvial plains)
Pleistocene		Backbarrier sand plains and freshwater wallum swamps
Triassic/Jurassic	Clarence–Moreton Basin sediments	Kangaroo Creek Sandstones
		Corindi Conglomerates
		Walloon Coal Measures
	Un-named granite intrusion	Emerald Beach Adamellite
Permian	Nambucca Block metasediments	Bellingen Slates
Carboniferous	Demon Block metasediments	Coramba Beds
		Brooklana Beds
		Moombill Siltstones

The Demon Block contains Carboniferous metasediments of the Coffs Harbour Association. The Coffs Harbour metasediments are divided into three units (Milford 1999). The *Coramba Beds* is the most extensive and occurs across the plateau, escarpments and hills. The *Brooklana Beds* and *Moombil Siltstones* occur further south. These metasediments, derived from old marine and/or riverine sediments, mainly support wet and dry sclerophyll forests with pockets of rainforest in sheltered higher rainfall sites. More-exposed sites with shallow soils occasionally support open forest, woodland and shrubland vegetation.

The Nambucca Block is characterised by more-recent metasediments of Permian age. The main geological unit (the *Bellingen Slates*) is restricted to the southern section of the study area and these metasediment areas form fine-grained quartz soils which, combined with sheltered aspects and high rainfall, can support tall wet eucalypt forest and rainforest.

In the north–west of the study area are more recent Triassic and Jurassic sandstones and conglomerates of the Clarence–Moreton Basin. The *Kangaroo Creek Sandstones* form undulating to rolling plateaus on the Kremnos Plateau at Andersons Mountain and Dicks Knob. The sandstone environments support distinctive dry sclerophyll forest and woodlands growing in shallow high-quartz soils. *Corindi Conglomerate* outcrops occur throughout the north-west of the study area in Wedding Bells and Conglomerate state forests and generally support dry heathy and grassy dry sclerophyll forest, with wet sclerophyll elements in sheltered localities. The *Walloon Coal Measures* underlay the conglomerate geology and the generally steep and moist sheltered terrain provides habitat for tall wet sclerophyll forest and rainforest.

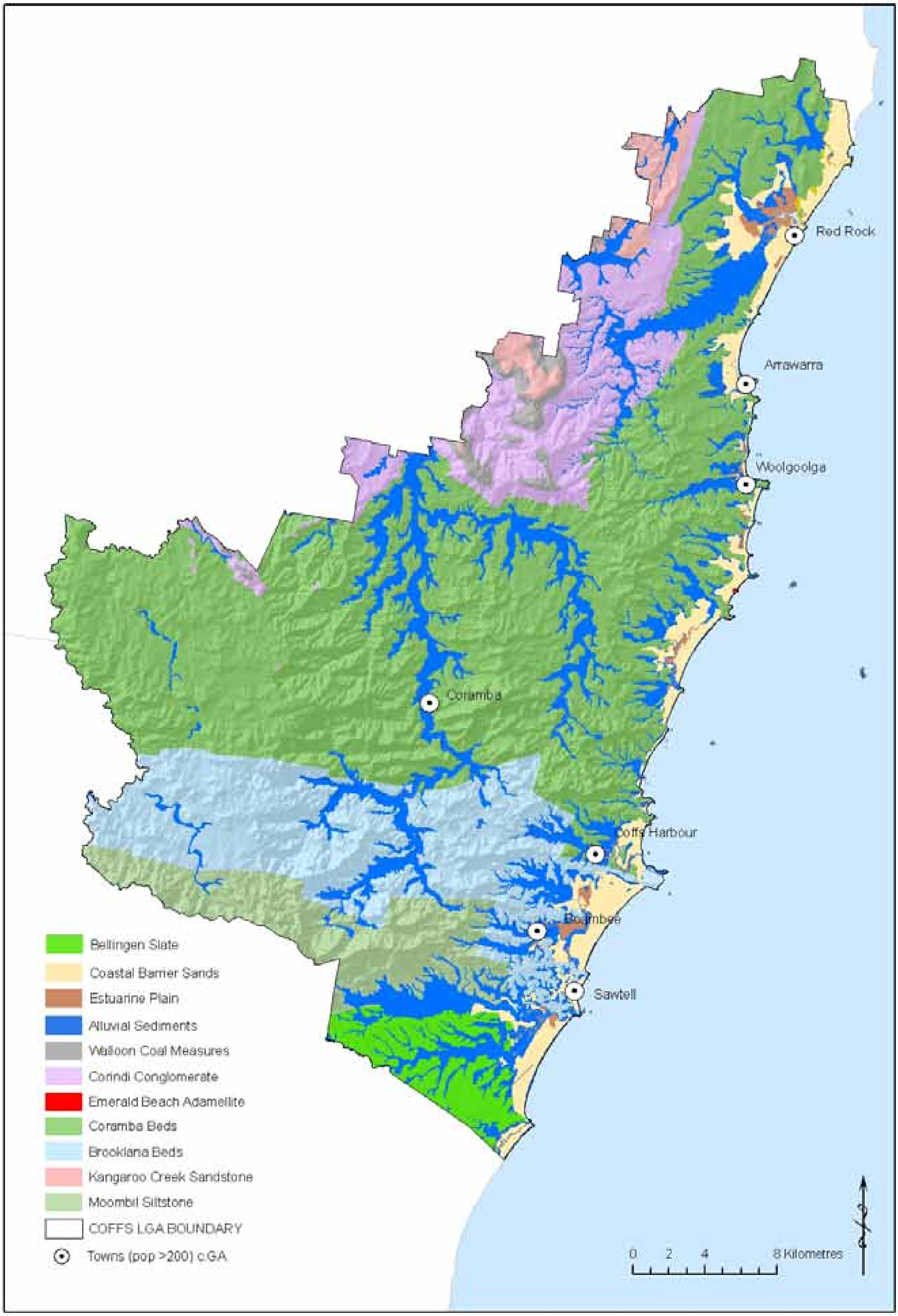

Figure 2 Major geological units of the Coffs Harbour LGA

A large percentage of the coastal plain is comprised of alluvial soils along major non-tidal drainage networks and valleys, and sands and muds of coastal backbarriers and estuaries. Unconsolidated alluvial sediments have been deposited in the valleys and floodplains of the Orara, Bobo and Corindi rivers and many coastal creeks. These areas support riparian forests, and forested and freshwater wetlands. Holocene estuarine sands, muds and clays have deposited in the tidally influenced main creeks and rivers of the study area. Examples include the Corindi, Pine and Boambee creek estuaries, which support areas of saltmarsh, mangrove and saline swamp forests.

Recent Holocene sand dunes have formed along the beaches. Located behind these are older, less fertile and poorly drained backbarrier sands of Pleistocene age which support wallum heathland, swamp forest/woodland, littoral rainforest, and grasslands.

1.5 Soils and soil landscapes

There are 44 soil landscapes recognised in the study area (Milford 1999). Soils have an important influence on the distribution of vegetation in the study area. Soil formation is influenced by the parent material's resistance to weathering, chemistry and mineral composition; slope and aspect; and soil moisture and permeability.

For example, the shallow coarse-grained, high-quartz soils of the *Kangaroo Creek Sandstones* support distinctive dry sclerophyll forests and woodlands with a high level of species diversity. In areas of fine-grained low-quartz metasedimentary geology, soils may vary from deep red soils in areas on sheltered slopes with high soil moisture, to shallow yellow earth on exposed slopes in drier locations. This is reflected in the distribution of tall moist forest and rainforests on the deep red soils in sheltered areas, to dry open forests on the shallow soils of exposed sites. Even the relatively infertile sandy soils of Holocene dunes may support luxuriant forms of littoral rainforest in sheltered areas.

1.6 Climate

Continental climatic patterns are controlled by the progression of high- and low-pressure systems and associated troughs across the country. Seasonal patterns of temperature and rainfall are driven by the north–south migration of high-pressure systems. The effects of tropical cyclones and landforms also have an impact on the climate of the region. Longer term trends in rainfall and temperature are influenced by the El Niño – Southern Oscillation, which determines the circulation and strength of trade winds directing moisture across eastern Australia (NRAC 1996).

In the study area, summers are generally hot and winters are moderate. The annual mean summer (February) maximum temperature for Coffs Harbour is 26.8 °C and the minimum is 19.5 °C. The annual mean winter (July) maximum and minimum temperatures at Coffs Harbour are 18.7 °C and 7.6 °C respectively (BOM 2012).

Rainfall is highest in February and March and lowest in late winter to spring, with September being the driest month. The mean annual rainfall at Coffs Harbour is 1699 mm (BOM 2012).

Topography and elevation play a significant role in the distribution of local climatic conditions across the study area — there is a clear correlation between increasing elevation and higher rainfall and lower maximum and minimum temperatures. For example, minimum winter temperatures range between 9.1 °C on the flatter, northern coastal areas and 1.8 °C on the highest parts of the escarpment ranges, while maximum summer temperatures range between 19.5 °C and 14 °C between these same locations. Annual rainfall also varies across the study area, with over 1950 mm falling on the high elevation plateaus and 1310 mm falling in the northern inland parts of the study area (some 650 mm less).

1.7 Fire history

Major fires in the Coffs Harbour LGA occurred in 1977, 1990 and 1994. Generally, similar forest types emerge after a fire, but in some cases fires can replace moist vegetation types with drier types, can convert areas of heathland to grassland, or can change the structure of a vegetation community. For example, adult plants of *Hakea actites* (an emergent shrub) are killed by fire and this changes the structure of the heathland vegetation at Garby Nature Reserve.

Most of the largest wildfires in the study area occurred in the conglomerate and sandstone landscapes in the north, and the steep gorge country in the north-west. These areas support dry sclerophyll and heathland communities that are adapted to fire and produce the major fuel loads needed for wildfires to occur. Predictably, areas that are more fertile and support wet sclerophyll vegetation have historically very low fire frequencies. Coastal areas have experienced several wildfires, particularly in Moonee Beach Nature Reserve and Bongil Bongil and Yuraygir national parks.

Fire management, including selection of fire regimes (frequency, seasonality and duration), can exert changes in vegetation patterns. There is considerable variation in the fire requirements of the communities occurring in the study area; from more fire-adapted dry sclerophyll forest and heathlands communities to those fire sensitive communities which require the exclusion of fire (e.g. littoral rainforests, forested wetlands, saltmarshes). Even the most fire-adapted communities are sensitive to inappropriate fire regimes.

2. Methods

The project was carried out in four main stages.

1. Trial and select methods to develop a land cover map and delineate vegetation community boundaries (see Section 2.1).

2. Map broad land cover types, including areas of extant vegetation, remnant vegetation and paddock trees (see Section 2.2):
    - Definiens segmentation and development of algorithms
    - edit and refine Definiens segmentation.

3. Develop a vegetation community classification for Coffs Harbour LGA:
    - conduct gap-filling flora surveys across the study area using stratified random sampling (see Section 2.3)
    - complete a numerical analysis of the flora survey site data to develop a vegetation classification for the study area (see Section 2.4)
    - refine the vegetation classification through expert review and field verification.

4. Map vegetation communities (see Section 2.5):
    - extract boundary of extant vegetation (using Stage 2 land-cover product) to define the area to be mapped
    - apply API techniques to map vegetation communities using Stereo Analyst™ and Planar monitor/viewer
    - field reconnaissance surveys to support API and refinement of vegetation classification
    - refine vegetation boundaries.

2.1 Trialling alternative mapping pathways

An overall objective of the project was to develop a survey and mapping methodology that could be more widely used by local governments across coastal New South Wales. Accordingly, a number of approaches to mapping were trialled before a final method, or pathway, was established.

Recent advances in image classification have shifted away from processing whole images to processing subsets or smaller polygons called 'objects' — this process is called object recognition and classification. This technology, together with the availability of high resolution airborne digital sensor (ADS40) imagery and light detecting and ranging (LiDAR) data, has led to the development of a number of techniques for automated or semi-automated vegetation mapping. Furthermore, API has moved away from stereoscopes to the use of digital stereo viewing (Planar stereo/3D monitor by Planar Systems Inc.) which can now take full advantage of the high resolution imagery available for interpretation. The Planar environment also allows the direct delineation and attribution of polygons in three-dimensional (3D) stereo view (Level 1 imagery) whilst simultaneously having a two-dimensional (2D) context view and any number of additional datasets to guide mapping decisions.

Discussion groups were held in the early phase of the project to explore alternative methods for developing land-cover maps (including extant vegetation cover) and delineating vegetation community boundaries.

As a result of the discussions, the following methods were trialled:

- For land-cover mapping, Definiens (see below) segmentation and development of algorithms for classification of vegetated versus non-vegetated lands.
- Crown delineation modelling using Definiens and image processing software (ERDAS Imagine™) to classify tree crown types to species level as an input to vegetation community mapping.
- Image enhancement techniques to exaggerate differences in spectral response of vegetation and thereby interpret different vegetation communities. Derived from manipulation of ADS40 multi-spectral imagery.
- Delineation of vegetation communities by interpretation of 3D ADS40 imagery using Stereo Analyst™ software (ERDAS) and Planar stereo/3D monitors (Planar Systems Inc.).

2.2 Land-cover mapping

High resolution airborne digital sensor (ADS40) imagery supplied by the Land and Property Management Authority and LiDAR data were used to map the broad land-cover types within the Coffs Harbour LGA. The ADS40 sensors recorded land surface information at 50 centimetre resolution in four bands, including near-infrared, and was flown between April 2009 and July 2010. The LiDAR data was supplied by Coffs Harbour City Council and was flown in January 2007.

The primary purpose of the land-cover mapping was to separate cleared areas from areas with extant vegetation cover. Thirteen classes for land-cover mapping were used as listed in Table 3.

Ancillary data to complete the land-cover mapping included:

- urban zone boundaries from Coffs Harbour LEP 2000
- boundary of Sapphire to Woolgoolga Pacific Highway upgrade from NSW Roads and Maritime Services
- Forests NSW plantation data as supplied in 2011
- tenure boundary data (e.g. national parks and state forest) from OEH and Forests NSW.

Definiens software (Definiens 2007a, 2007b) was used to produce the land-cover mapping. This software is based on object-based image analysis. The two fundamental principles of this analysis are segmentation and classification. Firstly, spatial data are segmented into smaller polygons (referred to as 'objects'), by a range of segmentation algorithms. Secondly, the image objects are then classified using an array of hierarchical, temporal, spectral and spatial context tools.

An important decision rule for inclusion in a Definiens rule set is the normalised difference vegetation index, especially for land cover. The effects of shadow were reduced using a combination of LiDAR parameters and Definiens rule sets.

The method chosen was to process each ADS40 tile separately in a Definiens Server framework. This required an intensive pre-processing strategy where LiDAR data were resized, formatted and collated to match ADS40 tiles so that a customised import into the Definiens Server could be performed.

After the segmentation was complete, the process of classifying the segmentations (or objects) was commenced. A rule set was developed to classify approximately 80% of an ADS40 tile's objects accurately, so that the remaining 20% could be finalised manually. The rule set was developed collectively and iteratively with experts reviewing and refining a centrally managed 'master' rule set. Experts also focussed their refinements on particular landscape features (e.g. shadows, paddocks, horticulture). To assist in the manual work of classification, additional algorithms were developed using object-orientated image processing. Further refinement was carried out using manual digitising.

Table 3 Summary of land-cover classes used in the study

Code	Description
1	Forest
1a	Urban & rural living vegetation remnant
2	Forestry plantation
2a	Hardwood plantation
2b	Softwood plantation
3	Trees–Shrubs
4	Grasslands–Pasture
5	Horticulture–Cropping
6	Impervious–Surfaces
7	Railways
8	Water
8a	Lake
8b	Reservoir–Dam
8c	River
8d	Marsh–Wetland
8e	Estuary–Coastal Waters
9	Sand–Beach
10	Headland Rock
11	Urban & rural living
12	Pacific Highway
13	Highway Upgrade 2011

2.3 Gap-filling flora surveys

Three tiers of survey were conducted during the study, as summarised in Table 4.

Table 4 Summary of flora surveys supporting this study

Survey type	No. of sites	Description of survey
Full floristic surveys	534	All vascular species recorded within a quadrat
Rapid data surveys	462	Recording of dominant species in each strata
	279	Set aside for Accuracy assessment
API site surveys (see Section 2.5)	2 479	Ground truthing of API mapping and assignment of vegetation community to a site
Total	**3 754**	

Within the study area there were 393 existing full floristic survey sites from the YETI (Ellis et al. 2009) flora database, which equates to about one site per 300 hectares. This number of sites was insufficient to complete a mapping exercise for the LGA and additional full floristic surveys were required.

A stratified random sampling technique was used to evenly allocate sites across the landscape. Spatial layers used to develop the strata were a composite of geology, soil landscapes, solar radiation and topographic position. To optimise site location across the landscape, Survey Gap Analysis ™ (Manion & Ridges 2009) software was used to efficiently allocate sites to strata.

To ensure a balance of sampling across Crown lands and private property, Council invited landowners with over five hectares of land to participate in the program by allowing a survey to be conducted on their property. There was a strong and positive response to this invitation. The surveys were conducted over the spring–summer season of 2010/11.

Full floristic survey data were generally collected within 20 x 50 metre nested quadrats (or 10 x 40 metre plots in linear environments such as creeklines). The information was collected digitally and entered into an Access database compatible with the NSW Government central flora database, YETI (Ellis et al. 2009). An additional 141 full floristic survey sites were surveyed within the LGA by Eco Logical Australia, giving a total of 534 full floristic flora sites available for the floristic analysis.

During the full floristic surveys, 462 rapid data sites were also surveyed and this information was used to guide the vegetation mapping work by providing reference points for photo patterns. Rapid surveys collected information on dominant species in each strata. The aim of rapid data site surveys was to cover as much ground as possible in those areas that were easily accessible. Therefore, there is a tenure bias to that data, with limited plots collected on private land or in more remote/off-road locations. Afterwards, a vegetation community was assigned to each of these sites to guide and confirm API decision making.

2.4 Vegetation community classification

Vegetation classification involves a 'cluster' analysis which groups floristic sites that are similar (Dale 1995). In this study, a numerical PATN analysis (Belbin 1994) was undertaken using the available 534 full floristic sites to determine the main floristic groups for the study area. PATN software requires the operator to select the number of groups required in the output. A '100-group' analysis was undertaken because over 60 forest types (Forestry Commission of NSW, 1989) occur within the forested landscapes of the study area without considering coastal heath and estuaries.

A hierarchical agglomerative classification of sites (Belbin, 1991) was produced using a clustering strategy with a default Beta value of -0.1 in a flexible unweighted pair group method with arithmetic mean (UPGMA) clustering strategy. A dendrogram of one hundred floristic groups (100) was derived from the Bray Curtis association measure (Bray and Curtis, 1957) and UPGMA clustering at a dissimilarity measure of approximately 0.75. Considerable refinement of the classification was done by deleting and merging of floristic groups, and removal and reallocation of floristic sites using the results of a nearest neighbour analysis (Belbin 1994), fidelity analysis (Bedward, unpublished software) and expert interpretation. Subsequent classification refinement and evaluation was carried out during the API mapping program and by testing the floristic communities in the field.

As field evidence was collated during the API mapping process (see Ground truthing surveys section below) the numerical vegetation classification was progressively reviewed and refined. This involved either re-allocation of flora plots to a neighbouring group in the dendrogram, or the un-allocation of plots if they were found not to be representative of the vegetation community, or the addition of a vegetation community not adequately sampled by existing flora surveys.

2.5 Vegetation mapping

API involves recognising patterns in the vegetation, understanding the species composition, delineating community boundaries, and assigning a suitable vegetation community label from the classification (Paine & Kiser 2012).

Vegetation mapping using conventional API was undertaken using the following three steps:

- Develop a draft vegetation community map (linework and attribution of data to polygons) using Stereo Analyst™ and Planar stereo/3D monitors.
- Conduct ground truthing surveys and record the API site survey information.
- Revisit vegetation map labels and refine vegetation boundaries.

This process can be iterative between developing the linework and finalising the attribution.

Develop a draft vegetation community map

Stereo API techniques were applied in this study using Planar stereo/3D monitors and Stereo Analyst™ software on an ESRI ArcGIS 10.0 platform. Additional ancillary information was used to assist in the API work, including:

- previous mapping and survey work in the study area (see Appendix 2)
- full floristic flora survey site data with the allocated floristic group
- image enhancement products — Stereo Analyst™ enhancement of ADS40 stereo imagery and a saturation stretch of ADS40 ortho-rectified imagery based on Roff (2009)
- hillshade using LiDAR-derived digital terrain model to assist interpretation of topographic variables (aspect, slope, position on slope, ridges and gullies)
- substrate information — quaternary near-surface geology where available (alluvial sediments) and soil landscapes or 1:250,000 geology in other areas.

The API decision pathway and specifications were designed to facilitate a one-to-one match with the floristic communities derived during the vegetation classification. All specifications and the API decision pathway are shown in Appendix 3.

Ground truthing surveys

Ground truthing surveys consisted of API site surveys. Ground truthing in the field undertaken extensively throughout the project with a focus on publicly accessible areas and areas that were visually accessible from public roads or tracks. Field information was collected using a geographic positioning system (Pocket PC, ASUS ™ A696) on an ArcPad™ platform and was recorded at 5–10 metre accuracy.

API site surveys collected information on the vegetation community and dominant species in order to interpret the vegetation patterns for a particular locality. The data from these points were viewed in the 3D Stereo Analyst™ mapping environment to guide and confirm decision making.

Completion of linework and attribution

Once linework was complete, a suitable vegetation community label from the vegetation classification was assigned to polygons. Additional data included a reliability score from 1 to 4, an indication of dominant species (where required), an indication of disturbance, presence of weeds and other comments as required.

Interpreters would use all available supporting data to attribute each polygon to one of the categories, and if uncertain, or a mosaic of categories existed, a dual category would be assigned.

Table 5 describes these additional attributes and their descriptions.

Table 5 API polygon attribution descriptions

Attribute	Description
Reliability	1 = Ground validation of polygon 2 = High level of confidence (adjacent polygons have survey data or distinct photo pattern) 3 = Moderate level of confidence (survey data in near vicinity) 4 = Low level of confidence (lack of nearby survey data or indistinct photo pattern)
Significant disturbance	Native vegetation with significant occurrence (30–50%) of environmental weeds or significant disturbance defined as either: • loss of or >50% disturbance to canopy • removal of >50% of understory/ground cover
Remnant trees	Significant disturbance where interpretation of vegetation community is no longer possible (significant alteration of structure and species composition)

The mapping was undertaken by six different aerial photograph interpreters. The study area was divided into manageable API tiles as shown in Figure 3, and tiles assigned to each interpreter. Consistency was achieved by having interpreters work in pairs during field surveys, and by regular calibration during the mapping exercise.

Once all API tiles were completed, they were stitched together and effectively edge-matched through manual digital editing in the 2D mapping environment with reference to the patterns in the 3D mapping environment.

Final checking for global errors, gross errors, consistency in mapping and other logical checks were made. Data was collected in the structure shown in Appendix 3. For details of the lineage of the data please refer to the metadata statement attached as Appendix 4.

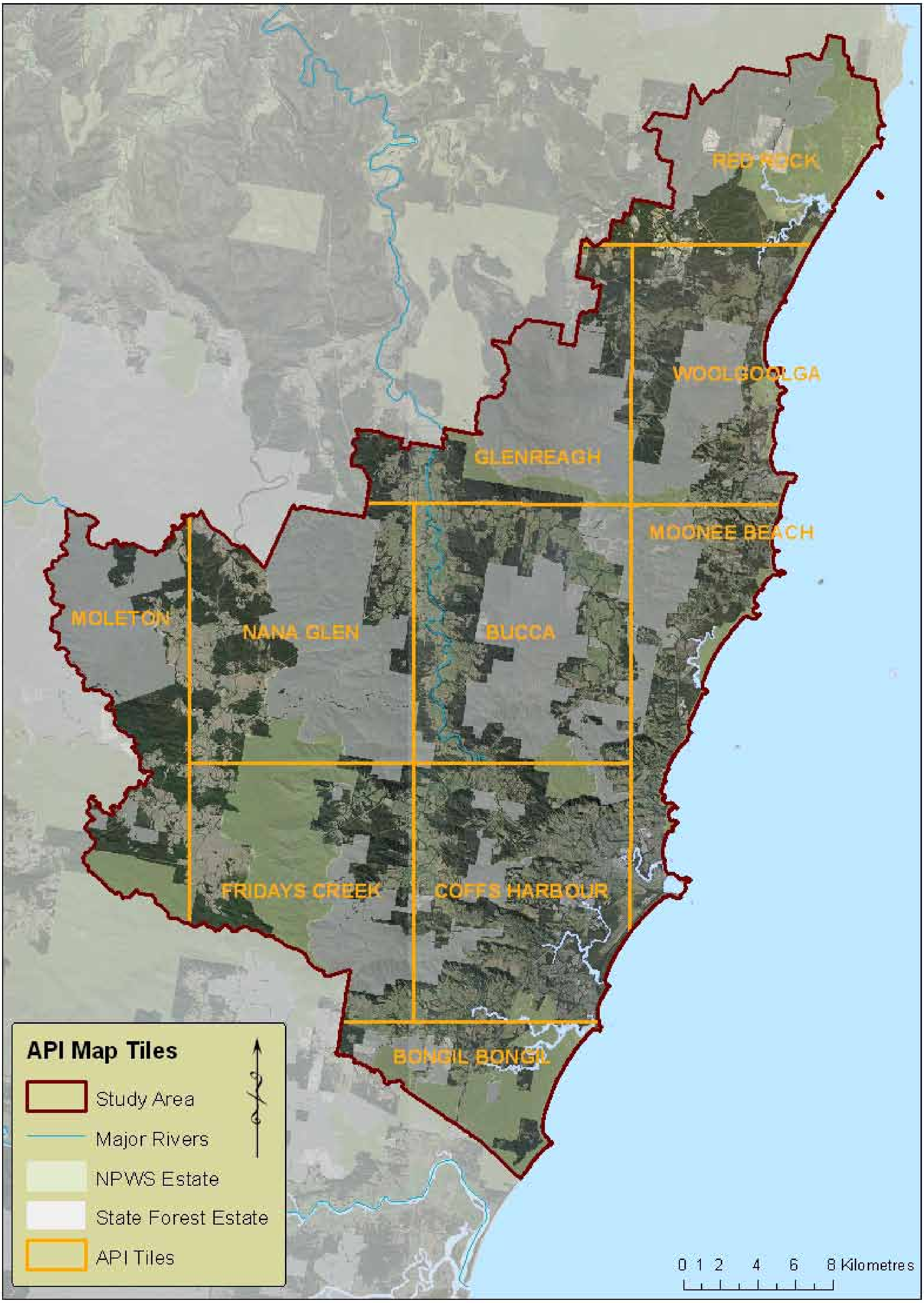

Figure 3 **API map tiles used in the study**

2.6 Accuracy Assessment

Accuracy assessments for vegetation maps typically have three phases: a response design, a sampling design, and analysis and estimation (Stehman and Czaplewski, 1998). A response design can be a hard classification (or deterministic with a binary choice) or using a soft classification (fuzzy set) to allow for natural variations within vegetation and uncertainty in assigning a vegetation type (Schowengerdt, 1997). Accuracy assessments which apply the deterministic approach generally use an error matrix (or confusion matrix) to arrive at statistics for 'user' and 'producer accuracy' and 'overall accuracy'. The diagonal elements of the error matrix represent agreement between the map and reference labels, and the off-diagonal elements reflect disagreements between the map and the reference labels. In fuzzy sets the row and column additions do not match correctly if applied to an error matrix and alternative methods are used to derive 'overall accuracy' (Stehman, et al 2007). For example, Gopal and Woodcock (1994) apply a 'right' function which is equivalent to the sum of the diagonal in an error matrix.

In this study a fuzzy set was used in the response design, with a stratified random sampling design, and the Gopal and Woodock (1994) method was used for the estimation of overall accuracy. For the study area, a total of 279 stratified random[1] plots, with a minimum of one plot per vegetation type and up to three plots for vegetation types with large areas were sampled. Plots were located at least 100m away from existing flora surveys (full floristic and rapid data points).

A team independent of the map production process completed the accuracy assessment for the purpose of conducting a "blind" test. To achieve this, only the polygon outlines (without labelled vegetation communities) were initially provided for the accuracy assessment by OEH and plot locations were also prepared independently by the sampling design team for the field assessors.

The plots were assigned to a vegetation community type using a fuzzy set (see degree of correctness Appendix 6 page 9). In the standards, a validation plot consists of recording the dominant species in each stratum, as well as the percentage cover for each species, and assigning each vegetation type a degree of correctness in the field.

In this study, variations to the standard occurred in two areas:

1. Percentage cover of each stratum was recorded rather than for each dominant species, and
2. Matching to vegetation type using the fuzzy set occurred in the office rather than in the field.

Results from the validation exercise were included in the final map product to make use of the additional field information and this was conducted in three stages:

1. Plots and polygon labels were compared with accuracy assessment (AA) and any inconsistencies were corrected as follows:
    a. Point/polygon and AA in agreement – no change
    b. Point/polygon and AA in disagreement (AA correct) – change mapped polygon (in part or all)
    c. Point/polygon and AA in disagreement (AA incorrect) – change AA but map is unchanged as original map label was found to be correct using information from the new and/or existing field data.
2. Feedback from the public exhibition period were then included.
3. Recommendations from the validation report implemented.

The AA is for thematic map accuracy only, with no assessment of linework accuracy. The AA was reported using the following two statistics:

1 Plots locations were constrained by proximity to the road network and away from existing surveys.

1. Original Overall Accuracy (OOA) – the Gopal and Woodcock (1994) *RIGHT* function was reported as the OOA.
2. Reviewed Overall Accuracy (ROA) – the ROA incorporates the above feedback and improvements to the map. Where no map changes can be justified from the field information available but the AA shows a mismatch, then the map was unchanged and the OOA reviewed to give the ROA. Revisions only applied to situations described by 1(c) above to arrive at the ROA statistic. This figure was also a weighted accuracy where the accuracies of the individual classes were weighted by their areas (Gopal and Woodcock, 1994), so that improvements to vegetation classes with small areas only result in marginal improvements to ROA.

3. Results

3.1 Selection of mapping pathways

Alternative mapping pathways (Section 2.1) showed promise for future development in a research environment with small study areas. However, only API using Stereo Analyst™ was demonstrated to be viable for vegetation mapping in an operational sense, and as such, this is the method we used to map vegetation in this study. The Definiens-based segmentation and classification technique was used for the land-cover mapping component of the project. Crown delineation modelling was not used because of the time and costs involved in calibrating each image or tile.

3.2 Land-cover mapping

The land-cover mapping showed that 75% of the study area had extant vegetation cover and 21% was cleared (see Table 6). Horticulture and cropping was the third largest land use, covering just over 2% of the LGA, including banana plantations, blueberry farms and other crops. Land-cover mapping was completed by three geographic information system / Definiens operators within three months.

Table 6 Summary of land cover in the Coffs Harbour LGA

Land-cover codes	Land-cover class	Area (ha)	Area (%)
1a,2,2a,2b,3	Extant vegetation cover	88 964	75.84
4,11	Cleared	24 050	20.50
5	Horticulture–Cropping	2 700	2.30
8e	Estuary–Coastal Waters	390	0.33
8b	Reservoirs–Dams	377	0.32
9	Sand–Beach	270	0.23
13	Highway upgrade 2011	193	0.16
8c	River	102	0.09
7	Railway strip	83	0.07
12	Pacific Highway	76	0.06
10	Headland Rock	59	0.05
8a	Lake	28	0.02
8	Water	8	0.01
	Total	**117 300**	**100%**

Land tenure was found to be almost equally divided between Crown land (48%) and freehold land (51%), however, almost half of the freehold land has been cleared as shown in Table 7.

Table 7 Summary of study area by tenure

Tenure	Area (ha)	Area (%)
NPWS estate	14 470	12%
Forests NSW estate	40 240	34%
Other Crown lands	2 040	2%
Total Crown land	**56 550**	**48%**
Freehold vegetated	32 400	28%
Freehold cleared	28 150	24%
Total Freehold	**60 249**	**51%**
Total	**117 300**	**100.0**

The fragmentation of remnant vegetation in some areas of the LGA was apparent. In the study area, 4 647 extant vegetation polygons were less than 5 hectares. The average remnant patch size was 2.4 hectares. There are just 28 extant vegetation polygons that are greater than 100 hectares (if roads and powerlines are considered as polygon sub-divisions). It is important to note that these results are calculated from an image analysis segmentation rather than API. The final vegetation extent was edited and re-mapped in the rural and fragmented areas to better reflect vegetation cover and the presence of significant remnant patches in those areas.

Table 8 Area of extant vegetation cover by polygon size classes (land-cover classification mapping)

Area class (ha)	No. of polygons	Area (ha)	Area (%)
0.2–5	4 647	2 878	3.2
5–10	147	1 030	1.2
10–100	143	3 701	4.2
100–1000	22	5 632	6.3
1 000–10 000	4	11 646	13.1
10 000–34 000	2	64 077	72
Total	**4 965**	**88 964**	**100.0**

3.3 Gap-filling flora surveys

An additional 141 full floristic sites and 741 rapid data sites were surveyed. Note that 279 rapid data sites were set aside for accuracy assessment or validation of the mapping at a later date.

Sampling rates are higher on Crown land than freehold land when considering both full floristic surveys and rapid survey sites, with an average sample coverage of one site per 66 hectares for Crown land and one site per 76 hectares for freehold land as shown in Table 9.

Table 9 Average site density and tenure sampling rates for sites used in the vegetation classification

Tenure	No. of full floristic sites	No. of rapid survey sites	Total sites	% of total sites	Sampling rate (ha per site)
NPWS estate	235	156	391	31%	
Forests NSW estate	110	246	356	28%	
Other Crown lands	15	89	104	8%	
Total Crown land			**851**	**67%**	**66**
Freehold (vegetated)	174	250	424	33%	76
Total	**534**	**741**	**1275**	**100%**	

The geographic spread of sites across the study area is show in Figure 4. The figure includes both flora sites collected during the mapping project and existing data for the study.

3.4 Vegetation classification

The PATN analysis was set at a 100 floristic group level. During the mapping program the PATN-derived groups were comprehensively tested and refined in the field. The result produced a list of 79 communities as listed in Appendix 5. This process was invaluable for the development of the final vegetation communities and the vegetation mapping classes.

One of the main challenges during the mapping and testing of the community list, was to ensure that vegetation communities identified by PATN analysis could be recognised and accurately delineated from the ADS40 imagery. Some map units represented potential plant communities or previously recognised communities that were not delineated by the PATN analysis due to lack of surveys or the restricted nature of the community.

These results show the value of having previous studies, numerical analysis, and mapping to inform the classification process. While it is desirable to have a fixed vegetation classification prior to mapping, deficiencies in the data used in the classification may be exposed by the mapping process. The final vegetation classification and mapped units are described in Volume 2 – Vegetation Community Profiles.

3.5 Vegetation mapping

The extent of vegetation in the study area was 88 964 hectares, with 18 311 polygons needing to be assigned to one of the 79 classified vegetation communities (see Appendix 5). The use of stereo API in combination with existing mapping products and field validation resulted in the completion of the study area in a 12 month API program. Table 10 summarises the area by vegetation formation and classes across the study area. Overall, 11 formations were mapped across 24 different classes of native vegetation. In general, it was more difficult to assign vegetation to a community in fragmented and disturbed landscapes than in contiguous forested areas.

Wet sclerophyll and rainforest formations dominate the landscape, covering over 60% (54 971 ha), and this is mainly due to the rich, fertile landscapes and high annual rainfall. Dry sclerophyll forests cover 19% (17 198 ha), while the coastal communities cover only 6% (5 274 ha) of the LGA. Derived communities including plantations, exotics and regenerating pioneers cover over 10% of the vegetated area in the LGA.

The vegetation map (see http://maps.coffsharbour.nsw.gov.au/eview-html/index.html#) illustrates the biodiversity of the Coffs Harbour LGA. Large areas of rainforest and wet sclerophyll forest are mapped in the west and south of the study area across the fertile areas of the eastern Dorrigo Plateau, escarpment ranges and the upper reaches of the Orara and Bucca valleys. In contrast, much of the sandstone and coastal metasediment-dominated landscapes in the north of the study area are mapped with large stands of dry sclerophyll forest, heathlands and forested wetlands. Overall, the variety of soil moisture gradients, geologies, altitudes and quaternary landscapes support a diverse array of floristic communities.

The final vegetation map shows that the major contributing influences to the floristic diversity are likely to be altitude and geology, followed by coastal/marine processes. The coastal areas have the most complex vegetation patterns and this is reflected by the number of communities mapped and the large numbers of small polygons.

Figure 4 **Flora sites used in analysis and mapping**

Table 10 Areas of formations and vegetation classes mapped across the Coffs Harbour LGA

Formation	Class	Class area (ha)	Formation area (ha)
Derived	Exotic vegetation	3 288	
	Native pioneer	209	
	Plantation	6 501	9 998
Dry Sclerophyll Forest	North Coast Dry Sclerophyll Forest	16 710	
	North Coast Dune Sclerophyll Forest	488	17 198
Forested wetlands	Coastal Floodplain Wetlands	289	
	Coastal Swamp Forests	2 021	
	Eastern Riverine Forests	576	2 886
Freshwater Wetlands	Coastal Heath Swamps	785	
	Coastal Lagoons	27	
	Derived Freshwater Wetlands	189	1 001
Grasslands	Maritime Grasslands	38	38
Heathlands	Coastal Headland Heaths	876	
	Coastal Wallum Heaths	113	
	Escapment rock outcrops	22	
	Northern Montane Heaths	16	1 027
Marine	Marine vegetation	3	3
Native remnant vegetation	Native remnant vegetation	1 456	1 456
Natural non-vegetated	Rock outcrop	0.2	
	Sand	26	26
Rainforest	Cool Temperate Rainforest	0.8	
	Dry Rainforest	470	
	Littoral Rainforest	225	
	Subtropical Rainforest	4 324	
	Warm Temperate Rainforest	5 631	1 0651
Saline Wetlands	Mangroves	146	
	Saltmarsh	214	360
Wet Sclerophyll Forest	North Coast Wet Sclerophyll Forest	44 320	44 320
Total		**88 964**	

3.6 Refinement of vegetation classification and map units

An iterative approach was taken to finalise the vegetation classification where the results of mapping and ground truthing surveys informed the classification. During the mapping process some grouping and splitting of the original classification occurred to better match communities identified from ground truthing.

As a result, of the 79 vegetation communities, 66 were derived from the numerical analysis (using the 534 full floristic sites), and 14 were identified from API. This step-wise method of reviewing the vegetation classification highlighted areas where further botanical work would be beneficial to adequately describe the diversity within the landscape.

Of particular note, the field ground truthing effort was extensive during the API mapping exercise with a total 2 479 API sites surveyed. Together with the 534 full floristic sites and 462 rapid data sites, a total of 3 475 sites were surveyed on the ground.

3.7 Accuracy Assessment

A full report of the independent accuracy assessment (AA) is provided in Appendix 6, with 279 plots contributing to the AA analysis. The result of the accuracy assessment was an Original Overall Accuracy (OOA) of 66%.

To improve the map product, polygon labels were compared to field plots to determine if the polygon label should be amended. Of the 279 AA plots, 31 plots were located in polygons which required no change when assessed against both new and existing field information, resulting in an improvement of 11% with a Reviewed Overall Accuracy (ROA) of 77% (area weighted).

The discrepancy between OOA and ROA can be due to a number of factors such as natural variation within a polygon, context of a sample point within a polygon and its neighbouring polygons, relationship of a data point to all existing data points in the vicinity, interpretation of the field plot information, and/or scoring vegetation types at the desktop rather than in the field. In these cases use of a mid-score is more applicable when using a fuzzy set for vegetation types that may qualify for a site.

As a result of recommendations from the AA report, edits to the vegetation map were made to Cool Temperate Rainforest and Dunn's White Gum Wet Forest. Firstly, Cool Temperate vegetation types (RF01, RF02) were relabelled as Warm Temperate Rainforest as these small areas were not detectable from aerial imagery, except for the main location on Tucker's Knob (RF01). The description of other locations referred to by local experts is given in the vegetation profiles. Secondly, some areas of the restricted Dunn's White Gum Wet Forest (WSF13) were found to be mislabelled due to crown dieback and disturbance and these have been corrected.

Further improvements to the map product were made as a result of two submissions from the public exhibition period. This included edits to recognise environmental plantings within riparian vegetation in the Orara Valley, and environmental plantings on a small property south of Coffs Harbour.

Three aims of the vegetation study were to provide a contiguous thematic layer, develop a community classification for the LGA, and a developing a fine-scale map product. Given the size of the study area and the number of vegetation classes that needed to be identified from aerial interpretation an OOA of 66% (and ROA of 77%) represents a major improvement in mapping quality for this LGA. A continuous improvement program will now be undertaken by CHCC as more site specific information is obtained from development applications and other sources as part of its data maintenance program.

3.8 Native species and weeds recorded in surveys

In the gap-filling surveys, 8 114 records of 689 plant taxa were made, including many species of conservation significance. Some of the most commonly recorded genera were *Eucalyptus* (23 taxa) and *Acacia* (17 taxa). The Lauraceae family (24 taxa) including *Cryptocarya*, *Endiandra* and *Neolitsea* were an abundant component of wet sclerophyll and rainforest communities. Other diverse plant families recorded across a range of wet and dry vegetation formations were Mrytaceae (74), Fabaceae (51), Poaceae (33), Cyperaceae (31) and Proteaceae (24).

In addition, 67 weed species were recorded in the surveys. Lantana (*Lantana camara*) was the most commonly recorded weed species. Other commonly recorded, highly invasive weed species included Bitou bush (Chrysanthemoides monilifera), Camphor Laurel (*Cinnamomum camphora*), Broad-leaved Paspalum (*Paspalum mandicanum*), *Senna pendula* var. *glabrata,* and Small Leaved Privet (*Ligustrum sinense*).

3.9 Threatened species of the Coffs Harbour LGA

During the gap-filling floristic surveys several threatened species were recorded in the study area, including new records of *Hakea ochroptera* and *Plectranthus cremnus*. Overall, six threatened flora species and 12 rare or threatened Australian plant (ROTAP) species were found during the Coffs Harbour LGA flora surveys. Additionally, in other recent surveys five threatened species and several ROTAP species were recorded, including *Alexfloydia repens*, *Pultenaea maritima*, *Lindsaea incisa* and *Ricinocarpos speciosus*. There are now 53 known significant plant species in the Coffs Harbour LGA. These species are listed in Table 11.

Table 11 Significant plants in the Coffs Harbour LGA

Species name	Common name	Threatened Species Conservation Act	ROTAP code
Acianthella amplexicaulis			3RC-
Acomis acoma			3RC-
Acronychia littoralis	Scented Acronychia	TSC-E	3ECi
Alexfloydia repens	Floyd's Grass	TSC-V	2K
Allocasuarina defungens		TSC-E	2E
Alloxylon pinnatum	Dorrigo Waratah		3RCa
Anetholea anisata	Ringwood		2RCa
Angophora robur	Sandstone Rough-barked Apple	TSC-V	2RC-
Austrobuxus swainii	Pink Cherry		3RCa
Arthraxon hispidus	Hairy Joint Grass	TSC-V	3VC-+
Arthrochilus prolixus			3K
Boronia umbellata	Orara Boronia	TSC-V	2VC-
Callistemon acuminatus	Tapering-leaved Bottlebrush		3RC-
Chamaesyce psammogeton		TSC-E	
Corybas undulatus	Tailed Helmet Orchid		3KC-
Cryptocarya dorrigoensis	Dorrigo Laurel		2RCa
Cryptostylis hunteriana	Leafless Tongue Orchid	TSC-V	3VC-
Cupaniopsis newmanii			2RC-
Elaeocharis tetraquetra	Square-stemmed Spike Rush	TSC-E	
Endiandra introrsa	Dorrigo Plum		3RCa
Eucalyptus ancophila			2K
Eucalyptus dunnii	Dunn's White Gum		3RCa
Eucalyptus fusiformis	Grey Ironbark		2RC-
Eucalyptus rummeryi	Steel Box		3RC-
Gahnia insignis			3RCa
Goodenia fordiana			2RC-
Hakea ochroptera			2K
Lindsaea incisa	Screw Fern	TSC-E	
Marsdenia fraseri	Narrow-leaved Milk Vine		3RC
Marsdenia liisae	Large-flowered Milk Vine		3RC-
Marsdenia longiloba	Slender Marsdenia	TCS-E	3RC-

Species name	Common name	Threatened Species Conservation Act	ROTAP code
Niemeyera whitei	Rusty Plum, Plum Boxwood	TSC-V	
Oberonia titania			
Olearia flocktoniae		TSC-E	2ECi
Olearia stillwelliae			3RCa
Parsonsia dorrigoensis	Milky Silkpod	TSC-V	2VCi
Phaius australis	Lesser Swamp Orchid	TSC-E	3VCa
Peristeranthus hillii	Brown Fairy-chain Orchid	TSC-V	
Plectranthus cremnus			3K
Plectranthus suaveolens			3KC-
Pultenaea maritima	Coast Headland Pea	TSC-V	
Quassia sp B		TSC-E	
Ricinocarpos speciosus			2RCi
Sarchochilus fitzgeraldii	Ravine Orchid	TSC-V	3VC-
Schistostylis purpuratus			3RCi
Senna acclinis	Rainforest Senna	TSC-E	3RC-
Sophora tomentosa	Silver Bush	TSC-E	
Thesium australe	Austral Toadflax	TSC-V	3VCi+
Tinospora tinosporoides	Arrow-head Vine	TSC-V	3RC-
Triplarina imbricata		TSC-E	2E
Typhonium sp aff *brownii*	Black Lily	TSC-E	
Tylophora woollsii		TSC-E	2E
Zieria prostrata		TSC-E	

TSC-E = endangered species listed on *Threatened Species Conservation Act 1995*
TSC-V = vulnerable species listed on *Threatened Species Conservation Act 1995*
ROTAP codes - see Briggs and Leigh (1996).

3.10 Endangered ecological communities of the Coffs Harbour LGA

Several of the classified vegetation communities are considered to be endangered ecological communities (EECs) or highly likely to contain EECs based on their substrate or altitudinal/landscape occurrence. Overall, 11 657 hectares have floristic communities that may be EECs. Table 12 shows vegetation communities in the study area that are likely to support threatened communities.

Table 12 Vegetation communities likely to contain endangered ecological communities

* Vegetation community CH_FW08 (Coastal Spike Rush Cumbungi Freshwater Wetland) covers 382 hectares across the LGA. Much of this includes farm dams and heavily disturbed creek lines where allocation as an EEC requires further field verification. For purposes of this report an area estimate has been omitted.

‡ Rainforest communities CH_RF03, CH_RF04 and CH_RF12 only qualify as EECs if their occurrence is below 600 m altitude, and areas have been calculated using this elevation threshold.

Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_SW02	Estuarine Twig Rush Saltmarsh	47
CH_SW03	Coastal Dune Sedgeland Soak	11
CH_SW04	Coastal Dune Prickly Couch Grasslands	0.40
CH_SW05	Coastal Headland Twig Rush Sedgeland Soak	4
CH_SW06	Estuarine Sea Rush Saltmarsh	38
CH_SW07	Estuarine Samphire - Saltwater Couch Saltmarsh	114
		214.4
Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_FW07	Coastal Jointed Twig-rush Freshwater Wetland	27
CH_FW08	Coastal Spike Rush Cumbungi Freshwater Wetland	* Area not available
		27
Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_RF07	Coastal Exposed Dune Littoral Rainforest	95
CH_RF08	Coast Headland Brush Box Littoral Rainforest	42
CH_RF13	Coastal Sheltered Dune Littoral Rainforest	93
		230
Lowland Rainforest in the NSW North Coast and Sydney Basin bioregions EEC		
CH_RF03	Plateau and Escarpment Coachwood Sassafras Warm Temperate Rainforest	‡ 1 201
CH_RF04	Plateau and Escarpment Hoop Pine Dry Rainforest	‡ 54
CH_RF05	Foothills Brown Myrtle Dry Rainforest	340
CH_RF06	Escarpment Grey Mrytle Brush Box Dry Rainforest	76
CH_RF11	Escarpment and Lowland Bangalow - Carabeen - Black Booyong Palm Gully Rainforest	4 271
CH_RF12	Escarpment Coachwood - Sassafras - Brush Box Warm Temperate Rainforest	‡ 286
CH_WSF15	Foothills Steel Box Brown Myrtle Wet Forest	557
		6 785
Lowland Rainforest on Floodplain in the New South Wales North Coast Bioregion EEC		
CH_FrW07	River Oak Riparian Forest of the Orara River Valley	189
CH_RF09	Hinterland White Booyong Floodplain Rainforest	44
		233
Subtropical Coastal Floodplain Forest of the NSW North Coast bioregion EEC		
CH_DOF06	Lowlands Swamp Paperbark Red Gum Dry Forest	2 013
		2 013

Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_FrW10	Estuarine Swamp Oak Forest	202
		202
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_FrW01	Coastal Paperbark Swamp Oak Floodplain Forest	944
CH_FrW02	Coastal Swamp Mahogany Forest	180
CH_FrW03	Coastal Paperbark Bottlebrush Channel Forest	80
CH_FrW04	Coastal Paperbark Sedgeland Dominated Forest	529
		1 733
Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner bioregions EEC		
CH_H03: Kangaroo Grass Headland Grasslands		46
CH_H06: Coastal Headland Banksia		46
		92
White Gum Moist Forest in the NSW North Coast Bioregion EEC		
CH_WSF13: Dunns White Gum Wet Forest		128
TOTAL		**11 657**

3.11 Project management and costs

The mapping program commenced in October 2011 and was completed by May 2012. As a general guide, it took each interpreter around two months to map each API tile segment, including fieldwork. Additional to this, corrections, adjustments and checking took approximately one additional week per tile. Total costs of the project were $400,000, and effectively equated to $3.40 per hectare, including the floristic plots and analysis, or $2.32 per hectare for API mapping work.

Before the mapping program commenced, a significant amount of preparation work, trials, research and development was undertaken to develop the best approach for fine-scale mapping. This added significantly to the project timeframe but was, however, an invaluable exercise in determining the most appropriate use of the current technology available for Class 5 vegetation mapping. This process supported the development of a proposed methodology for Class 5 mapping projects that is the most efficient, practical and cost effective.

3.12 Research and development

Over the course of this project, several new approaches were tested for fine-scale, LGA-wide vegetation mapping. It was found that the use of conventional API techniques within the Stereo Analyst™ 3D environment with the use of high resolution ADS40 imagery and LIDAR digital terrain models was the most accurate, efficient and cost-effective approach to vegetation mapping at this scale.

The use of a computer-generated segmentation to delineate extant vegetation extent proved to be more time consuming than the conventional approach through API due to misalignment of the segmentation lines due to shadow or other anomalies with the imagery (smoke, haze or water bodies). This line work required extensive editing by traditional API methods.

Extensive work and research was carried out to determine a suitable image manipulation technique (stretch) to see if communities, tree species and vegetation patterns in general could be highlighted to allow delineation in a 2D environment or alternatively to allow automated delineation of communities. It was found that the manipulation of the ADS40 imagery, in particular the near infra-red bands, displayed the contrasting vegetation patterns well and, in some cases, illustrated the mix of species or at times the specific canopy species present in the landscape. However, the automated delineation of communities was not accurate and the process was not time-effective. Nonetheless, this research and development opportunity produced an additional highly useful data set that was referred to and utilised throughout the project to support traditional API mapping and editing.

Future research and development work could be directed towards improving multi-scale segmentation techniques for coastal complexes, especially if combined with LiDAR information. For example, coastal heaths communities can in some cases be well differentiated using height information and spectral response. Automated segmentation methods seemed to provide adequate delineation of vegetation communities, but the segmentation parameters only applied to specific areas. A multi-scale approach would enable broader landscape patterns or context to be considered to refine the scale at which segmentation is applied.

3.13 Conclusion

A fine-scale map was produced for the Coffs Harbour LGA to support environmental planning purposes at the 1:5000 scale. API was found to be the current best practice for fine-scale vegetation mapping for this coastal local government area. This was largely due to the complexity of coastal vegetation communities where significant vegetation changes occur within short distances requiring numerous small polygons to describe the vegetation patterns.

The approach of using conventional API is labour intensive and resulted in relatively high costs per hectare compared to modelled vegetation map products, but conventional API also results in significantly higher overall accuracy.

The Definiens segmentation, object-orientated approach was found to be useful for land-cover mapping but was not found to be useful for vegetation mapping over a large region. Further research is required to enable multi-scale segmentation processes to define community boundaries. This approach is most promising in coastal heath areas in conjunction with the use of LiDAR, as height differences are an important distinguishing feature.

It was found that classification and mapping go 'hand-in-hand' and mapping does not necessarily follow classification in consecutive steps. The classification process was found to inform the mapping process and the mapping process and field checking informed the classification.

Intensive field sampling effort was required to achieve the desired mapping scale and accuracy of 77% for this coastal LGA. This was largely due to the varied landscapes within the study area the rapid changes in landform and elevation moving from east to west. Heathland and saline wetland types had the highest accuracy (87% and 82%), whereas wet sclerophyll forest, rainforests, freshwater and forested wetlands had the lowest accuracy of between 59% and 63%.

Image enhancement techniques often provide important supplementary information for the interpreter, but not all differences shown in image stretches amount to floristic changes on the ground. Availability of additional flora survey site data and ancillary information such as digital terrain models and access to previous vegetation mapping products were all found to be useful in the attribution and delineation of vegetation communities.

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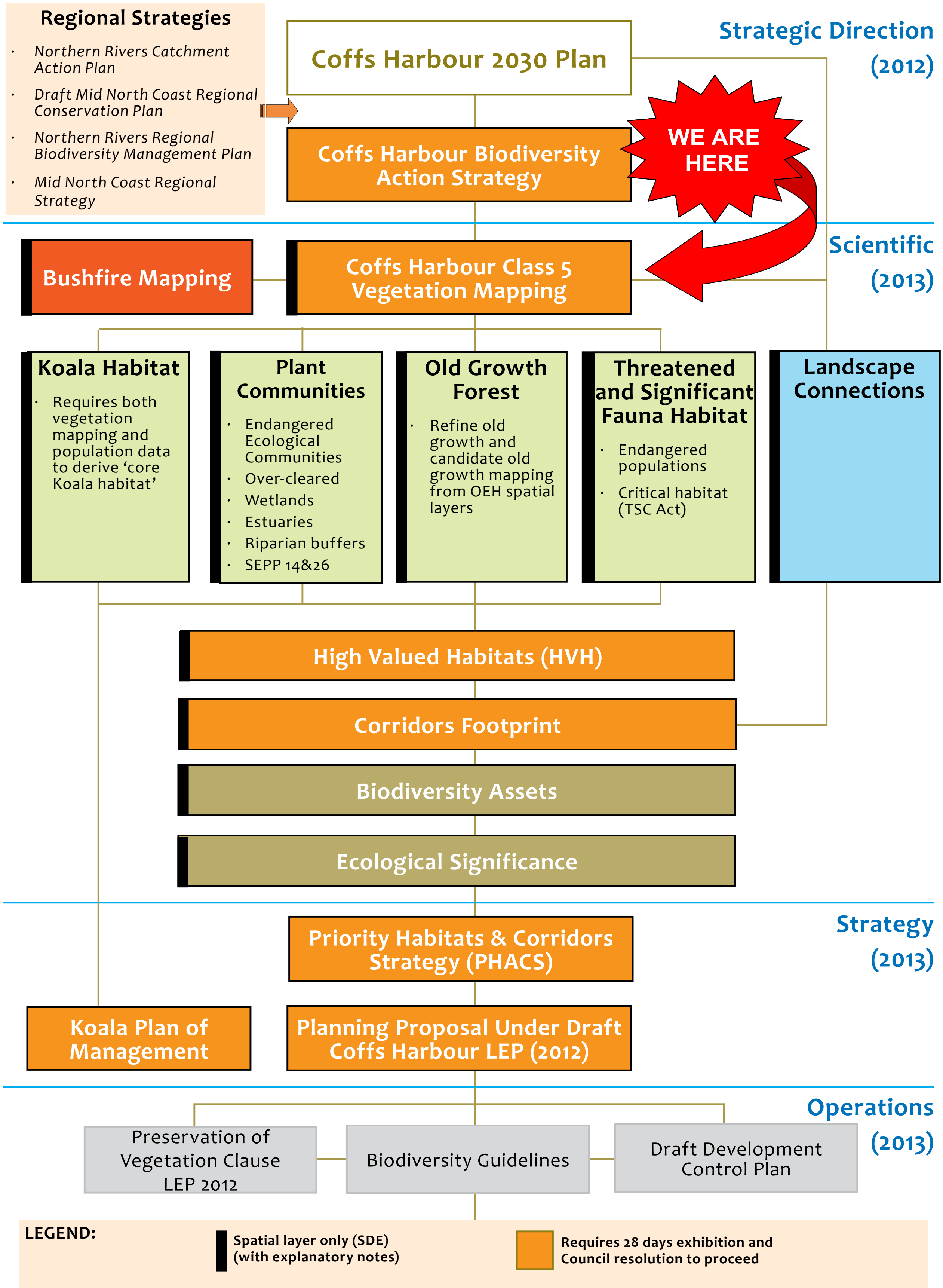
Appendix 1 Coffs Harbour Biodiversity Strategy

Figure A5.1 from Coffs Harbour Biodiversity Action Strategy (2012)



Appendix 2 Previous vegetation mapping and flora surveys in the study area.

See the Reference section for full publication details.

Author/Citation	Description/Method
Aerial photograph interpretation	
Forestry Commission of NSW (1989)	Research Note 17 Forest Type mapping. Complete for the following state forests: Orara East, Conglomerate, Wedding Bells, Lower Bucca, Boambee, Orara West, Pine Creek, Nana Creek and Bagawa. Method: Traditional API methods. Stereoscopic API transposed to hard copy maps then subsequently digitised.
Kendall (2005)	Vegetation mapping of the Corindi and Red Rock extension to the Coffs Harbour LGA. Mapped to classification used by Fisher et al. (1996). Method: Traditional stereoscopic API scanned, ortho-rectified and vectorised.
Griffith & Wilson (2007)	API mapping of coastal reserves and Crown land on the north coast of NSW.
Systematic survey and/or mapping	
Griffith (1984)	Systematic survey and mapping of the vegetation of Yuraygir National Park
Austin & Heyligers (1989)	A presence–absence gradsect survey of overstorey species undertaken to obtain a representative sample of the floristic variation in a forested area of about 20,000 square kilometres.
Gilmour & Helman (1991)	Rainforest survey of remnant vegetation in the Clarence Valley.
NPWS (1994)	Systematic flora survey of north-east NSW as part of the NSW North East Forest Biodiversity Study.
NRAC (1995)	Systematic flora survey and multi-attribute mapping of north-east NSW. Floristic surveys done for a regional biodiversity audit in 1995.
Tweedie et al. (1995)	Systematic survey and analysis of vegetation in the Coffs Harbour – Urunga State Forest Management Area.
Fisher et al. (1996)	Systematic survey and mapping of vegetation in the Coffs Harbour LGA.
Clode & Burgman (1997)	Systematic survey sites to characterise old-growth forest, as part of the Natural Resource Audit Council's Joint Old -growth project.
NPWS (1999)	Systematic flora survey for north-east NSW supporting the Regional Forest Agreement process.
Griffith (2002)	Systematic survey and mapping of the wallum heath of north-east NSW.
Cameron et al. (2010)	Systematic survey and mapping of the vegetation of Bongil Bongil National Park.
Office of Environment and Heritage (in prep.)	Systematic gap-filling surveys for the North Coast Vegetation Classification project.
Non-systematic survey and mapping	
Williams (1958 to 1993)	Rainforest species lists. Method: Random meanders.
Clancy (1988)	Recorded 280 plant taxa in a study area encompassing Bonville Beach.

Author/Citation	Description/Method
Floyd (1990)	Surveys of littoral rainforest at Bundagen Flora Reserve and Scrub Creek. Method: Random traverse.
Smith et al. (1990)	Flora and fauna survey of the Orara and Bucca valleys.
Bale et al. (1992)	Survey of the vegetation of the Bonville Beach Sand mass. A list of plant taxa was compiled and 19 vegetation communities were described.
Elks (2006)	Site survey for a fire-response study and review of environmental factors that included a vegetation assessment.
Lunney (in prep.)	Survey sites for Koala habitat assessment. Methods: canopy only survey.

Appendix 3 Mapping Specifications

Polygon size and dimensions

Coastal lowland, alluvial plains, sands and estuaries	
Reference scale for review of linework	1:4,000
Minimum remnant size for floristic group attribution	0.2 ha
Minimum size for delineation of community within larger patch in **coastal lowland** ladscape	0.2 ha
Minimum width for linear feature in **coastal lowland** landscape	5m

Coastal foothills, escarpment and plateau forests and woodlands	
Reference scale for review of linework	1:6,000
Minimum remnant size for floristic group attribution	0.2 ha
Minimum size for delineation of community within larger patch in **forest** landscape	0.5 ha
Minimum width for linear feature in **forest** landscape	10m

Dual coding of floristic communities	
Polygons can be coded with dual floristic communities where they occur as a mosaic . Code should be denoted FGA/FGB. E.g. 17/16 where 17 is the most likely or dominant group. At least **30%** of each community should be present for a dual community code attribution.	

Polygon confidence	
Ground validation of polygon	1
High level of confidence (adjacent polygons within survey data or distinct photo pattern)	2
Moderate level of confidence (survey data in near vicinity)	3
Low level of confidence (lack of nearby survey data or indistinct photo pattern)	4

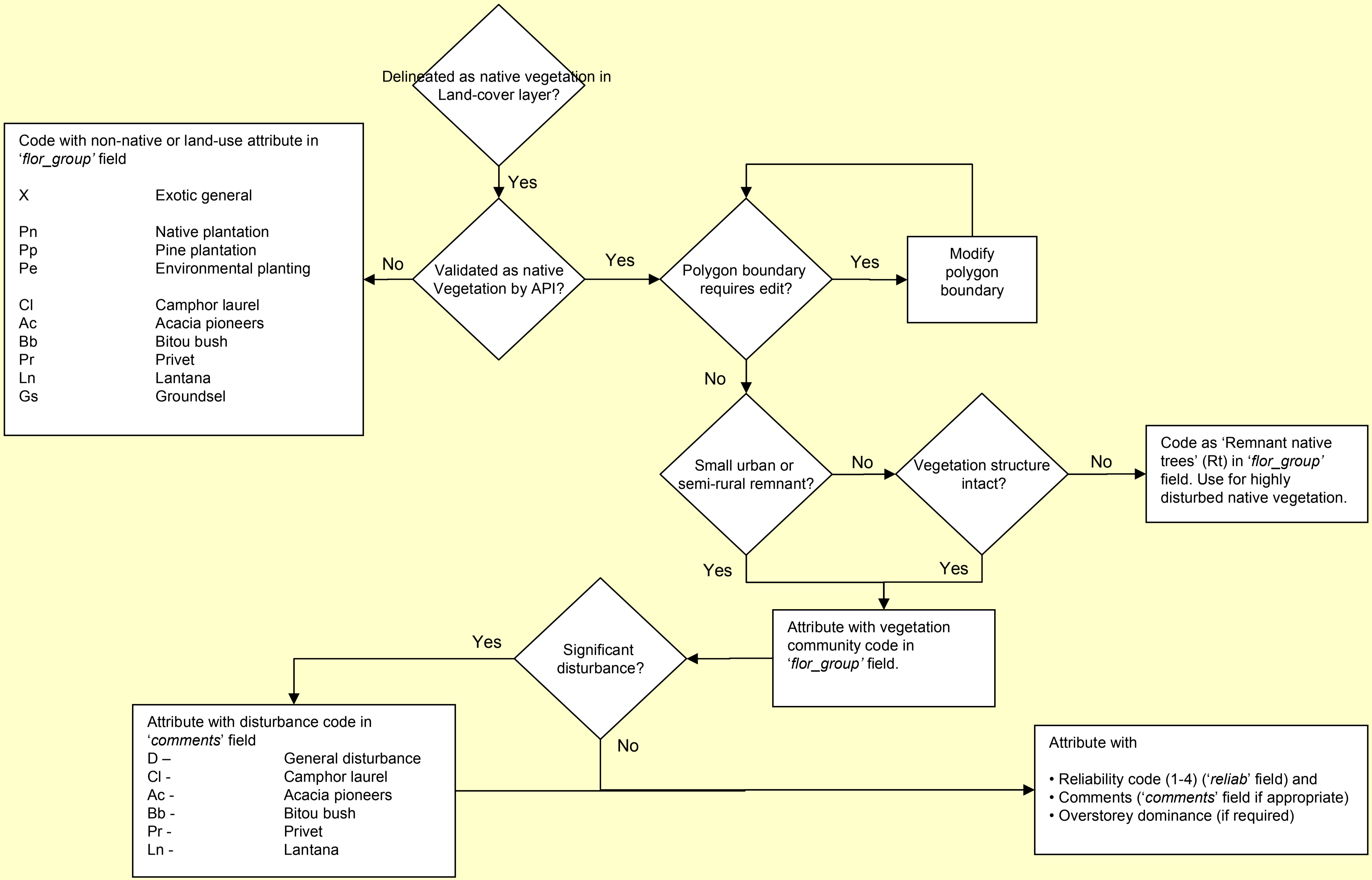
Coding of Exotic and disturbance features

Exotic dominated (>50% of polygon) features	*Flor_group* field
Exotic vegetation. Includes exotic dominated urban and rural residential vegetation which has been delineated as native vegetation in the land-cover layer.	x
Environmental weeds	See below
Native plantations	Pn
Pine / softwood planations	Pp
Environmental plantings (revegetation areas, windbreaks, raodside plantings etc.	Pe

Native vegetation with significant occurrence (30-50%) of environmental weeds or significant disturbance defined as either: a) Loss or >50% disturbance to canopy; or b) Removal of >50% of understorey/ground cover	*Comments* field
General disturbance	D
Environmental weeds	See below
Significance disturbance where interpretation of vegetation community is no longer possible (significant alteration of structure and species composition	Rt

Environmental weeds or native pioneers	
Camphor laurel	Cl
Acacia spp. Native pioneers (Not including FG 53 - Coast Wattle Shrublands). E.g. A. irrorata or A. melanoxylon.	Ac
Bitou bush	Bb
Privet	Pr
Lantana	Ln
Groundsel	Gs
Pine species	Pp
Horse-tail She-oak	Hs

API flow chart for polygon attribution



Appendix 4 Metadata Statement

Coffs Harbour Vegetation Map

DATASET Coffs Harbour City Council Floristic Vegetation Map - 2012

CUSTODIAN Coffs Harbour City Council

JURISDICTION New South Wales

DESCRIPTION Abstract

This layer is a fine-scale floristic vegetation map of the Coffs Harbour Local Government Area. There are 92 map categories in total with almost all of these being the result of statistical analysis and field-based full floristic data sites. Mapping was conducted by vegetation mapping experts in a digital three-dimensional (3D) Planar environment. Additionally, basic disturbance information was captured along with a selection of prominent weeds where discernible by interpreters.

Geographic Extent Name

GEN Category: Local Government Areas (LGA)
GEN Custodial Jurisdiction: New South Wales
GEN Name: Coffs Harbour Local Government Area
Geographic Extent Polygon
Geographic Bounding Box
Min E: 480360.3
Max E: 525096.1
Max Y: 6692556.6
Min Y: 6631522.8

DATA CURRENCY

Beginning Date 2009-09-01
Ending Date 2012-04-07

DATASET STATUS

Progress: Complete

Maintenance and Update Frequency: As required

ACCESS

Stored Data Format: ESRI ArcSDE
Available Format Type: DIGITAL - ESRI Geo-database/shapefile
Access Constraint: Contact the GIS Team Leader to discuss access and costs

DATA QUALITY

Lineage: Source data for this layer has two components, the floristic field-based site data and the other being high resolution aerial photography.

SITE DATA

An initial site data audit from the NSW VIS Flora Survey database was conducted to determine the full floristic (FF) sites of sufficient quality available for PATN statistical analysis. Statistical gap analysis and stratification identified remaining ecological gaps and a further 180 FF sites (funded by Coffs Council) were funded to target these gaps. A subsequent further review of sites determined a total of 534 FF sites for PATN analysis. PATN analysis produced 66 vegetation communities with floristic descriptions ready for mapping.

In addition, a further 462 rapid data sites were funded by Coffs Council to inform the mapping. The rapid sites collected up to 5 dominant species for 6 levels of vertical strata at each site. An enormous achievement of this project was site density is almost equal across both vegetated freehold and public tenures, a normally unavoidable bias that plagues most multi tenure mapping programs.

AREIAL PHOTOGRAPHY

The NSW Land and Property Management Authority (LPMA) captures airborne ADS40 4-band digital imagery at 50 cm resolution for most of NSW. The Coffs Harbour (Sep 09), Dorrigo (Sep 09) and Bare Pt (June 10) 1:100k ADS40 tiles covered the Coffs LGA. Two levels of imagery were utilised for the project, the 4-band 2-dimensional orthorectified images and the Level 1 Rectified stereo image pair strips. The Level 1 data was used for 3-dimensional (3D) mapping in a GIS stereo environment. Significant spatial errors up to +- 30 metres between Level 1 and the orthorectified data were discovered.

MAPPING PROCESS

Mapping was conducted by API/botanical experts in a stereo view workstation comprising of Planar stereo/3D monitors, ESRI ArcMap software and ERDAS Stereo Analyst™ software. The environment allows the direct delineation and attribution of polygons in 3D stereo view (Level 1 imagery) whilst simultaneously having a 2D context view and any number of additional datasets to guide mapping decisions. Interpreters had at their disposal all site data (733 sites) in 3D. Interpreters routinely collected field check points with geographic positioning systems to help extrapolate across areas of difficult interpretability. A total of 2479 check points were collected for the project but points were constrained to publicly accessible areas and areas that were visually accessible from public roads or tracks. This fieldwork resulted in an additional 14 map units being added to the existing 66 classified communities. The mapping was conducted on-screen at a range of scales but the final reference scale is deemed to be 1:5000. Linework was digitised using live streaming with a stream tolerance average of 5 metres (i.e. a vertex every 5 metres).

The study area was divided into 10 tiles for stereo mapping and the interpreters cross-referenced each other whenever possible to help guide their mapping decisions. The tiles were stitched together in GIS and interpreters then reviewed the edges and re-mapped any inconsistencies. A final quality review of the stitched map was conducted by examining each community in isolation and reviewing it for errors and ecological distribution anomalies. This review process fed back in further refinements. Vegetation clearing from the Sapphire-to-Woolgoolga highway upgrade was applied to the map. A Worldview2 image captured 7 April 2012 with 43 cm spatial resolution was the baseline for delineating the highway clearing footprint.

Due to the spatial accuracy issue between the Level 1 and orthorectified products, a final linework adjustment process for the study area was conducted using the orthorectified products as the accuracy reference. The focus of linework refinement was on vegetated/clearing interfaces, urban remnants, water bodies and other high contrast edges. Linework accuracy within contiguous vegetated areas were not systematically reviewed. All data stored and edited within ESRI File Geo-database format.

Positional Accuracy:

Accuracy is determined by the spatial accuracies of both the Level 1 and 2-dimensional orthorectified ADS40 imagery supplied by NSW LPMA. Orthorectified imagery is +- 2metres and Level 1 accuracy is not known.

Attribute Accuracy:

In this study, a numerical PATN analysis (Belbin 1994) was undertaken using 534 full floristic sites to determine the main floristic clusters for the study area. A 100-group analysis was undertaken. An agglomerative hierarchical approach was applied using the Bray-Curtis (Bray & Curtis1957) association measure to produce a dendrogram. In the agglomerative method, clustering is 'bottom-up' with the most similar sites being aggregated into larger clusters until there is a single cluster containing all sites. The dissimilarity between clusters was calculated using average values (or unweighted pair group method with arithmetic mean — UPGMA), where two clusters with the lowest average distance (with a beta value setting of -0.1) are merged to form the new cluster. To support the interpretation of the results a nearest neighbour analysis and fidelity was also carried out. 66 communities resulted with a further 14 map units added that resulted from findings in fieldwork. There are an additional 12 units that relate to disturbance and non-vegetated characteristics which produced 92 map categories in all. Interpreters would use all available supporting data to attribute each polygon to one of the categories and if uncertain or a mosaic of categories existed then a dual category would be assigned. Many factors affect the interpreters reliability to assign a category to a polygon (i.e. disturbance factors, clearing, regrowth, accessibility etc). For every polygon though, the interpreter was required to assign a reliability score from 1 to 4. The scoring is as follows: 1=Field survey confirmation; 2=high confidence; 3=moderate confidence; and 4=Low confidence.

In reality, some areas are disturbed to the point where none of the 92 categories reflect entirely what is present on the ground. Interpretation is then performed such that an expert needs to predict what occurred prior to disturbance in order to allocate to a category. This interpretation can occur within the 3D mapping environment or *in situ* and should be reflected within the interpreters reliability score.

Logical Consistency:

Geodatabase XY tolerance set at 0.2 metres and the resolution set at 0.1 metres. Topology validation was performed with a tolerance of 0.2 metres and all subsequent gaps and overlapping polygons fixed. Topology is correct.

Completeness:

Vegetation for the entire Coffs Harbour Local Government area has been mapped and every polygon attributed. Non-natural areas devoid of vegetation have not been mapped.

METADATA INFO

Metadata Date: 24/5/12

Appendix 5 Final vegetation community list for the Coffs Harbour LGA vegetation map.

Map code and name of floristic community		Area (ha)
CH_DOF01	Coast and Escarpment Blackbutt Dry Forest	6 809
CH_DOF02	Sandstone Bloodwood - Needlebark Stringybark Heathy Forest	3 382
CH_DOF04	Hinterland Needlebark Stringybark - Scribbly Gum - Red Mahogany Dry Forest	163
CH_DOF05	Foothills Grey Gum - Ironbark - Mahogany Dry Forest	1 998
CH_DOF06	Lowlands Swamp Box - Paperbark - Red Gum Dry Forest	2 013
CH_DOF07	Escarpment New England Blackbutt Dry Forest	37
CH_DOF08	Coastal Sand Bloodwood - Banksia Forest	154
CH_DOF09	Coast Sand Blackbutt - Bloodwood - Apple Forest	334
CH_DOF10	Foothills Spotted Gum Mahogany Grey Gum Ironbark Dry Forest	2 248
CH_DOF11	Northern Escarpment Mahogany Grassy Dry Forest	60
CH_FrW01	Coastal Paperbark Swamp Oak Floodplain Forest	944
CH_FrW02	Coastal Swamp Mahogany Forest	180
CH_FrW03	Coastal Paperbark Bottlebrush Channel Forest	80
CH_FrW04	Coastal Paperbark Sedgeland Dominated Forest	529
CH_FrW05	Coastal Paperbark Swamp Box Littoral Forest	158
CH_FrW06	Coastal Wallum Swamp Mahogany Paperbark Satinwood Forest	131
CH_FrW07	River Oak Riparian Forest of the Orara River Valley	189
CH_FrW08	Plateau Tea-tree Water Gum Riparian Shrubland	387
CH_FrW09	Coastal Wallum Swamp Mahogany Sieber's Paperbark Forest	124
CH_FrW10	Swamp Oak Forested Wetland	202
CH_FrW11	Estuarine Paperbark Twig-rush Forest	87
CH_FW01	Coastal Wallum Teatree Banksia Wet Heathland Shrubland	125
CH_FW02	Coastal Wallum Paperbark Banksia Grass Tree Wet Heathland	290
CH_FW03	Coastal Wallum Slender Twine Rush Sedgeland	33
CH_FW04	Coastal Wallum Baumea Sedgeland	5
CH_FW05	Coastal Wallum Paperbark Wet Shrubland	145
CH_FW06	Coastal Wallum Teatree Tall Wet Shrubland	39
CH_FW07	Coastal Jointed Twig-rush Freshwater Wetland	27
CH_FW08	Coastal Freshwater Wetland	189
CH_FW09	Coastal Wallum Fernland	24
CH_G01	Strandline Grassland	30
CH_G02	Maritime Grasslands - Offshore Islands	8
CH_H01	Coast Banksia Shrubland on Holocene Dunes	404
CH_H02	Coast Wattle Shrublands	273
CH_H03	Kangaroo Grass Headland Grasslands	46

Map code and name of floristic community		Area (ha)
CH_H04	Coastal She-oak Hakea Clay Heathland	62
CH_H05	Coastal Dagger Hakea Clay Heathland	34
CH_H06	Coastal Headland Banksia	46
CH_H07	Coastal Headland Swamp Oak Shrublands	12
CH_H08	Wallum Banksia Black She-oak Shrubland	113
CH_H09	Plateau Teatree Rock Outcrop Shrubland	16
CH_H10	Escarpment Tea-tree Rock Outcrop Shrubland	16
CH_H11	Tall Tea Tree Crabapple Montane Closed Forest	6
CH_RF01	Plateau Beech Cool Temperate Rainforest	1
CH_RF02	Plateau Beech - Coachwood Cool Temperate Rainforest	-
CH_RF03	Plateau and Escarpment Coachwood Sassafras Warm Temperate Rainforest	3 952
CH_RF04	Plateau and Escarpment Hoop Pine Dry Rainforest	54
CH_RF05	Foothills Brown Myrtle Dry Rainforest	340
CH_RF06	Escarpment Grey Mytle Brush Box Dry Rainforest	76
CH_RF07	Coastal Exposed Dune Littoral Rainforest	95
CH_RF08	Headland Brush Box Littoral Rainforest	42
CH_RF09	Hinterland White Booyong Floodplain Rainforest	44
CH_RF11	Escarpment and Lowland Bangalow - Carabeen - Black Booyong Palm Gully Rainforest	4 280
CH_RF12	Escarpment Coachwood - Sassafras - Brush Box Warm Temperate Rainforest	1 679
CH_RF13	Coastal Sheltered Dune Littoral Rainforest	87
CH_SW01	Estuarine Mangrove Forest	146
CH_SW02	Estuarine Twig Rush Saltmarsh	47
CH_SW03	Coastal Dune Sedgeland Soak	11
CH_SW04	Coastal Dune Prickly Couch Grasslands	0.4
CH_SW05	Twig Rush Headland Sedgeland Soaks	4
CH_SW06	Sea Rush Saltmarsh	38
CH_SW07	Estuarine Samphire - Saltwater Couch Saltmarsh	114
CH_WSF01	Coast and Hinterland Riparian Flooded Gum Bangalow Wet Forest	4 748
CH_WSF02	Hinterland Blackbutt - Bangalow - Turpentine Wet Shrubby Tall Forest	3 902
CH_WSF03	Foothills and Escarpment Blue Gum Tallowwood - Turpentine Wet Shrubby Forest	3 525
CH_WSF05	Foothills to Escarpment Brush Box - Tallowwood - Blackbutt Wet Forest	4 774
CH_WSF06	Plateau Blue Gum - Tallowwood - Flooded Gum Wet Shrubby Forest	3 956
CH_WSF07	Plateau and Escarpment Rim Brush Box - Blackbutt Wet Forest	2 158
CH_WSF08	Southern Foothills Blackbutt - Turpentine - Tallowwood Wet Ferny Forest	1 292
CH_WSF09	Northern Escarpment Blackbutt - Apple Wet Ferny Forest	7 716
CH_WSF10	Hinterland and Escarpment Tallowwood - Blackbutt - Blue Gum Wet Ferny Forest	5 035
CH_WSF11	Foothills Spotted Gum - Mahogany - Grey Gum Wet Shrubby Forest	2 631
CH_WSF12	Brush Box Corkwood Forest on Sand	10
CH_WSF13	Dunns White Gum Wet Forest	128
CH_WSF14	Coastal Headland Red Gum Forest	39

Map code and name of floristic community		Area (ha)
CH_WSF15	Foothills Steel Box Brown Myrtle Wet Forest	557
CH_WSF16	Escarpment White Mahogany Wet Shrubby Forest	161
CH_WSF17	Foothills Turpentine - Grey Gum - Ironbark Moist Shrubby Forest	3 053
CH_WSF18	Escarpment New England Blackbutt Wet Ferny Forest	635
CH_EX01	Bitou bush	2
CH_EX02	Camphor laurel	633
CH_EX03	Exotic vegetation	2 576
CH_EX04	Lantana	62
CH_EX05	Privet	13
CH_MV01	Seagrass beds	3
CH_NP01	Acacia pioneers	209
CH_NRV01	Native remnant vegetation	1 456
CH_P01	Plantation - native species	5 938
CH_P02	Plantation - exotic/pine species	357
CH_P03	Environmental plantings	206

Appendix 6 EcoLogical: Map Accuracy Assessment

eco logical AUSTRALIA

Multi-agency Vegetation Mapping Program for Coffs Harbour Local Government Area

Map Accuracy Assessment

Final report prepared for
Coffs Harbour City Council

8h November 2012




DOCUMENT TRACKING

ITEM	DETAIL
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Abbreviations

ABBREVIATION	DESCRIPTION
API	Aerial Photographic Interpretation
CHCC	Coffs Harbour City Council
GPS	Global Positioning System
LGA	Local Government Area
NSW	New South Wales
OEH	Office of Environment and Heritage
PCT	Plant Community Type (vegetation type listed in the NSW VCA)
VCA	Vegetation Classification and Assessment database (a module within the NSW Vegetation Information System

1 Introduction

The NSW Office of Environment and Heritage (OEH) recently completed fine-resolution vegetation mapping within the Coffs Harbour Local Government Area (LGA). This new mapping aims to capture the distribution of vegetation types within the Coffs Harbour LGA using the NSW Native Vegetation Interim Type Standard (Sivertsen 2009). The methodology involves manual (non-automated) on-screen capture of vegetation patterns using aerial photographic interpretation (API), a task performed by experienced photogrammetry officers. The process is supported by 3-dimensional display of ADS-40 ortho-photographic imagery on an ArcGIS platform.

This project aims to assess the accuracy of the new vegetation map across the Coffs Harbour LGA using an approach that adheres to the NSW Vegetation Type Standard (Sivertsen 2009). Broadly, the accuracy assessment involves comparison of mapped vegetation types with classified reference localities obtained through field assessment. The extent to which mapped polygons and field points correspond is a function of the map accuracy.

2 Study Area

The study area covers the Coffs Harbour LGA (Figure 1) which is administered by Coffs Harbour City Council (CHCC). It encompasses 1,174 km^2 on the mid north coast of NSW and is henceforth referred to as “Coffs LGA”.

Figure 1 Study region – Coffs LGA

3 Vegetation classification

A fine-resolution vegetation classification for the Coffs Harbour City Council (CHCC) study area was developed by OEH using a 100 group analysis. This was conducted because the results of the NSW PCT list was not yet available at the commencement of the mapping program. The analysis used a total of 534 full floristic sites from 393 existing sites and 141 additional sites. This classification resulted in a total of 66 unique vegetation types that were used as the basis for API mapping and an additional 14 were identified from API giving a total of 80 CHCC types. Native vegetation types and associated map codes are shown in Table 1.

Table 1. Vegetation types mapped in Coffs LGA

Rainforests

Community Name	MAP CODE
Antarctic Beech - Coachwood Warm/Cool Temperate Rainforest	CH_RF02
Antarctic Beech - Sassafras Cool Temperate Rainforest	CH_RF01
Brown Myrtle Dry Rainforest of Creeklines and Sheltered Slopes of the Bagawa Range and Madmans Creek	CH_RF05
Brush Box Littoral Rainforest on Headlands	CH_RF08
Coachwood - Callicoma - Sassafras - Hoop Pine Warm Temperate Rainforest	CH_RF03
Coachwood - Sassafras - Prickly Ash - Brush Box Warm Temperate Rainforest of the Dorrigo Escarpment	CH_RF12
Grey Myrtle - Brush Box Dry Rainforest	CH_RF06
Hoop Pine Dry Rainforest of steep slopes in the Little Nymboida River, Mt Coramba and Woolgoolga areas	CH_RF04
Small-leaved Lilly Pilly - Pear-fruited Tamarind Sheltered Littoral Rainforest	CH_RF13
Tuckeroo - Beach Bird's Eye Exposed Littoral Rainforest	CH_RF07
White Booyong - Maidens Blush Riparian Rainforest on Floodplains	CH_RF09
Yellow Carabeen - Black Booyong - Maidens Blush - Bangalow Palm Subtropical Lowland Rainforest	CH_RF11

Wet sclerophyll forests

Community Name	MAP CODE
Blackbutt - Bangalow Palm -Turpentine Sheltered Wet Shrubby Forest of the Escarpment Hills	CH_WSF02
Blackbutt – Smooth-barked Apple - Rose Myrtle Ferny Forest of escarpment and hinterland metasedimentary hills	CH_WSF09
Blackbutt - Turpentine - Tallowwood - Forest Oak Grassy Ferny Forest of southern foothills on metasediments	CH_WSF08
Brush Box - Blackbutt Wet Forest to Warm Temperate Rainforest of exposed ridges and slopes of the plateau and escarpment rim	CH_WSF07
Brush Box - Corkwood - Open Forest on Sand	CH_WSF12

Wet sclerophyll forests (cont'd)

Community Name	MAP CODE
Brush Box - Tallowwood - Blackbutt - Flooded Gum Wet Shrubby Forest of sheltered gully heads and slopes on metasedimentary geology	CH_WSF05
Dunn's White Gum Tall Wet Forest of Creeklines and Lower Slopes of the Moleton and Little Nymboida Hills	CH_WSF13
Flooded Gum - Bangalow Palm Riparian Forest of Coastal and Hinterland Floodplains	CH_WSF01
Flooded Gum - Tallowwood - Brush Box Wet Shrubby Forest of metasedimentary foothills	CH_WSF04
Forest Red Gum Wet Open Forest to Woodland on Metasedimentary Headlands	CH_WSF14
New England Blackbutt-Blackbutt - Smooth-barked Apple Tall Forest of the Orara and Dorrigo Escarpment	CH_WSF18
Spotted Gum - White Mahogany - Small-fruited Grey Gum Wet Shrubby Forest on metasediments and conglomerate of the Bagawa Range and Madmans Creek Hills	CH_WSF11
Steel Box - Grey Gum - Brown Myrtle Wet Forest of the Bagawa Range and Madmans Creek	CH_WSF15
Sydney Blue Gum - Tallowwood Wet Shrubby Forest on sheltered metasedimentary hills of the Eastern Dorrigo Plateau	CH_WSF06
Tallowwood - Blackbutt - Sydney Blue Gum Ferny Wet Forest of the Plateau Escarpment and Coastal Foothills	CH_WSF10
Turpentine - Sydney Blue Gum -Tallowwood Sheltered Wet Shrubby Forest of Metasedimentary Hinterland Foothills and Escarpment	CH_WSF03
Turpentine - Tallowwood - Small-fruited Grey Gum - Grey Ironbark - White Mahogany Wet Shrubby Forest	CH_WSF17
White Mahogany Moist Shrubby Forest of steep sheltered slopes of the Little Nymboida River Valley	CH_WSF16

Dry sclerophyll forests

Community Name	MAP CODE
Blackbutt - Turpentine - Pink Bloodwood Grassy Dry Open to Tall Open Forest	CH_DOF01
Needlebark Stringybark - Scribbly Gum – Red Mahogany Dry Open Forest on gentle slopes on clay and sandy riparian creek lines	CH_DOF04
New England Blackbutt - Blackbutt - Thick-leaved Mahogany Dry Tall Forest of the Orara Escarpment	CH_DOF07
Pink Bloodwood - Blackbutt - Smooth-barked Apple Dry to Tall Open Forest on Sand	CH_D0F09
Pink Bloodwood - Coast Banksia Shrubby Dry Open Forest on Holocene Dunes	CH_D0F08
Red Bloodwood - Needlebark Stringybark Heathy Dry Open Forest on sandstone and conglomerate	CH_DOF02
Small-fruited Grey Gum - Grey Ironbark - Thick-leaved Mahogany - Tallowwood Grassy Dry Open Forest of ridges and exposed slopes on metasediments	CH_DOF05
Spotted Gum - Thick-leaved Mahogany - Small-fruited Grey Gum - Grey Ironbark Grassy Dry Open Forest of coastal foothills on exposed aspects on sediments and metasediments	CH_DOF10
Swamp Box - Broad-leaved Paperbark - Forest Red Gum - Red Mahogany Transitional Dry Open Forest of Coastal Lowlands and Valleys	CH_DOF06
Thick-leaved Mahogany Grassy Dry Open Forest of exposed slopes on shallow meta-sedimentary soils of the Little Nymboida River	CH_DOF11

Forested wetlands

Community Name	MAP CODE
Broad-leaved Paperbark - Swamp Box Tall Forest with Littoral Rainforest Elements on Hind Dunes	CH_FrW05
Broad-leaved Paperbark - Swamp Oak - Willow Bottle Brush Forested Wetland on Floodplain	CH_FrW01
Broad-leaved Paperbark - Twigrush Saline Swamp Forest	CH_FrW11
Broad-leaved Paperbark - Willow Bottlebrush Channel Forested Wetland of near coastal creeks	CH_FrW03
Broad-leaved Paperbark Sedge Forested Wetland of drainage lines	CH_FrW04
River Oak Riparian Forest of the Orara River Valley	CH_FrW07
Swamp Mahogany - Broad-leaved Paperbark - Satinwood - Tassell Rush Wallum Swamp Sclerophyll Shrubland to Open Forest on poorly drained sandy soils	CH_FrW06
Swamp Mahogany - Prickly-leaved Paperbark Forested Wetland on Sandy Soils	CH_FrW09
Swamp Mahogany - Willow Bottlebrush Forested Wetland of coastal creeks	CH_FrW02
Swamp Oak - Sea Rush Saline Swamp Forest	CH_FrW10
Teatree - Water Gum Riparian Shrubland of the Eastern Dorrigo Plateau of the Bobo and Little Nymboida River Valleys	CH_FrW08

Freshwater wetlands

Community Name	MAP CODE
Baumea rubiginosa - Lepyrodia scariosa Wallum Sedgeland of Coastal Sandplains	CH_FW04
Coral Fern - Saw Sedge - Freshwater Wetland	CH_FW09
Jointed Twig-rush Freshwater Wetland	CH_FW07
Leptocarpus tenax Wallum Sedgeland of Coastal sandplains	CH_FW03
Prickly-leaved Paperbark - Fern-leaved Banksia - Swamp Grasstree Wet Heathland of Coastal Sandplains	CH_FW02
Sieber's Paperbark - Prickly-leaved Paperbark- Wallum Heathland to Tall Shrubland of Coastal Sandplains	CH_FW05
Spike Rush - Broadleaf Cumbungi Freshwater Wetland	CH_FW08
Tantoon Tea-tree - Whites Tea-tree Tall Shrubland of Coastal Sandplains	CH_FW06
Whites Tea-tree - Olive Tea-tree - Fern-leaved Banksia Wet Heathland to Shrubland of Coastal Sandplains	CH_FW01

Saline wetlands

Community Name	MAP CODE
Club Rush Dune Soak	CH_SW03
Prickly Couch - Blue Couch Grassland/Saltmarsh of intermittent coastal lakes and lagoons	CH_SW04
River Mangrove - Grey Mangrove Riparian Estuarine Forest	CH_SW01
Samphire - Saltwater Couch Saltmarsh	CH_SW07
Sea Rush Saltmarsh	CH_SW06
Twig Rush Saltmarsh	CH_SW02
Twig Rush Sedgeland Soaks on Headlands	CH_SW05

Heathlands

Community Name	MAP CODE
Black She-oak - Hakea laevipes subsp. laevipes - Horned Sedge Clay Heathland	CH_H04
Coast Banksia Shrubland on Headlands	CH_H06
Coast Banksia Shrubland to Open Forest on Holocene Dunes	CH_H01
Coast Wattle Shrubland of Holocene Dunes	CH_H02
Dagger Hakea Clay Heathland	CH_H05
Grey gum - White Mahogany- Tea-tree Open Woodland on Rocky Outcrops Tea Tree Rock Outcrop Shrubland of the Orara Escarpment with emergent Grey Gum and Mahogany	CH_H10
Kangaroo Grass Headland Grassland	CH_H03
New England Tea-tree Open Shrubland on Rocky Outcrops of the Dorrigo Escarpment	CH_H09
Swamp Oak- Broad-leaved Paperbark Low Closed Shrubland on Headlands	CH_H07
Wallum Banksia - Black She-oak Dry Heath to Shrubland of Pleistocene dunes	CH_H08

Grasslands

Community Name	MAP CODE
Maritime Grasslands of Offshore Islands	CH_G02
Strandline Grassland	CH_G01

4 Methods

4.1 BACKGROUND

The methods used for accuracy assessment of mapping in the Coffs LGA were developed in accordance with Chapter 10 "Accuracy Assessment" of the Standards (Sivertsen 2009) to enable appropriate statistical analysis. It included three basic components:

1. **Sample design** - the method by which sample units (field points) were selected;
2. **Response design** – protocols used for capturing field data associated with the sampling unit, and rules for labelling each sampling unit with a 'degree of correctness'.
3. **Analysis and estimation** – the mathematic approach used to determine the overall level of accuracy of the map product, reported as a percentage.

4.2 SAMPLE DESIGN

A 'blind' vegetation map[1], constituting the final line work assigned with numeric map units 1 to 80 was provided by OEH for undertaking site selection. A proportional sampling design was then employed in the office in which field sites were pre-selected, guided by the following rules:

- Number of field plots for each map unit linked to the total area of the map unit:
  - minimum of 3 plots per map unit;
  - 4 plots for maps units with a combined area of 100 – 1,000 ha;
  - 5 plots for maps units with a combined area of 1,000 – 5,000 ha;
  - 6 plots for map units with a combined area > 5,000 ha.
- target of 100 plots on private land, the remainder on public land;
- plots not to be located within 100 m of an existing full-floristic or rapid vegetation plot;
- sample relatively accessible areas only.

---

[1] A 'blind' map does not include vegetation descriptors, so that OEH's attribution of plant communities to individual polygons could not influence the assessment of the plant community in the field by the ecologist conducting the field validation.

4.3 RESPONSE DESIGN

4.3.1 Field assessment

Field reconnaissance for the Coffs LGA was undertaken by Senior Botanists Phil Gilmour and Lachlan Copeland over three months commencing June 2012. It involved driving as close as possible to each pre-selected site, then locating a plot on foot with assistance of a Global Positioning System (GPS) to the pre-programmed waypoints. The validation plot was selected within a typical part of the target polygon (avoiding ecotones or atypical areas) as an area within a 15 m radius of the chosen point (approximately 175 m^2). A number of pre-selected plots for which access was initially sought were not able to be accessed due to landholder objections. Where possible these were replaced with alternative sites.

A field validation proforma was provided by OEH for this project (Appendix A) onto which the following field attributes were recorded:

- SiteID
- Date
- Observer
- Coordinates
- Photo Number
- Location description
- Topographic position
- Exposure class
- Geology (if known)
- Disturbance type
- Disturbance intensity
- Disturbance history
- Structural Class (m)
- Five dominant species and stratum cover % in the canopy (if present)
- Five dominant species and stratum cover % in the upper storey (if present)
- Five dominant species and stratum cover % in mid layer 1 (if present)
- Five dominant species and stratum cover % in the mid layer 2 (if present)
- Five dominant species and stratum cover % in the lower layer 1 (if present)
- Five dominant species and stratum cover % in the lower layer 2 (if present)
- Vegetation community type
- Vegetation community score (5-1)

Field attributes recorded at each validation plot were entered into the YETI database.

4.3.2 Degree of Correctness

A key part of fieldwork was to record the 'level of correctness' of the vegetation community sampled in the field to each of the vegetation types provided by OEH (Table 1). The following codes were applied to each vegetation type at each plot (from Woodcock and Gopal 2000):

1. Absolutely wrong

   Match is completely wrong and absolutely unacceptable

2. Understandable but wrong

   Something that makes the match understandable, but there are much better options and the match is wrong

3. Reasonable/acceptable

   Probably not the best possible match, but it is acceptable, as it does not pose a problem to the user when interpreting the map

4. Mostly correct

   User would be happy with this match

5. Absolutely right

   No doubt about the match – a perfect fit

These data were entered into a MS Access database and exported into Excel as a crosstab table.

4.4 ANALYSIS AND ESTIMATION

4.4.1 Background

The approach used in this assessment is based on fuzzy set theory and thematic mapping as outlined in Gopal and Woodcock (1994) and Woodcock and Gopal (2000). Fuzzy set theory enables thematic maps to be treated as a continuum of classes rather than a set of distinctive classes, and thus allows for assessment of the magnitude of error as part of map accuracy.

4.4.2 Data Preparation

On completion of field assessment, the final vegetation map including type attribution was provided by OEH.

GPS co-ordinates of the validation field plots were intersected with the vegetation polygons in ArcMap to enable assignment of the mapped vegetation units to each site recorded in the field.

4.4.3 Data Analysis

An analysis file was developed for this project in Microsoft Excel, named "Coffs_Accuracy_Assessment_ Final.xls". Data analysis involved comparison of mapped vegetation units with vegetation types observed in the field, and was facilitated using three tools: the 'Max' function, the "Right' function, the confusion matrix and the "Difference" function (Woodcock and Gopal 2000).

The **'Max' function** was used to return a "match" where the most correct (or equally most correct) vegetation type recorded at the plot corresponded with the mapped vegetation type (or in the case of a mosaic polygon, one of the mapped vegetation types) within which the plot was located. This suggested that the attribution of the polygon was "absolutely right". Conversely, a "mismatch' was returned where the most correct (or equally most correct) vegetation type recorded at the plot did *not* correspond with the mapped vegetation type within which the plot was located.

The **'Right' function** was employed to measure the overall accuracy of the map by returning a "match" for each field plot where the mapped vegetation type (or in the case of a mosaic polygon, one of the mapped vegetation types) within which the plot was located was equivalent to a vegetation type identified as being either 'absolutely right', 'mostly correct' or 'reasonable/ acceptable' in the degree of correctness table (section 4.2.3).

A **confusion matrix** was developed that summarised key information obtained from the sampling and response designs, where each row and column represented a unique CHCC vegetation type (79 in total). Each cell in the confusion matrix was assigned a value that represented the number of times a vegetation type allocated "maximum" within a field plot (column) corresponded with a vegetation unit mapped by OEH (row). This approach to accuracy assessment was most stringent because any cell value in the matrix that contributed to the accuracy score was reduced if more than one vegetation type was assigned the 'maximum value' in the field plot (e.g. if three equally most correct vegetation types were assigned in the field, one of which matched the mapped vegetation type, then the cell score would be 0.33 rather than 1.00).

The ideal situation in map accuracy is where only the diagonal line in the confusion matrix (top left to bottom right) contains non-zero values. In this case the most correct (or equally most correct) vegetation community sampled at each plot would represent the respective map unit within which the plot was located. The confusion matrix was created as a separate worksheet in the final analysis file "Coffs_Accuracy_Assessment_Final.xlsx"

The **'Difference' function** was used to assess the overall 'magnitude of error' of the map product. A 'Difference' value was determined for each plot as the difference between the score assigned to the mapped community (1 to 5) and the highest score assigned to all other communities (1 to 5). The highest 'Difference' value (4) was assigned to plots in which the mapped vegetation community was absolutely right and all other communities in the 'degree of correctness' table were absolutely wrong; conversely the lowest 'Difference' value (-4) was assigned to plots in which the mapped vegetation community was absolutely wrong and at least one community in the 'degree of correctness' table was absolutely right.

The 'Difference' value for each mapped community was tallied using a crosstab query in MS Access. A resultant matrix was derived that showed the number of plots in each mapped vegetation community and the plots' corresponding 'Difference' score. From this an 'arithmetic mean' was calculated indicating the 'magnitude of error' of each mapped community.

5 Results

5.1 RESPONSE DESIGN

5.1.1 Field assessment

A total of 279 plots were completed for this accuracy assessment. A number of plots that were identified for visitation on private lands were not able to be accessed at the time of survey, and these were replaced where possible. The number of plots sampled in different structural formations (according to OEH mapping), in private and public land, is shown in Table 2. The location of sites is illustrated in Figure 2.

Table 2. Number of plots by structural formation (as mapped by OEH) and land tenure

	Tenure		
Formation	Public	Private	**Total**
Rainforest	32	8	**40**
Wet sclerophyll forest	39	36	**75**
Dry open forest	28	9	**37**
Forested wetland	21	8	**29**
Freshwater wetland	32	10	**42**
Saline wetland	15	2	**17**
Heathland	29	2	**31**
Grassland	6	0	**6**
Other	1	1	**2**
Total	**203**	**76**	**279**

5.1.2 Degree of Correctness

For each field plot, a sub set of 'correct' vegetation communities was identified and assigned its appropriate level of correctness of '3' (acceptable), '4' (right) or '5' (absolutely right). A default correctness value of '1' (absolutely wrong) was then uniformly applied to all other non-conforming communities (i.e. those not considered to be either 3, 4 or 5). Due to the large number of plots sampled and the large number of vegetation types for which level of correctness was required, upgrade from '1' (absolutely wrong) to '2' (understandable but wrong) was not systematically carried out within the correctness matrix.

Figure 3 summarises the level of correctness of the CHCC vegetation classification according to the field assessment. Of the 279 plots sampled, only 1 plot contained vegetation that was not able to be allocated to a CHCC vegetation community with an accuracy of more than 2 (understandable but wrong). Of the remaining 278 plots, 26% were assigned to one or more CHCC vegetation types with a correction level of 5 (absolutely right) and 54% were assigned to one or more CHCC vegetation types with a correction level of 4 (mostly right). In summary, the CHCC classification is reasonably strongly representative of the field plots that were sampled.

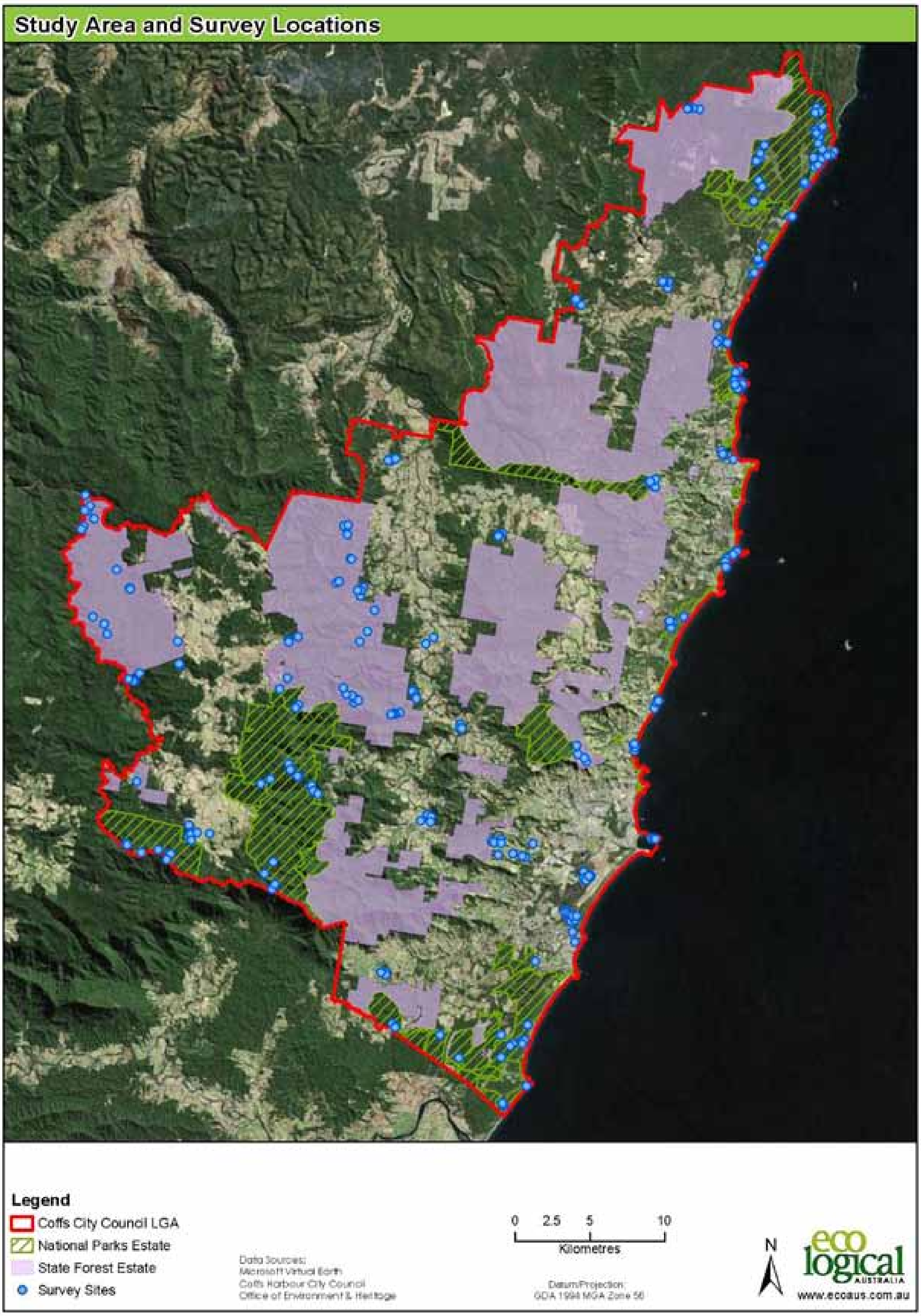

Figure 2 Survey locations across the Coffs LGA

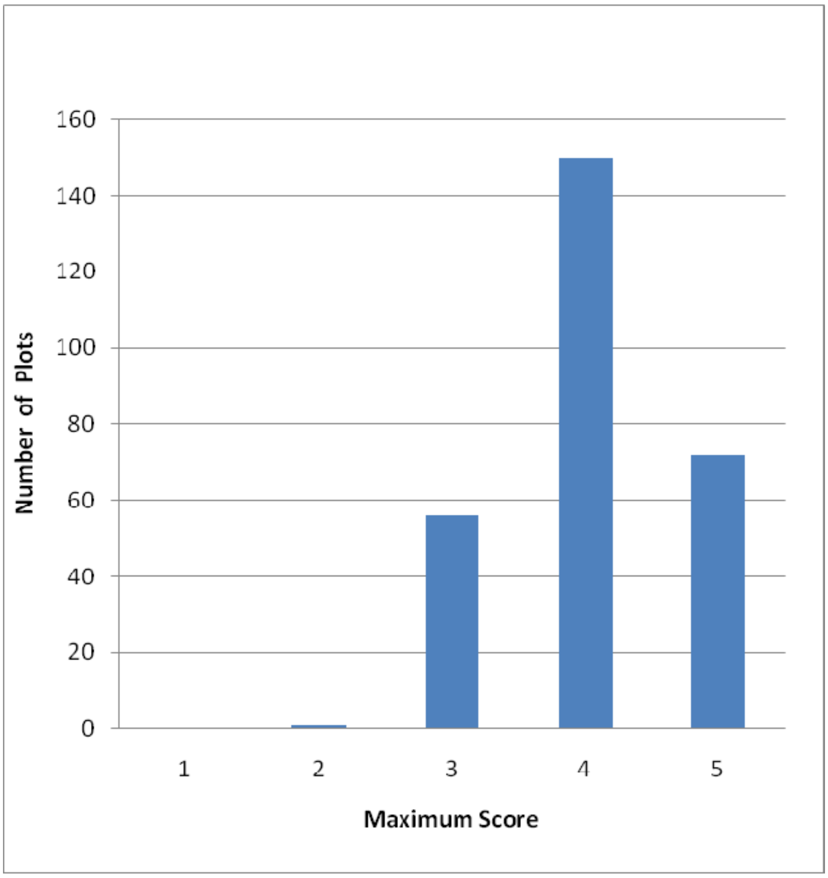

Figure 3. Summary of vegetation classification correctness

5.1.3 Data analysis

A summary of the main analysis for this project that includes application of the "Max", "Right" and "Difference" commands is shown in Appendix B.. Application of the "Max" function found that 141 of the 279 plots (50.5%) were located in a map unit that matched the most correct vegetation type (or equally most correct type) associated with the plot. Application of the "Right" function found that 185 of the 279 plots (66.3%) were located in a map unit that matched a vegetation type that was classed as "correct" in the field (i.e. factor of 3, 4 or 5), but was not necessarily the *most* correct type.

Using the "Right" command as the basis for accuracy, the overall level of *attributional* accuracy for the CHCC map product was 66%. An area-weighted application of the "Right" command resulted in an overall level of *spatial* accuracy of 62%, slightly less than the attributional accuracy of 66%. This is because, as a general trend, the more extensively mapped vegetation types had lower accuracy than the more confined types.

Analysis of accuracy by broad tenure found that mapping within private lands was lower (53%) than mapping in public lands (71%). Analysis of map accuracy by vegetation formation revealed that accuracy varied from 100% to less than 60%, with the following attributional accuracies observed:

other types = 100%	grassland types = 67%	freshwater wetland types = 62%
heathland types = 87%	dry open forest types = 65%	rainforest types = 60%
saline wetland types = 82%	wet sclerophyll forest types = 63%	forested wetland types = 59%

Individual correctness scores listed in Appendix B are shown as a 'magnitude of error' in Table 3 for each map unit (or vegetation type), where 4.0 is the optimum score (completely right) and -4.0 is the worst score (completely wrong). Given that most types only had 3 or 4 plots completed, interpretation of results on a type by type basis needs to be taken with a level of caution.

Table 3. Magnitude of error table

Community	# Plots	Mismatches				Matches					Arithmetic Mean
		-4	-3	-2	-1	0	1	2	3	4	
CH_DOF01	8	1	1	1	3	0	2	0	0	0	-1.3
CH_DOF02	4	1	0	0	0	2	0	1	0	0	-0.5
CH_DOF04	2	0	0	1	1	0	0	0	0	0	-1.5
CH_DOF05	3	0	0	1	0	0	1	1	0	0	0.3
CH_DOF06	3	0	2	1	0	0	0	0	0	0	-2.7
CH_DOF07	3	1	1	0	0	0	1	0	0	0	-2.0
CH_DOF08	4	0	0	0	1	1	1	1	0	0	0.5
CH_DOF09	4	0	0	0	0	1	2	0	0	1	1.5
CH_DOF10	4	0	2	0	1	0	1	0	0	0	-1.5
CH_DOF11	2	0	0	0	0	0	0	2	0	0	2.0
CH_FrW01	4	0	1	2	1	0	0	0	0	0	-2.0
CH_FrW02	4	0	0	0	1	2	1	0	0	0	0.0
CH_FrW03	3	0	0	1	0	0	0	2	0	0	0.7
CH_FrW04	4	0	1	0	0	3	0	0	0	0	-0.8
CH_FrW05	4	0	1	1	1	0	1	0	0	0	-1.3
CH_FrW06	3	0	0	0	1	0	1	1	0	0	0.7
CH_FrW07	4	1	0	0	0	1	0	0	1	1	0.8
CH_FrW08	4	0	1	1	0	0	1	0	0	1	0.0
CH_FrW09	4	0	0	3	0	0	0	1	0	0	-1.0
CH_FrW10	5	0	0	1	1	2	0	0	0	1	0.2
CH_FrW11	3	0	2	0	0	0	1	0	0	0	-1.7
CH_FW01	4	0	0	2	0	1	0	1	0	0	-0.5
CH_FW02	4	1	0	3	0	0	0	0	0	0	-2.5
CH_FW03	3	0	1	0	1	0	1	0	0	0	-1.0
CH_FW04	1	0	0	1	0	0	0	0	0	0	-2.0
CH_FW05	5	1	0	3	1	0	0	0	0	0	-2.2
CH_FW06	3	0	0	1	0	0	1	1	0	0	0.3
CH_FW07	3	0	0	0	0	0	0	0	0	3	4.0
CH_FW08	3	0	0	0	0	0	0	0	0	3	4.0
CH_FW09	3	0	0	0	0	1	0	2	0	0	1.3
CH_G01	3	0	0	0	0	1	1	0	1	0	1.3
CH_G02	3	0	0	2	0	0	0	0	0	1	0.0
CH_H01	5	0	0	0	1	0	1	2	1	0	1.4
CH_H02	3	0	0	0	0	0	0	1	2	0	2.7
CH_H03	3	0	0	1	0	0	0	0	0	2	2.0
CH_H04	3	0	0	1	1	1	0	0	0	0	-1.0
CH_H05	4	0	0	0	0	1	1	1	0	1	1.8

Community	# Plots	Mismatches				Matches					Arithmetic Mean
		-4	-3	-2	-1	0	1	2	3	4	
CH_H06	4	0	1	0	0	1	1	0	0	1	0.5
CH_H07	1	0	0	0	0	0	0	0	1	0	3.0
CH_H08	3	0	0	0	0	0	0	0	2	1	3.3
CH_H09	2	0	1	0	0	0	0	0	0	1	0.5
CH_H10	3	0	0	0	0	1	0	2	0	0	1.3
CH_NRV01	1	0	0	0	0	0	1	0	0	0	1.0
CH_P03	1	0	0	0	0	0	0	1	0	0	2.0
CH_RF01	3	1	1	1	0	0	0	0	0	0	-3.0
CH_RF02	4	3	0	0	1	0	0	0	0	0	-3.3
CH_RF03	4	0	1	0	1	0	0	1	0	1	0.5
CH_RF04	2	0	0	0	0	2	0	0	0	0	0.0
CH_RF05	3	0	1	0	1	0	0	0	1	0	-0.3
CH_RF06	1	0	0	0	0	1	0	0	0	0	0.0
CH_RF07	4	0	0	1	0	2	0	1	0	0	0.0
CH_RF08	3	0	0	0	0	1	1	1	0	0	1.0
CH_RF09	3	0	1	0	0	0	0	1	0	1	1.0
CH_RF11	5	0	1	0	1	1	2	0	0	0	-0.4
CH_RF12	5	2	0	0	3	0	0	0	0	0	-2.2
CH_RF13	3	0	2	0	1	0	0	0	0	0	-2.3
CH_SW01	4	0	1	0	0	0	0	0	0	3	2.3
CH_SW02	3	0	0	0	2	0	1	0	0	0	-0.3
CH_SW03	3	0	1	0	1	1	0	0	0	0	-1.3
CH_SW06	3	0	0	0	0	0	1	1	1	0	2.0
CH_SW07	4	0	0	0	1	0	0	0	2	1	2.3
CH_WSF01	6	0	2	0	1	2	1	0	0	0	-1.0
CH_WSF02	4	0	1	0	1	1	1	0	0	0	-0.8
CH_WSF03	5	0	1	0	0	2	2	0	0	0	-0.2
CH_WSF05	9	0	2	2	2	2	1	0	0	0	-1.2
CH_WSF06	4	0	0	0	2	1	1	0	0	0	-0.3
CH_WSF07	4	0	0	0	2	1	1	0	0	0	-0.3
CH_WSF08	5	0	0	0	2	0	2	1	0	0	0.4
CH_WSF09	7	0	3	0	2	0	1	1	0	0	-1.1
CH_WSF10	8	1	3	1	0	1	2	0	0	0	-1.6
CH_WSF11	2	0	1	1	0	0	0	0	0	0	-2.5
CH_WSF13	3	0	2	0	0	0	0	0	0	1	-0.7
CH_WSF14	3	0	0	1	0	0	0	1	0	1	1.3
CH_WSF15	3	0	2	0	1	0	0	0	0	0	-2.3
CH_WSF16	3	0	1	0	2	0	0	0	0	0	-1.7
CH_WSF17	5	0	1	1	1	1	0	1	0	0	-0.8
CH_WSF18	4	0	0	0	2	1	1	0	0	0	-0.3
Total	279	13	43	35	45	39	38	29	12	25	-0.2

5.1.4 Confusion matrix

For this project the confusion matrix was used to derive a level of 'user accuracy' for each map unit that was influenced by:

- the proportion of plots located in a map unit in which the most correct vegetation type matched the map unit; and
- whether any other vegetation type(s) associated with those plots were equally as correct, but did *not* match the map unit.

This metric of accuracy is more stringent in that it only allows a match with the best fit community (i.e. same as the "Max" function), but it also reduces accuracy based on the fuzziness of the vegetation classification, when two or more vegetation communities are assigned the highest level of correctness in the field, but only one matches the map unit. The overall level of accuracy of the vegetation map, based on results of the confusion matrix, was 43.6% (refer to the file Coffs_Accuracy_Assessment_final.xlsx that accompanies this report for a digital version of the confusion matrix).

Table 4 compares the three reported levels of map accuracy (confusion matrix vs. "Max" vs. "Right") for each of the vegetation types, and collectively. This table can be used to assess which map units have been confidently mapped and which have not.

Table 4. Comparison of "Max" and "Right" scores with user accuracy from the confusion matrix

		Accuracy (%)		
Map Unit (Vegetation Type)	No plots	User accuracy (from confusion matrix)	Exact match (from "Max command)	Correct match (from "Right" command)
CH_DOF01	8	25.0	25.0	62.5
CH_DOF02	4	50.0	75.0	75.0
CH_DOF04	2	0.0	0.0	50.0
CH_DOF05	3	66.7	66.7	66.7
CH_DOF06	3	0.0	0.0	0.0
CH_DOF07	3	33.3	33.3	33.3
CH_DOF08	4	62.5	75.0	100.0
CH_DOF09	4	87.5	100.0	100.0
CH_DOF10	4	25.0	25.0	50.0
CH_DOF11	2	100.0	100.0	100.0
CH_FrW01	4	0.0	0.0	25.0
CH_FrW02	4	45.8	75.0	100.0
CH_FrW03	3	66.7	66.7	66.7
CH_FrW04	4	37.5	75.0	75.0
CH_FrW05	4	25.0	25.0	50.0
CH_FrW06	3	66.7	66.7	100.0
CH_FrW07	4	62.5	75.0	75.0
CH_FrW08	4	50.0	50.0	50.0
CH_FrW09	4	25.0	25.0	25.0

		Accuracy (%)		
Map Unit (Vegetation Type)	No plots	User accuracy (from confusion matrix)	Exact match (from "Max command)	Correct match (from "Right" command)
CH_FrW10	5	31.7	60.0	80.0
CH_FrW11	3	33.3	33.3	33.3
CH_FW01	4	37.5	50.0	50.0
CH_FW02	4	0.0	0.0	0.0
CH_FW03	3	33.3	33.3	66.7
CH_FW04	1	0.0	0.0	0.0
CH_FW05	5	0.0	0.0	20.0
CH_FW06	3	66.7	66.7	100.0
CH_FW07	3	100.0	100.0	100.0
CH_FW08	3	100.0	100.0	100.0
CH_FW09	3	83.3	100.0	100.0
CH_G01	3	83.3	100.0	100.0
CH_G02	3	33.3	33.3	33.3
CH_H01	5	80.0	80.0	100.0
CH_H02	3	100.0	100.0	100.0
CH_H03	3	66.7	66.7	66.7
CH_H04	3	16.7	33.3	66.7
CH_H05	4	83.3	100.0	100.0
CH_H06	4	58.3	75.0	75.0
CH_H07	1	100.0	100.0	100.0
CH_H08	3	100.0	100.0	100.0
CH_H09	2	50.0	50.0	50.0
CH_H10	3	83.3	100.0	100.0
CH_NRV01	1	100.0	100.0	100.0
CH_P03	1	100.0	100.0	100.0
CH_RF01	3	0.0	0.0	0.0
CH_RF02	4	0.0	0.0	0.0
CH_RF03	4	50.0	50,0	75.0
CH_RF04	2	50.0	100.0	100.0
CH_RF05	3	33.3	33.3	66.7
CH_RF06	1	50.0	100.0	100.0
CH_RF07	4	43.8	75.0	75.0
CH_RF08	3	77.8	100.0	100.0
CH_RF09	3	66.7	66.7	66.7
CH_RF11	5	40.0	60.0	80.0
CH_RF12	5	0.0	0.0	60.0
CH_RF13	3	0.0	0.0	33.3
CH_SW01	4	75.0	75.0	75.0
CH_SW02	3	33.3	33.3	100.0
CH_SW03	3	16.7	33.3	33.3
CH_SW06	3	100.0	100.0	100.0
CH_SW07	4	75.0	75.0	100.0

		Accuracy (%)		
Map Unit (Vegetation Type)	No plots	User accuracy (from confusion matrix)	Exact match (from "Max command)	Correct match (from "Right" command)
CH_WSF01	6	30.6	50.0	66.7
CH_WSF02	4	50.0	50.0	75.0
CH_WSF03	5	56.7	80.0	80.0
CH_WSF05	9	22.2	33.3	55.6
CH_WSF06	4	37.5	50.0	100.0
CH_WSF07	4	37.5	50.0	100.0
CH_WSF08	5	60.0	60.0	100.0
CH_WSF09	7	28.6	28.6	57.1
CH_WSF10	8	29.2	37.5	37.5
CH_WSF11	2	0.0	0.0	0.0
CH_WSF13	3	33.3	33.3	33.3
CH_WSF14	3	66.7	66.7	66.7
CH_WSF15	3	0.0	0.0	0.0
CH_WSF16	3	0.0	0.0	66,7
CH_WSF17	5	30.0	40.0	60.0
CH_WSF18	4	37.5	50.0	100.0
ALL	**279**	**43.6**	**50.5**	**66.3**

6 Discussion

The accuracy assessment undertaken in this report finds the following in relation to the accuracy of the CHCC vegetation map for Coffs LGA:

1. **An overall *attributional* map accuracy of 66%** from application of the "Right" command (where a vegetation type recorded as 3, 4 or 5 in a field plot matched the vegetation type(s) recorded in the map unit within which the plot was located). This value (66%) should be used as the basis of reporting accuracy in relation to the CHCC map.

2. An overall *spatial* map accuracy of 62% from area-weighted application of the "Right" command.

3. An exact match for 51% of plots (where the most correct type or one of the most correct types recorded at a field plot match the/a vegetation type recorded within the map unit within which the plot was located).

4. A 'fuzzy' accuracy of 44% from application of the confusion matrix, in which results of the exact match assessment (51%) are weighted down by fuzziness in the vegetation classification (i.e. where some equally as correct vegetation types did *not* match the map unit). This measure of accuracy is useful for establishing the complexity of the vegetation classification adopted (in this case, relatively complex).

The 66% level of map accuracy obtained in this analysis using the "Right" algorithm is considered a reasonable result given the fineness of resolution of the vegetation classification to which mapping was undertaken. Consideration of the fuzziness of the vegetation classification[2] through application of the confusion matrix provides lesser confidence in product accuracy, as in many cases non-matched vegetation types could be equally as correct as matched vegetation types. However, the limitation of applying a fuzzy rather than binary dataset to the confusion matrix, particularly in relation to multiple vegetation types (mapped and surveyed), is acknowledged.

Some general findings were that cool temperate rainforest types (CH_RF01 and CHRF-02) were over-mapped along the ranges, and that forest types had relatively lower accuracy than non-forest types. Mapping of some eucalypt forest types such as CH_DOF06, CH_WSF11, CH_WSF15 and CH_FW02 need reviewing.

Map accuracy would be improved by simplifying the vegetation classification so that it better services the mapping process (yet still addresses community needs for a regional scale map). A glance through the list of vegetation types in Table 1 shows that within (and even between) broad forest formations,

[2] only 26% of plots were able to be assigned a single, absolutely right type, while 54% were able to be assigned one or more 'almost right' types and 20% were able to be assigned one or more 'acceptable' types

many are floristically similar in the canopy and occupy the same or overlapping geographic areas[3]. Where floristic separation of these communities is driven foremost by understorey plants that are difficult (if not impossible) to separate using API (interpretation is drive by the canopy floristic, not understorey floristic), there is good reason to amalgamate them for the purpose of mapping, if there is no specific requirement to otherwise retain them. A key output of the original floristic analysis, the dendrogram, might greatly assist in the lumping up of similar types for the purpose of mapping.

Reduction in the number of map units will have a number of other benefits, as well as improving map accuracy:

1. It will reduce significantly the cost of mapping. For example, a halving the number of map units from 80 to 40 in the Coffs LGA would result in an approximate 4-fold reduction in the complexity of the map line work, but still retain ecological diversity to level that satisfies constructive conservation and management objectives.

2. It will reduce significantly the complexity of the accuracy assessment. Providing fewer vegetation types thus clearer separation between types will provide an opportunity to better replicate plots within types, and to reduce overall fuzziness of the dataset.

3. It will encourage uptake and application by the local community. The major users of regional vegetation maps are local councils, NRM bodies and the farming community. The more complex the classification and line work, the less likely it is to be understood by people who require it the most, and the more cynical users may become about it (particularly if accuracy is poor in places). Major users need to be familiar with the characteristics of mapping units that are contained on a regional vegetation map, and on their properties. Even if fine-resolution types are available as part of the mapped product, for some audiences it may be better to present broader level types within an established vegetation hierarchy.

Any effort to map to Level 5 in future should be targeted and should take place at local scale, supported by comprehensive ground reconnaissance. The often diffuse boundaries between similar vegetation types means that physically walking the ecotone may be required in some instances to adequately plot, define and map the boundary. Targeted local mapping can readily feed into a regional map product.

[3] For example, the number of forested wetlands seems excessive

7 Recommendations

The following are recommended for consideration by OEH and Coffs Harbour City Council.

Recommendation 1 – Define a list of broader mapping units for regional mapping

A set of broader map units should be derived from the current CHCC classification in Coffs LGA (facilitated by expert interpretation of the dendrogram). It is strongly suggested that no more than 40 – 50 types be defined in Coffs LGA for the purpose of mapping. Some broader units may be mosaics of closely related types (e.g. 2 or more wet sclerophyll forest types).

Recommendation 2 – Simplify and review the vegetation map

The vegetation map should be simplified based on the above revision of vegetation types, and reviewed in the context of findings in this report. New line work may not be necessary, although additional ground truthing to correct some types (e.g., cool temperate rainforest) should be undertaken.

Recommendation 3 – Accuracy assessment

A second accuracy assessment should be carried out upon completion of the final product, using the same technique as presented in this report. OEH should aim for an overall accuracy of 85% using the "Right" command, and 70% using the confusion matrix.

References

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Appendix A

Field Validation Proforma

Rapid Vegetation Plots—Coffs harbour LGA

SiteID	Observer (ELA)	Date
GDA Zone: 56	MGA Easting	MGA Northing
Location desc:		Photo
Topo position: Gully; LowerSlope; MidSlope; UpperSlope; Ridge; Flat		Structural Class(m):0-2; 2-8; 8-30; 30+
Exposure class***: Exposed; Intermediate; Sheltered; Flat	Geology (if known)*	
Disturbance Intensity: heavy; moderate; light; +/-none	Disturbance type: logging; weeds; clearing; grazing; other	
Disturbance History: recent (<3); not recent (3-10); old (>10 yrs)	Comment:	

Emergent 1	% Cover**
Emergent 2	
Emergent 3	
Emergent 4	
Emergent 5	

Tallest 1	% Cover**
Tallest 2	
Tallest 3	
Tallest 4	
Tallest 5	

Mid layer 1-1	% Cover**
Mid layer 1-2	
Mid layer 1-3	
Mid layer 1-4	
Mid layer 1-5	

Mid layer 2-1	% Cover**
Mid layer 2-2	
Mid layer 2-3	
Mid layer 2-4	
Mid layer 2-5	

Lower layer 1-1	% Cover**
Lower layer 1-2	
Lower layer 1-3	
Lower layer 1-4	
Lower layer 1-5	

Lower layer 2-1	% Cover**
Lower layer 2-2	
Lower layer 2-3	
Lower layer 2-4	
Lower layer 2-5	

Vegetation Community								
Score (5-1)								

Appendix B

Summary of plot results

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
1	CH_WSF01	no	-3	no	Wet sclerophyll forest	Private	4742
2	CH_WSF05	no	-3	no	Wet sclerophyll forest	Private	4782
3	CH_WSF03	yes	1	yes	Wet sclerophyll forest	Private	3504
4	CH_FrW07	yes	4	yes	Freshwater wetland	Private	13
5	CH_WSF09	no	-3	no	Wet sclerophyll forest	Private	7703
6	CH_WSF10	no	-3	no	Wet sclerophyll forest	Private	5030
7	CH_WSF03	no	-3	no	Wet sclerophyll forest	Private	3504
8	CH_WSF01	no	-1	yes	Wet sclerophyll forest	Private	4742
9	CH_WSF10	no	-3	no	Wet sclerophyll forest	Private	5030
10	CH_WSF09	no	-3	no	Wet sclerophyll forest	Private	7703
11	CH_WSF05	no	-2	no	Wet sclerophyll forest	Private	4782
12	CH_WSF05	no	-2	no	Wet sclerophyll forest	Private	4782
13	CH_DOF01	yes	1	yes	Dry sclerophyll forest	Private	6804
18	CH_RF01	no	-2	no	Rainforest	Public	3
19	CH_RF01	no	-4	no	Rainforest	Public	3
20	CH_RF01	no	-3	no	Rainforest	Public	3
21	CH_G02	no	-2	no	Grassland	Public	8
22	CH_G02	no	-2	no	Grassland	Public	8
23	CH_G02	yes	4	yes	Grassland	Public	8
24	CH_SW03	yes	0	yes	Saline wetland	Public	11
25	CH_DOF09	yes	4	yes	Dry sclerophyll forest	Public	327
27	CH_G01	yes	1	yes	Grassland	Public	30
30	CH_SW03	no	-1	no	Saline wetland	Public	11
31	CH_SW03	no	-3	no	Saline wetland	Public	11
32	CH_FrW03	no	-2	no	Freshwater wetland	Public	13
33	CH_FW07	yes	4	yes	Forested wetland	Public	27
35	CH_FrW05	no	-1	yes	Freshwater wetland	Public	13
36	CH_RF07	no	-2	no	Rainforest	Public	97
37	CH_FW04	no	-2	no	Forested wetland	Public	5
38	CH_FW05	no	-1	yes	Forested wetland	Public	165
39	CH_FrW09	no	-2	no	Freshwater wetland	Public	13
40	CH_H03	no	-2	no	Heathland	Public	46
43	CH_H05	yes	2	yes	Heathland	Public	33
45	CH_H04	yes	0	yes	Heathland	Public	80
47	CH_FrW10	yes	0	yes	Freshwater wetland	Public	13
48	CH_SW02	yes	1	yes	Saline wetland	Public	47
49	CH_DOF06	no	-2	no	Dry sclerophyll forest	Public	2021
50	CH_DOF01	no	-1	yes	Dry sclerophyll forest	Public	6804
51	CH_DOF01	no	-1	yes	Dry sclerophyll forest	Public	6804

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
53	CH_H05	yes	0	yes	Heathland	Public	33
54	CH_H05	yes	1	yes	Heathland	Public	33
55	CH_FW05	no	-4	no	Forested wetland	Public	165
56	CH_P03	yes	2	yes	Other	Public	206
57	CH_G01	yes	3	yes	Grassland	Public	30
58	CH_H02	yes	3	yes	Heathland	Public	273
59	CH_H07	yes	3	yes	Heathland	Public	12
60	CH_RF07	yes	0	yes	Rainforest	Public	97
61	CH_FrW01	no	-2	no	Freshwater wetland	Public	13
62	CH_H06	no	-3	no	Heathland	Public	46
63	CH_WSF14	yes	2	yes	Wet sclerophyll forest	Public	39
64	CH_H01	yes	2	yes	Heathland	Public	402
65	CH_RF08	yes	0	yes	Rainforest	Public	42
66	CH_H10	yes	2	yes	Heathland	Public	10
67	CH_H10	yes	2	yes	Heathland	Public	10
68	CH_H10	yes	0	yes	Heathland	Public	10
72	CH_WSF02	no	-1	yes	Wet sclerophyll forest	Public	3917
73	CH_DOF01	no	-1	yes	Dry sclerophyll forest	Public	6804
74	CH_DOF05	yes	2	yes	Dry sclerophyll forest	Public	1977
76	CH_H09	no	-3	no	Heathland	Public	17
77	CH_WSF06	yes	0	yes	Wet sclerophyll forest	Public	3926
78	CH_H09	yes	4	yes	Heathland	Public	17
80	CH_WSF07	no	-1	yes	Wet sclerophyll forest	Public	2154
81	CH_WSF07	yes	0	yes	Wet sclerophyll forest	Public	2154
84	CH_FrW09	no	-2	no	Freshwater wetland	Public	13
85	CH_FW09	yes	0	yes	Forested wetland	Public	91
86	CH_DOF09	yes	0	yes	Dry sclerophyll forest	Public	327
87	CH_FW01	no	-2	no	Forested wetland	Public	126
88	CH_H04	no	-1	yes	Heathland	Public	80
90	CH_FW09	yes	2	yes	Forested wetland	Public	91
91	CH_DOF09	yes	1	yes	Dry sclerophyll forest	Public	327
93	CH_H08	yes	3	yes	Heathland	Public	113
94	CH_FW02	no	-2	no	Forested wetland	Public	270
95	CH_FW09	yes	2	yes	Forested wetland	Public	91
96	CH_FrW01	no	-3	no	Freshwater wetland	Public	13
104	CH_FW05	no	-2	no	Forested wetland	Public	165
106	CH_FW01	no	-2	no	Forested wetland	Public	126
107	CH_FW02	no	-2	no	Forested wetland	Public	270
111	CH_H01	no	-1	yes	Heathland	Public	402
112	CH_RF07	yes	0	yes	Rainforest	Public	97
113	CH_H01	yes	1	yes	Heathland	Public	402
114	CH_FW07	yes	4	yes	Forested wetland	Public	27
115	CH_FrW04	yes	0	yes	Freshwater wetland	Public	13
116	CH_FrW05	yes	1	yes	Freshwater wetland	Public	13

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
119	CH_H06	yes	1	yes	Heathland	Public	46
120	CH_H03	yes	4	yes	Heathland	Public	46
121	CH_FW07	yes	4	yes	Forested wetland	Public	27
122	CH_H05	yes	4	yes	Heathland	Public	33
123	CH_H08	yes	4	yes	Heathland	Private	113
125	CH_FW03	no	-3	no	Forested wetland	Private	33
127	CH_FW03	no	-1	yes	Forested wetland	Private	33
128	CH_FW02	no	-2	no	Forested wetland	Private	270
130	CH_FrW04	no	-3	no	Freshwater wetland	Private	13
131	CH_FrW05	no	-2	no	Freshwater wetland	Private	13
132	CH_H01	yes	2	yes	Heathland	Public	402
134	CH_FW03	yes	1	yes	Forested wetland	Private	33
135	CH_FW02	no	-4	no	Forested wetland	Private	270
136	CH_H08	yes	3	yes	Heathland	Private	113
139	CH_RF09	yes	2	yes	Rainforest	Public	38
141	CH_DOF10	no	-3	no	Dry sclerophyll forest	Public	2163
143	CH_WSF10	no	-3	no	Wet sclerophyll forest	Public	5030
149	CH_WSF10	no	-4	no	Wet sclerophyll forest	Public	5030
150	CH_WSF08	yes	1	yes	Wet sclerophyll forest	Public	1292
151	CH_WSF01	yes	1	yes	Wet sclerophyll forest	Public	4742
152	CH_RF09	no	-3	no	Rainforest	Public	38
153	CH_RF09	yes	4	yes	Rainforest	Public	38
154	CH_FrW09	no	-2	no	Freshwater wetland	Public	13
155	CH_FW01	yes	2	yes	Forested wetland	Public	126
156	CH_DOF09	yes	1	yes	Dry sclerophyll forest	Public	327
157	CH_FrW02	no	-1	yes	Freshwater wetland	Public	13
158	CH_SW06	yes	1	yes	Saline wetland	Public	38
159	CH_SW07	no	-1	yes	Saline wetland	Public	114
160	CH_FrW10	no	-1	yes	Freshwater wetland	Public	13
161	CH_FrW11	no	-3	no	Freshwater wetland	Public	13
163	CH_FrW01	no	-1	yes	Freshwater wetland	Public	13
164	CH_SW06	yes	2	yes	Saline wetland	Public	38
165	CH_FrW11	yes	1	yes	Freshwater wetland	Public	13
166	CH_FrW06	yes	2	yes	Freshwater wetland	Public	13
167	CH_FrW10	yes	4	yes	Freshwater wetland	Public	13
169	CH_FW06	yes	2	yes	Forested wetland	Public	39
170	CH_FW01	yes	0	yes	Forested wetland	Public	126
171	CH_FW06	yes	1	yes	Forested wetland	Public	39
172	CH_FrW01	no	-2	no	Freshwater wetland	Public	13
173	CH_SW01	yes	4	yes	Saline wetland	Private	146
174	CH_RF03	no	-1	yes	Rainforest	Private	3378
175	CH_WSF06	yes	1	yes	Wet sclerophyll forest	Private	3926
176	CH_RF02	no	-1	no	Rainforest	Private	573
178	CH_WSF07	no	-1	yes	Wet sclerophyll forest	Private	2154

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
183	CH_RF03	no	-3	no	Rainforest	Private	3378
184	CH_WSF06	no	-1	yes	Wet sclerophyll forest	Private	3926
185	CH_RF12	no	-1	yes	Rainforest	Public	1734
186	CH_WSF18	yes	1	yes	Wet sclerophyll forest	Public	635
190	CH_RF12	no	-4	no	Rainforest	Public	1734
192	CH_WSF09	no	-1	yes	Wet sclerophyll forest	Private	7703
193	CH_WSF11	no	-3	no	Wet sclerophyll forest	Private	2656
194	CH_WSF03	yes	0	yes	Wet sclerophyll forest	Private	3504
196	CH_RF11	no	-3	no	Rainforest	Public	4226
197	CH_WSF17	no	-1	yes	Wet sclerophyll forest	Private	3061
199	CH_WSF17	yes	0	yes	Wet sclerophyll forest	Private	3061
200	CH_WSF15	no	-3	no	Wet sclerophyll forest	Private	568
210	CH_WSF03	yes	0	yes	Wet sclerophyll forest	Public	3504
211	CH_WSF10	no	-2	no	Wet sclerophyll forest	Private	5030
212	CH_RF11	yes	1	yes	Rainforest	Private	4226
213	CH_WSF05	yes	0	yes	Wet sclerophyll forest	Private	4782
214	CH_DOF02	yes	0	yes	Dry sclerophyll forest	Private	3460
215	CH_DOF05	no	-2	no	Dry sclerophyll forest	Private	1977
216	CH_WSF11	no	-2	no	Wet sclerophyll forest	Private	2656
217	CH_WSF17	no	-3	no	Wet sclerophyll forest	Private	3061
222	CH_DOF05	yes	1	yes	Dry sclerophyll forest	Private	1977
223	CH_WSF17	no	-2	no	Wet sclerophyll forest	Private	3061
224	CH_DOF10	no	-3	no	Dry sclerophyll forest	Private	2163
225	CH_FW08	yes	4	yes	Forested wetland	Private	189
226	CH_WSF05	no	-1	yes	Wet sclerophyll forest	Private	4782
227	CH_WSF17	yes	2	yes	Wet sclerophyll forest	Private	3061
228	CH_WSF05	yes	1	yes	Wet sclerophyll forest	Private	4782
229	CH_WSF02	yes	1	yes	Wet sclerophyll forest	Private	3917
234	CH_RF12	no	-1	yes	Rainforest	Public	1734
235	CH_WSF18	no	-1	yes	Wet sclerophyll forest	Public	635
236	CH_RF05	no	-3	no	Rainforest	Public	342
240	CH_DOF10	no	-1	yes	Dry sclerophyll forest	Public	2163
241	CH_RF05	yes	3	yes	Rainforest	Public	342
242	CH_RF05	no	-1	yes	Rainforest	Public	342
243	CH_WSF15	no	-1	no	Wet sclerophyll forest	Public	568
244	CH_FrW08	no	-2	no	Freshwater wetland	Private	13
245	CH_RF02	no	-4	no	Rainforest	Private	573
246	CH_RF03	yes	4	yes	Rainforest	Private	3378
247	CH_WSF07	yes	1	yes	Wet sclerophyll forest	Private	2154
248	CH_FW08	yes	4	yes	Forested wetland	Private	189
249	CH_DOF02	no	-4	no	Dry sclerophyll forest	Private	3460
250	CH_DOF01	no	-4	no	Dry sclerophyll forest	Private	6804
251	CH_DOF06	no	-3	no	Dry sclerophyll forest	Private	2021
258	CH_FrW06	no	-1	yes	Freshwater wetland	Public	13

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
259	CH_FrW03	yes	2	yes	Freshwater wetland	Public	13
260	CH_DOF08	yes	2	yes	Dry sclerophyll forest	Public	155
261	CH_WSF08	yes	2	yes	Wet sclerophyll forest	Public	1292
262	CH_WSF08	no	-1	yes	Wet sclerophyll forest	Public	1292
274	CH_WSF03	yes	1	yes	Wet sclerophyll forest	Private	3504
275	CH_WSF08	no	-1	yes	Wet sclerophyll forest	Private	1292
276	CH_WSF01	no	-3	no	Wet sclerophyll forest	Private	4742
277	CH_WSF01	yes	0	yes	Wet sclerophyll forest	Private	4742
287	CH_FrW02	yes	0	yes	Freshwater wetland	Private	13
289	CH_FrW05	no	-3	no	Freshwater wetland	Private	13
290	CH_RF07	yes	2	yes	Rainforest	Private	97
291	CH_H01	yes	3	yes	Heathland	Public	402
292	CH_G01	yes	0	yes	Grassland	Public	30
293	CH_FW08	yes	4	yes	Forested wetland	Private	189
298	CH_DOF11	yes	2	yes	Dry sclerophyll forest	Public	60
300	CH_RF04	yes	0	yes	Rainforest	Public	54
302	CH_WSF16	no	-1	yes	Wet sclerophyll forest	Public	175
303	CH_WSF16	no	-1	yes	Wet sclerophyll forest	Public	175
306	CH_RF04	yes	0	yes	Rainforest	Public	54
308	CH_WSF13	no	-3	no	Wet sclerophyll forest	Public	147
311	CH_DOF11	yes	2	yes	Dry sclerophyll forest	Public	60
312	CH_WSF16	no	-3	no	Wet sclerophyll forest	Public	175
313	CH_FrW08	yes	4	yes	Freshwater wetland	Public	13
314	CH_WSF13	no	-3	no	Wet sclerophyll forest	Public	147
315	CH_WSF13	yes	4	yes	Wet sclerophyll forest	Public	147
316	CH_RF13	no	-3	no	Rainforest	Public	93
318	CH_FrW02	yes	0	yes	Freshwater wetland	Public	13
320	CH_FrW04	yes	0	yes	Freshwater wetland	Public	13
321	CH_FrW06	yes	1	yes	Freshwater wetland	Public	13
323	CH_SW07	yes	3	yes	Saline wetland	Private	114
324	CH_WSF14	yes	4	yes	Wet sclerophyll forest	Public	39
325	CH_WSF14	no	-2	no	Wet sclerophyll forest	Public	39
326	CH_H06	yes	4	yes	Heathland	Public	46
327	CH_RF08	yes	2	yes	Rainforest	Public	42
328	CH_RF13	no	-1	yes	Rainforest	Public	93
329	CH_RF08	yes	1	yes	Rainforest	Public	42
330	CH_DOF10	yes	1	yes	Dry sclerophyll forest	Public	2163
331	CH_WSF08	yes	1	yes	Wet sclerophyll forest	Public	1292
332	CH_WSF18	no	-1	yes	Wet sclerophyll forest	Public	635
333	CH_WSF18	yes	0	yes	Wet sclerophyll forest	Public	635
334	CH_WSF15	no	-3	no	Wet sclerophyll forest	Public	568
335	CH_WSF05	yes	0	yes	Wet sclerophyll forest	Public	4782
336	CH_FW05	no	-2	no	Forested wetland	Public	165
337	CH_SW02	no	-1	yes	Saline wetland	Public	47

Plot No	Map Unit	Exact match [A]	Correctness [B]	Acceptable [C]	Formation	Tenure	Map Unit area (ha)
338	CH_SW07	yes	4	yes	Saline wetland	Public	114
339	CH_SW01	yes	4	yes	Saline wetland	Public	146
340	CH_SW06	yes	3	yes	Saline wetland	Public	38
341	CH_DOF04	no	-2	no	Dry sclerophyll forest	Public	145
342	CH_SW02	no	-1	yes	Saline wetland	Public	47
344	CH_FrW10	yes	0	yes	Freshwater wetland	Public	13
345	CH_FrW10	no	-2	no	Freshwater wetland	Public	13
347	CH_SW01	no	-3	no	Saline wetland	Public	146
348	CH_FrW07	yes	3	yes	Freshwater wetland	Private	13
349	CH_FrW07	no	-4	no	Freshwater wetland	Private	13
350	CH_WSF01	yes	0	yes	Wet sclerophyll forest	Private	4742
352	CH_FrW02	yes	1	yes	Freshwater wetland	Public	13
353	CH_DOF08	yes	0	yes	Dry sclerophyll forest	Public	155
354	CH_DOF08	yes	1	yes	Dry sclerophyll forest	Public	155
355	CH_DOF08	no	-1	yes	Dry sclerophyll forest	Public	155
356	CH_RF13	no	-3	no	Rainforest	Public	93
357	CH_FrW03	yes	2	yes	Freshwater wetland	Public	13
358	CH_H03	yes	4	yes	Heathland	Public	46
360	CH_SW07	yes	3	yes	Saline wetland	Public	114
361	CH_SW01	yes	4	yes	Saline wetland	Public	146
362	CH_H04	no	-2	no	Heathland	Public	80
370	CH_DOF01	yes	1	yes	Dry sclerophyll forest	Public	6804
371	CH_DOF02	yes	0	yes	Dry sclerophyll forest	Public	3460
372	CH_DOF02	yes	2	yes	Dry sclerophyll forest	Public	3460
373	CH_DOF04	no	-1	yes	Dry sclerophyll forest	Public	145
374	CH_RF06	yes	0	yes	Rainforest	Public	76
375	CH_DOF01	no	-3	no	Dry sclerophyll forest	Public	6804
382	CH_FW05	no	-2	no	Forested wetland	Public	165
383	CH_FW06	no	-2	yes	Forested wetland	Public	39
384	CH_DOF07	no	-3	no	Dry sclerophyll forest	Public	44
385	CH_DOF07	yes	1	yes	Dry sclerophyll forest	Public	44
386	CH_WSF09	no	-3	no	Wet sclerophyll forest	Private	7703
387	CH_WSF10	yes	0	yes	Wet sclerophyll forest	Public	5030
388	CH_DOF07	no	-4	no	Dry sclerophyll forest	Public	44
391	CH_RF12	no	-4	no	Rainforest	Public	1734
393	CH_FrW04	yes	0	yes	Freshwater wetland	Public	13
394	CH_FrW07	yes	0	yes	Freshwater wetland	Private	13
395	CH_FrW11	no	-3	no	Freshwater wetland	Public	13
396	CH_WSF09	yes	1	yes	Wet sclerophyll forest	Public	7703
397	CH_RF11	no	-1	yes	Rainforest	Public	4226
398	CH_DOF06	no	-3	no	Dry sclerophyll forest	Private	2021
403	CH_FrW09	yes	2	yes	Freshwater wetland	Public	13
404	CH_H02	yes	2	yes	Heathland	Public	273
405	CH_H06	yes	0	yes	Heathland	Public	46

Plot No	Map Unit	Exact match A	Correctness B	Acceptable C	Formation	Tenure	Map Unit area (ha)
406	CH_RF02	no	-4	no	Rainforest	Public	573
407	CH_RF11	yes	0	yes	Rainforest	Public	4226
409	CH_WSF10	yes	1	yes	Wet sclerophyll forest	Public	5030
410	CH_DOF01	no	-2	no	Dry sclerophyll forest	Public	6804
411	CH_WSF09	yes	2	yes	Wet sclerophyll forest	Public	7703
412	CH_RF12	no	-1	yes	Rainforest	Public	1734
413	CH_FrW08	yes	1	yes	Freshwater wetland	Private	13
414	CH_WSF05	no	-3	no	Wet sclerophyll forest	Public	4782
415	CH_WSF02	yes	0	yes	Wet sclerophyll forest	Public	3917
416	CH_RF11	yes	1	yes	Rainforest	Public	4226
417	CH_RF02	no	-4	no	Rainforest	Private	573
419	CH_RF03	yes	2	yes	Rainforest	Public	3378
420	CH_WSF06	no	-1	yes	Wet sclerophyll forest	Public	3926
421	CH_H02	yes	3	yes	Heathland	Public	273
422	CH_NRV01	yes	1	yes	Other	Private	1445
423	CH_FrW08	no	-3	no	Freshwater wetland	Public	13
589	CH_WSF10	yes	1	yes	Wet sclerophyll forest	Public	5030
857	CH_WSF09	no	-1	yes	Wet sclerophyll forest	Public	7703
858	CH_WSF02	no	-3	no	Wet sclerophyll forest	Public	3917
860	CH_WSF05	no	-1	yes	Wet sclerophyll forest	Public	4782

A. Based on application of the “Max” command
B. Based on application of the “Difference” command
C. Based on application of the “Right” command

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