Vegetation Survey and Mapping

Hunter, Central and Lower North Coast Region of NSW

A project completed under the Hunter and Central Coast Regional Environmental Management Strategy for the Hunter-Central Rivers Catchment Management Authority

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ABBREVIATIONS USED IN THIS REPORT

AGD66	Australian Geodedic Datum 1966
AMG	Australian Map Grid
CCP	Crown Cover Percent
CLID	Crown Land Information Database
CMA	Catchment Management Authority
CRAFTI	Comprehensive Regional Assessment Aerial Photograph Interpretation
DEC	NSW Department of Environment and Conservation
DEM	Digital Elevation Model
DP	Deposited Plan
DNR	NSW Department of Natural Resources
EBDB	Eastern Bushlands Database
EEC	Endangered Ecological Community
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
GDA94	Geodedic Datum of Australia 1994
GIS	Geographic Information System
GPS	Global Positioning System
HCC	Hunter, Central and Lower North Coast region of NSW
HCCREMS	Hunter Central Coast Regional Environmental Management Strategy
HCRCMA	Hunter-Central Rivers Catchment Management Authority
IBRA	Interim Biogeographic Regionalisation of Australia
LGA	Local Government Area
LHCCREMS	Lower Hunter Central Coast Regional Environmental Management Strategy
M305	Murray Darling Basin Vegetation Mapping Program
NDVI	Normalised Difference Vegetation Index
NIR	Near Infra-Red
NPWS	NSW National Parks and Wildlife Service
RAMSAR	Convention on the protection of wetlands signed in Ramsar, Iran in 1971
RBCS	Regional Biodiversity Conservation Strategy
ROTAP	Rare or Threatened Australian Plant (Briggs and Leigh, 1996)
SPOT5	Satellite Pour l'Observation de la Terre number 5
TSC Act	Threatened Species Conservation Act 1995 (NSW)
WSI	Water Stress Index
YETI	Yet another vegetation survey database

Foreword

The main components of this project include systematic vegetation surveys, ground truth surveys, and vegetation mapping of the Hunter, Central and Lower North Coast Region of NSW. These project components form the basis of the individual chapters of this report and are prefaced by an introduction to the study. Key findings are presented in the final chapter, along with recommendations for future work.

Chapter 1: Background

This first chapter provides the background and context of the project and presents an overview of the study area, including: the study area boundary, location and extent, history, climate, natural regions, geology and soil, land use, and vegetation. Citations are also made for reference texts and other information sources that provide additional details on the human and physical geography of the region.

Chapter 2: Systematic Vegetation Surveys

The selection of site locations for completing systematic vegetation surveys was predicated by the compilation of baseline data to identify poorly sampled environments. This chapter describes the methods by which sites were selected, landholders consulted, and surveys undertaken, and presents the results of this work, including the plant species recorded, preliminary findings on the conservation significance of both plant species and vegetation communities that were surveyed, and contextual findings on vegetation condition.

Chapter 3: Rapid Vegetation Surveys

Rapid vegetation surveys were completed as the ground truth for vegetation mapping. These surveys included assessments of vegetation type, dominant species in each vegetation strata, growth forms, disturbance, and habitat. This chapter presents the methods used to complete the rapid surveys, and the results of a preliminary analysis of the survey data.

Chapter 4: Vegetation Mapping

This chapter describes the methods used to produce a seamless vegetation map covering the entire study area, including the use of SPOT5 satellite imagery, the integration of this data to produce a seamless mosaic, and the classification of this data to yield map classes for extant vegetation. The results are presented as figures in the text and are also available as spatial data layers and hard copy folded or flat maps.

Chapter 5: Project Results

As a concluding chapter to this study, the project objectives are again presented along with a brief description of how these objectives were met. Recommendations are made for expanding on this work in order to achieve the ultimate objective of catchment-wide vegetation community mapping for the Hunter, Central and Lower North Coast region of NSW.

CHAPTER 1

Background to the Vegetation Survey and Mapping Project in the Hunter, Central and Lower North Coast Region of NSW

Angela M^cCauley [1]

This chapter outlines the background to the Hunter and Central and Lower North Coast Vegetation Survey and Mapping Project, including the development of a 10 year plan to establish baseline data in the region for assisting regional and local planning. The structure of this report is presented, followed by a brief description of the study area, including its location and extent, geography, land use and vegetation.

Title illustration: A review of conservation assessment map outputs at the 2004 workshop of the Lower Hunter and Central Coast Regional Biodiversity Conservation Strategy.

1. INTRODUCTION

1.1 Background

The Hunter, Central and Lower North Coast Vegetation Survey and Mapping project has been undertaken by the Environment Division of Hunter Councils Inc. on behalf of the Hunter-Central Rivers Catchment Management Authority (HCRCMA). The project is a key initiative of the CMA's current investment program and Catchment Action Plan. The origin of this project dates back to 1998. It has involved ongoing collaboration between all three levels of government and catchment management authorities committed to improving knowledge and understanding of the region's key biological resources to better guide land use planning and development. The project has evolved over three distinct phases – and these are summarised below.

Phase One (1998 – 2001)

(i) The seven Councils of the Lower Hunter & Central Coast committed to the implementation of a collaborative regional environmental management strategy in 1996. The aim of the Lower Hunter & Central Cost Regional Environmental Management Strategy (LHCCREMS) was primarily to facilitate regional partnerships and resource sharing to address key environmental management issues best managed at a regional scale in a co-ordinated, pro-active and efficient manner. An early priority for member councils was the survey and mapping of the region's biodiversity in order to help guide land use planning given the population and development pressures the region was increasingly experiencing.

(ii) By 1998, the LHCCREMS program had produced a regional biodiversity conservation plan and partnered with the former NSW Department of Urban Development and Planning (DUAP), the former National Parks & Wildlife Service, and the Federal Government (through the Natural Heritage Trust) over subsequent years to implement the first stage. Extensive surveys and assessments were conducted to produce the region's first ever extant vegetation map, pre-1750 vegetation model and key regional fauna habitat mapping.

Phase Two (2002 – 2003):

(i) The LHCCREMS team worked with their seven member Councils (supported again by the Federal Government through the Natural Heritage Trust) to: (a) update the mapping's extant accuracy with more recently available aerial photography; and (b) undertake a comprehensive analysis of the data and mapping and produce a detailed regional biodiversity conservation strategy to guide the LHCCREMS councils in a coordinated approach to planning and development.

(ii) At the same time, representatives from LHCCREMS, the former NPWS, the former Central Coast Catchment Management Authority, the former Hunter Catchment Management Trust and the former Department of Land & Water Conservation, agreed to build on the previous work and develop a 10 year mapping and assessment program which would deliver a staged approach to:

- Data Collection (survey and mapping at 1:25000 scale across the entire Hunter and Central Coast region);
- Data analysis and Assessment ;

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- Planning (the development of tools, strategies and policies that will promote sustainable land use throughout the region); and
- Management (the implementation of planning strategies including for example, rehabilitation works, fencing, fire management, reservation of priority areas for conservation, other actions to ameliorate threatening processes).

(iii) Councils submitted three project applications to the former Central Coast Catchment Management Board and the Hunter Catchment Management Trust to meet the next stage of both regional and sub-regional needs, namely:

1. The Hunter Catchment Vegetation Mapping Interim Priority Project (catchment wide extant vegetation mapping and surveys within priority areas 1, and 2 – Figure 1)
2. Regionally Significant Vegetation Mapping for the Central Coast at 1:16,000 scale
3. Hunter Vegetation Mapping Extension - the first in a series of detailed vegetation community mapping for priority areas in the Hunter catchment involving 3 components: plot data for priority areas 1 and 2, modeled communities for priority are 1 and an extant layer for the Gloucester LGA.

Phase Three (2003 -2006)

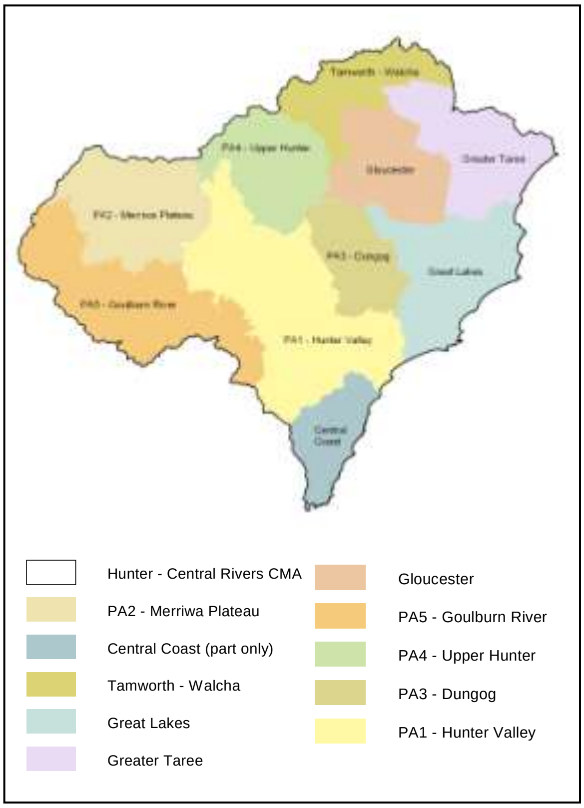
(i) Whilst these three projects were under consideration (and pending funding approval), a restructure of natural resource management authorities and government agencies took place throughout NSW. The consequence was the cessation of the Hunter Catchment Management Trust, and the Central Coast and Manning Catchment Management Boards, and the creation of the Hunter-Central Rivers Catchment Management Authority.

(ii) At the same time, the LHCCREMS initiative expanded its membership to include all 14 councils in the Hunter, Central and Lower North Coast regions of NSW (Figure 2). This new regional collaboration of councils generally aligns with the boundaries of the HCRCMA jurisdiction.

(iii) These changes created a different context for the completion of the three projects as originally envisaged. While the objectives of the Central Coast Mapping project remained relevant, the Hunter projects needed to be reviewed and redesigned to accommodate the expanded HCRCMA region.

In addition, upon consideration of the proposed methodology listed in the initial specifications, additional project revisions became necessary particularly regarding the nature of existing data, which was of varying age, resolution, scale and mapping technique. Combined with the usual project constraints on time and resources, an approach was needed that provided a consistent, region-wide assessment of current (extant) vegetation cover, vegetation formation, and floristic composition, all at a relatively high resolution and degree of spatial accuracy.

Figure 1: Priority Areas (PA) within the HCRCMA



1.2 Project Integration

To achieve the objectives of the Hunter, Central Coast and Gloucester projects within the constraints of time and funding, these three projects were combined and a standardised, consistent methodology developed that incorporated the recently acquired SPOT5 satellite imagery. The result was the development of two main studies, namely: (i) the Hunter, Central and Lower North Coast Vegetation Survey and Mapping Project; and (ii) Regionally Significant Vegetation of the Central Coast. To test the proposed methodology, a third project component was developed following a recommendation from an expert panel that was convened to specifically deliberate on the application of SPOT5 data to vegetation mapping in the Hunter region. The project components now included:

a) SPOT5 Pilot Study;
b) Vegetation Mapping of the Hunter, Central and Lower North Coast Region; and
c) Vegetation of Regional Significance on the NSW Central Coast.

This report deals with the first of these projects, whilst separate reports document the methods and results of the Central Coast and Pilot Study project components (McCauley, et al., 2006).

1.3 Specific Objectives

The specific objectives of this project are to:

- Produce a map of extant vegetation for the Hunter-Central Rivers CMA area;
- Produce a map of vegetation formation (broad descriptions of vegetation type or structure) for the Hunter-Central Rivers CMA area;
- Complete systematic vegetation surveys within priority areas.

The extant vegetation map will provide baseline data on the location, connectivity and patch size of remaining vegetation in the region. This data can be used to monitor vegetation change over time, to guide the location of restoration projects (and hence strategic investments for on-ground works), can contribute to an assessment of key habitats and corridors, and provide the baseline data to assist future conservation assessments in the region. It is envisaged that the systematic vegetation surveys will contribute to a more comprehensive catchment-wide vegetation survey database that will be subject to a detailed analysis of vegetation communities in the Catchment area, whilst the vegetation formation mapping will be used to guide the mapping of vegetation communities in the region.

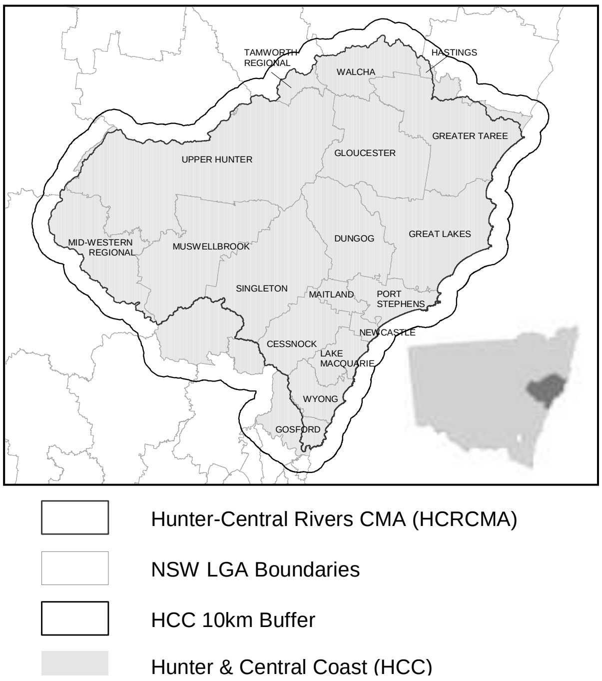
2. THE STUDY AREA

The following overview provides summary details on the location, geography, and vegetation of the study area. For more detailed accounts on the geography of the broader Hunter region, the following references provide accounts on cultural heritage, natural environments, biodiversity, and vegetation: Greening Australia (2003); Keith (2004); House (2003); NPWS (2000); Hunter Valley Research Foundation (2005); Horton (1994); the Hunter Region Botanic Gardens web site (www.huntergardens.org.au) and the Hunter-Central Rivers CMA web site (www.hcr.cma.nsw.gov.au).

2.1 Location and Extent

The Hunter, Central and Lower North Coast region of NSW is located in subtropical eastern Australia, approximately 50km north of Sydney, between latitudes 31°16' to 33° 35' South and longitudes 149° 40' to 152° 48' East. The study area includes the Hunter-Central Rivers CMA boundary and the full extent of the 14 HCCREMS member councils (the HCRCMA boundary intersects Greater Taree, Upper Hunter, Singleton and Gosford Local Government Areas). A 10km buffer zone was generated for the study area for the purpose of data collation. The area figures for each of these boundaries is listed below and illustrated in Figure 2. The study area referred to in this document is the Hunter, Central and Lower North Coast (HCC), unless otherwise specified.

Figure 2: Hunter, Central and Lower North Coast Study Boundary



Study Boundary	*Area (ha)*
Hunter-Central Rivers CMA	3,592,596
Hunter and Central Coast (HCC)	3,902,172
HCC and 10km Buffer	4,920,337

2.2 Geography

2.2.1 Settlement and Development

Prior to European settlement, the Hunter region was inhabited by the Awabakal, Worimi, Wonnarua, Geawegal, Birrpai and Darkinung Aboriginal tribes (Horton, 1994). The high rainfall, permanent rivers and large estuaries provided a richness and reliability of natural resources, resulting in a relatively high population density and relatively sedentary lifestyle. In 1797, Lieutenant John Shortland discovered the waterway he named the Hunter River and reported the occurrence of coal outcrops in the region. Two years later saw the first cedar logs and coal loads being exported from the Hunter River. In 1801, Governor King dispatched a major expedition under the command of Lieutenant Colonel Paterson, who sailed some 60km inland (to a point near today's City of Maitland) aboard the Lady Nelson. Colonel Paterson explored two major tributaries, the Paterson and Williams Rivers, and confirmed Shortland's earlier reports of abundant timber and coal resources. By 1819, John Howe had

blazed a land route across the mountains from Sydney, to be later followed by pardoned convicts and free settlers who began agricultural and pastoral activities. In the early 1820s the first wine grapes were introduced to the Valley.

By 1804 the town of Newcastle was first proclaimed and became a city by 1847. BHP steelworks began production at the time of the First World War, and in 1918 the Commonwealth Steel Company was formed. Major developments in heavy industry and infrastructure have taken place during and since the Second World War; power stations were established at Wangi (1953), Munmorah (1970), Liddell (1974), Bayswater (1980), and Eraring (1982); Aluminium smelters established (Tomago in 1983); gas pipeline to Newcastle completed (1982); dams constructed (Chichester Dam in 1923, Grahamstown Dam in 1964, Glennies Creek Dam in 1983, Glenbawn Dam enlargement in 1987); and major roads constructed (Sydney-Newcastle freeway 1963, F3 Freeway in 1993). More information on historical events that have taken place in the Hunter Region can be found at www.newportcorp.com.au; www.hvrf.com.au; and www.winecountry.com.au.

The region currently encompasses the major urban population centres of Newcastle, Gosford, Wyong, Lake Macquarie, Forster-Tuncurry, Taree, Maitland, Cessnock, Singleton, Raymond Terrace, Muswellbrook and Scone, with a combined regional population of around 561,522 people. The Hunter is also one of the State's fastest growing regions, with an increase in population of about 4000 people each year (NSW Department of Planning, 2005).

2.2.2 Climate

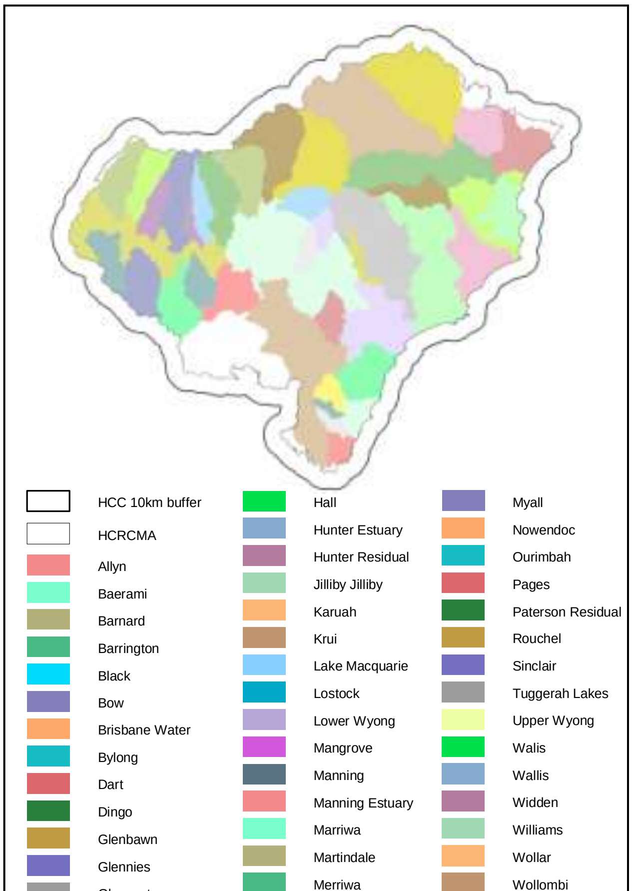
According to the Hunter Valley Research Foundation (2005), the Hunter region is characterised by mid-latitude westerly winds and high pressure systems that alternate with cold fronts during winter. Winter conditions are drier than summer (particularly the months of July and August), with gusty westerly winds a principle feature of August. South-easterly winds dominate during summer, however north-easterly sea breezes also occur and provide a cooling effect as far inland as Scone. Based on figures from the Maryville recording station, the highest rainfall in a 24-hour period between 1964 and 2004 was 288.6 mm, recorded on 3 February 1990. The highest temperature recorded during this same period was 42.4^{o} C on 23 December 1990 and the lowest temperature was -0.5 ^{o} C on 27 July 1986. Since the anemograph was installed in 1980, the maximum wind gust recorded at Maryville was 58 knots (107 km per hour) on 11 December 1989. A maximum wind gust at Nobby's Signal Station of 92 knots (170 km per hour) was recorded during the storm of 26 May 1974. Newcastle has an average of 6.3 hours of sunshine per day and the average wind speed is 13.0 km per hour. Observations from a number of weather stations in the Hunter region can be accessed at the Bureau of Meteorology's website at: www.bom.gov.au.

2.2.3 Natural Regions

The Hunter, Central and Lower North Coast region covers a diverse landscape, ranging from the wide floodplain and extensive estuarine wetlands of the Lower Hunter to the undulating country and escarpment of the Barrington Tops and Bowman Range, and southwards to the rugged sandstone gorges of the Wollomi Wilderness. The unique region encompasses a number of catchment areas, bioregions, and botanical subdivisions, as will be discussed.

Catchment areas: The study area encompasses 46 sub-catchments (Figure 3), is the third largest coastal valley in NSW, and the only part of the State where a major westward facing valley crosses a subdued Great Dividing Range. The major waterways of the region are the Hunter, Manning and Karuah Rivers and the coastal waterways of Myall Lakes, Wallis Lake, Port Stephens, Lake Macquarie, Tuggerah Lakes and Brisbane Waters. The catchment extends from the Merriwa Plateau in the west to the RAMSAR wetlands and estuary systems in the east, and includes the Barrington Tops and Greater Blue Mountains World Heritage Areas. On its southern perimeter, a sandstone barrier separates it from the Hawkesbury-Nepean and Central Coast catchments (Greening Australia 2003).

Figure 3: Sub-catchments of the HCRCMA



IBRA: The IBRA bioregions (Interim Biogeographic Regionalisation of Australia) and sub-regions are the reporting units for assessing the status of native ecosystems, their protection in the national reserve system and for use in the monitoring and evaluation framework in the Australian Government's current Natural Resource Management initiatives (Department of Environment and Heritage, 2006). The IBRA sub-regions (where available) have previously been used as the unit of analysis for continent-wide assessments of landscape health and biodiversity by the National Land and Water Resources Audit. The IBRA regions are currently used as the basis for identifying overcleared landscapes in conducting assessments for the Property Vegetation Planning Developer. The study area is located within four biogeographic regions, namely the Sydney Basin, NSW North Coast, New England Tableland and Brigalow Belt South. These bioregions are described below (Environment Australia, 2000).

<u>Sydney Basin:</u> Mesozoic sandstones and shales; dissected plateaus; forests, woodlands and heaths; skeletal soils, sands and podzolics.

<u>NSW North Coast:</u> Humid; hills, coastal plains and sand dunes; *Eucalyptus* - *Lophostemon confertus* tall open forests, *Eucalyptus* open forests and woodlands, sub-tropical rainforest often with *Araucaria cunninghamii*, *Melaleuca quinquenervia,* wetlands, and heaths.

<u>Brigalow Belt South</u>: Predominantly Jurassic and younger deposits of the Great Artesian Basin and Tertiary deposits with elevated basalt flows. Subhumid Eucalyptus woodlands and open forests of ironbarks, poplar box, spotted gum (*E. maculata*), cypress pine (*Callitris glaucophylla*), Bloodwoods (eg. *E. trachyphloia*, *E. hendersonii*) brigalow-belah forests (*E. harpophylla*, *Casuarina cristata*) and semi-evergreen vine thicket.

<u>New England Tableland:</u> Elevated plateau of hills and plains on Palaeozoic sediments, granites and basalts; dominated by stringy bark/peppermint/box species, including *E. caliginosa, E. nova-anglica, E. melliodora* and *E. blakelyi.*

Botanical Subdivisions: The study area straddles two main botanical divisions in NSW, the Coastal Division and Tablelands Division. Within these, the study area lies within four botanical subdivisions, namely the Central Coast (CC), North Coast (NC), Central Western Slopes (CWS), and Northern Tablelands (NT) (Figure 5). As described by Harden (1990), the divisions are largely determined by the belt of elevated tableland country towards the east which influences both temperature and rainfall. The north has more rainfall in summer, in the south more rain falls in winter, whilst the intermediate zone has fairly evenly distributed rainfall. Complete winter dormancy of the vegetation is found only in the highest parts of the tableland, although there is a pronounced depression in plant growth in the colder months for most of the Tablelands and parts of the Western Slopes. The botanical subdivisions of the study area are characterised in the following section.

Figure 4: IBRAs within NSW and the HCC Study Area

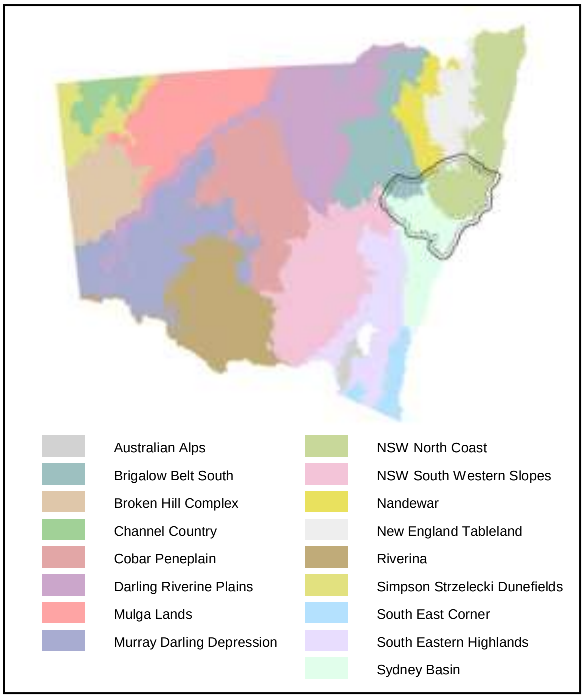


Figure 5: NSW Botanical Subdivisions

Source: Royal Botanic Gardens, Sydney.

<u>The North Coast</u> extends from the Queensland border to Lake Macquarie and is largely subtropical. Rainforests at one time were characteristic of the alluvial flats and rich basaltic soils, although these have now largely been destroyed to make way for

agriculture. The richer loamy soils support tall eucalypt forests, but there are also stretches of poor sandy or stony soils and tidal flats with stunted forest, heath or mangroves.

The Central Coast covers the area between Lake Macquarie and the Shoalhaven River. Rainforests of relatively low species diversity occur in the moister or more sheltered sites and eucalypt forests are widespread. Areas of nutrient-poor sandstone, eg. Hawkesbury Sandstone, support a characteristic hard-leaved shrubby vegetation of many species.

The Northern Tablelands extends south from the Queensland border to the northern boundary of the Hunter Valley. The plateau region is covered with dry sclerophyll forest or more open grassy woodland dominated by species of eucalypt of moderate size although some higher altitude areas support tall wet sclerophyll forest and cool temperate rainforest.

The Central Western Slopes includes hilly, undulating and plains country comprising important agricultural, pastoral and forest areas. Lighter sandy and stone soils support dry sclerophyll forest or sometimes stunted shrubs. Soils of intermediate loamy texture were once occupied by tall woodland of eucalypt or Cypress pine, whilst heavier black soils often supported grassy woodland. These areas have now been extensively cleared.

2.2.4 Substrate

The following summary description of the geology and soils of the study area has been sourced from Greening Australia's Bushcare Report of 2003. For additional details regarding the geology of the region, refer to the NSW Department of Primary Industries web site (www.minerals.nsw.gov.au), and the Community Access to Natural Resource Information web site (www.canri.nsw.gov.au). Soil types of the region are further described in Kovac and Lawrie (1991); Chapman and Murphy (1989); Matthei (1995); McInnes (1997), and Murphy (1993).

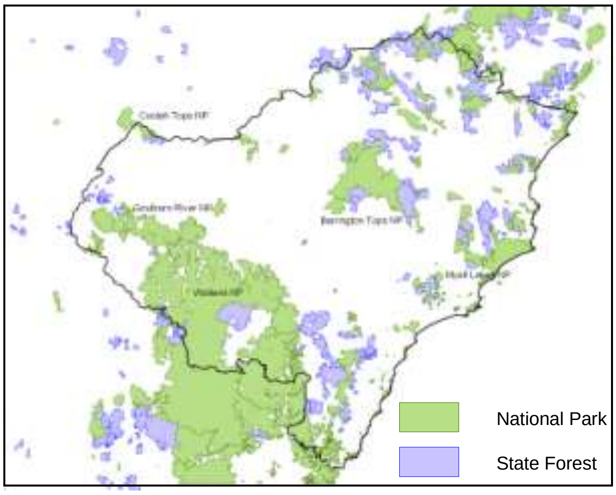
Geology: A dominant geological structural feature of the region is the Hunter Fault, which separates the Carboniferous sediments to the north-east of the catchment and Permian sediments to the south-west, which underpin the coal measures that the Hunter Valley is renowned for. There is also an area of Triassic sediments to the south. There is a small area of Permian granite overlain by tertiary basalt in the Barrington Tops area. Extensive deposits of Quaternary alluvium and Aeolian sands occur in the coastal plain.

Soil: Soil types are dominated by podsolic and soloths in the mid-Hunter, alluvials on floodplains and terraces, chocolate soils (alluvium enriched basalt) formed from the basaltic influence of the Barrington Tops and black earths which characterise the Merriwa Plateau. Infertile sands based on Quaternary sediments displaying varying degrees of podsolisation dominate the eastern margin of the catchment. Acid sulphate soils exist under some of the coastal and estuarine areas. The gradual rise of the water table in weathered soils on the valley floor leave some areas in the mid-Hunter predisposed to dryland salinity.

3.3 Land Use

The main landuse types within the region are primarily agricultural (broad-acre farming/grazing), power generation and extractive industry in the upper Hunter area; heavy and light industry, viticulture and agriculture (intensive) in the mid Hunter; and forestry, conservation, and urban and rural residential in the lower Hunter area (Greening Australia, 2003). There are two World Heritage Areas within the study area, namely Greater Blue Mountains and Barrington Tops, wetlands of international significance that are listed by the RAMSAR Convention, including Myall Lakes and Hunter Estuary (www.deh.gov.au and www.ramsar.org), and 116 National Parks and Nature Reserves (approximately 801,918 ha or 20% of the study area). An additional 291,375 ha are under State Forest multiple use management, an area comprising a further 7.5% of the study area (Figure 6).

Figure 6: National Parks and State Forests



2.4 Vegetation

There are numerous publications and datasets that describe or map the vegetation of the Hunter, Central and Lower North Coast region at a range of scales, from state-wide to bioregional and local map scales, although none of these specifically deal with the current distribution and composition of vegetation for the study area at the catchment scale. These data sources include Keith (2004); Peake (2006); NPWS (2000, 2002); McRae and Cooper

(1985); Bell (2002, 2004); NPWS (1999a and 1999b); Floyd (1990); Forestry Commission (1989); McCauley et al. (2006b); Hunter Region Botanic Gardens (2006); Specht et al. (1995); Read (1994), Holme (1993); Roberts (1992); Beadle, N. C. W. (1981); and Land and Water Australia (2001). A summary of the vegetation formations that are known to occur within the study area is provided below, along with the citation for additional detail on each of these.

3.4.1 Vegetation Formations

Vegetation formations are based on vegetation structure, specifically canopy cover and growth form, and has provided the basis for vegetation description throughout NSW (cf. Specht classes, Appendix 7; Walker and Hopkins, 1990). The study area supports a range of vegetation formations, including closed forests, tall open forests, open forests, woodlands, heathland, grassland, sedgeland and wetland. Within each of these formations are a variety of subforms and alliances.

3.4.2 Closed Forest or Rainforest

Rainforest is characterised by a closed forest canopy with more than 70% foliage projection of the tallest stratum. Rainforest types include subtropical, littoral, warm subtropical, monsoon, dry, warm temperate, and cool temperate (Floyd, 1990). As briefly described by the Hunter Region Botanic Gardens (2006), the main types within the Hunter region include subtropical, warm temperate, cool temperate, and dry. Subtropical rainforest occurs in deep valleys, usually with a south to easterly aspect and at lower altitudes where richer soils occur. Warm temperate rainforest occurs at higher altitudes and occupies less favourable areas. Cool temperate rainforest typically occurs at high altitudes and is characterised by *Nothofagus moorei*. Dry rainforest occurs in sheltered situations in more adverse sites, such as rocky outcrops or areas with low rainfall, such as the upper Hunter (eg. Towarri) and on the slopes of the Coolah Tops. Floyd (1990) provides a detailed account of the rainforest sub-formations and alliances.

3.4.3 Tall Open Forest

Tall open forests occur in the higher rainfall areas on good soils, along the coast, on the lowlands of the Valley, in the Liverpool and Mount Royal Ranges, Watagans, parts of the Hunter range and Nullo Mountain areas. A number of sub-forms have been recognised within these areas, and detailed descriptions are provided by Keith (2004), Beadle (1981) and the Baur forest typing (Forestry Commission, 1989).

3.4.4 Open Forests and Woodlands

Open forests and woodlands occur throughout the study area and include Blackbutt, Bloodwood, Spotted Gums and Eucalypt types with varying understories of shrubs, grasses, and ferns. Many of these forests are described by Keith (2004), Beadle (1981), and the Baur forest typing (Forestry Commission, 1989).

3.4.5 Heathland

Heathland typically occurs near the coast on exposed coastal sands, dune systems and headlands, but also occurs further inland on exposed or seasonally wet and poorly drained areas and on skeletal soils (eg. Triassic sandstone and granite rock types). Heath vegetation comprises species of the Proteaceae, Fabaceae, Mimosaceae, Myrtaceae and Epacridaceae families. More detailed descriptions of heathland types are provided by Keith (2004), Beadle (1981) and Read (1994).

3.4.6 Sedgeland and Wetlands

Sedgeland and wetland types include riverine, estuarine and coastal habitats, such as the swamps and water logged areas of the Lower Hunter River and creeks draining into Lake Macquarie. Grasslands are widespread throughout the study area and also occur in frost hollows, such as the Barrington Tops plateau. Keith (2004), Beadle (1981) and Read (1994) provide additional detail on these wetland types as well as all the vegetation formations listed above.

4. CONCLUSION

The Hunter, Central and Lower North Coast Vegetation Survey and Mapping project is addressing a critical milestone in achieving the ultimate objective of catchment-wide data products and the comprehensive mapping of vegetation communities of the HCRCMA region.

In meeting this objective there are likely to be inevitable challenges posed by a 3.4million hectare study area that is biologically and geographically diverse, with significant conservation values at the local, regional, national and international level, competing land use interests, and a growing demand for urban development. The Hunter, Central and Lower North Coast region has endured a history of land use change, from the extraction of cedar and coal, to the establishment of industrial complexes and urbanisation. In recent years, there has been a shift towards custodianship, sustainable management and restoration of our natural environments, and the instigators of the Regional Strategy are to be commended on providing the platform to achieve these ambitions and accept these responsibilities on behalf of current and future generations.

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CHAPTER 2

Title illustration

Systematic Vegetation Surveys in the Hunter, Central and Lower North Coast

Angela McCauley [1]

This chapter describes the methods used in vegetation survey site selection and in conducting systematic surveys within priority areas throughout the Hunter, Central and Lower North Coast study area. The results of this survey are presented in terms of the environmental variability sampled, the contribution of this survey effort to existing knowledge, and the vascular plant species that were recorded.

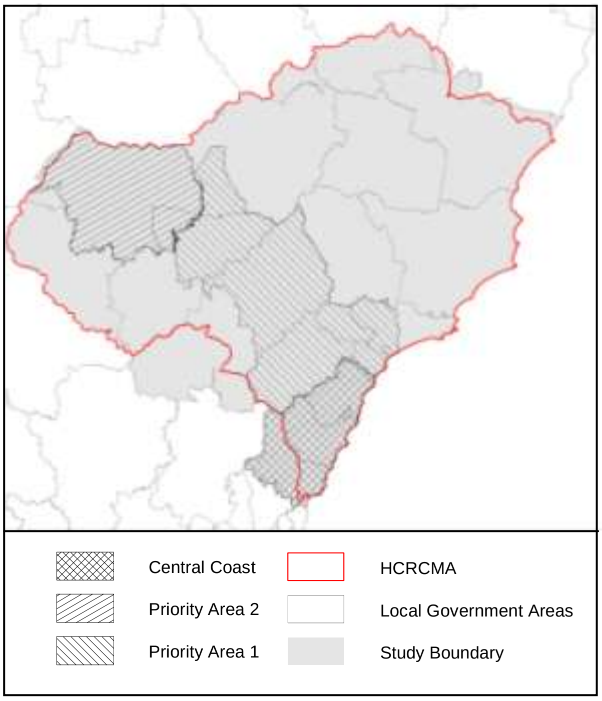
Title illustration: Field botanist Bruce Mullins from Ecological Australia completing a calibration site for standardising observations between field teams.

1. BACKGROUND

1.1 Priorities for Survey

Systematic vegetation surveys in the Hunter, Central and Lower North Coast region of NSW were undertaken within priority areas as a staged approach to completing catchment-wide vegetation community mapping. The priority areas were determined through stakeholder input and include the Valley Floor (PA1), Merriwa Plateau (PA2), and Central Coast (Figure 1).

Figure 1: Priority Areas for Systematic Survey



1.2 Project Objectives

Given the focus on regional-scale objectives and sub-regional survey priorities, the following aims were formulated:

1. Conduct landscape-wide and tenure-blind gap analysis to determine poorly sampled environments and vegetation map classes.
2. Within the priority areas of the Central Coast, Valley Floor and Merriwa Plateau, undertake systematic vegetation surveys at sites identified in the gap analysis and at opportunistic sites that account for local variation in vegetation patterns.
3. Establish a subset of the survey sites as long-term monitoring sites that can assist in future assessments of vegetation condition (eg. weeds, regeneration).
4. Complete data entry, data checking and vetting of site records.
5. Compile systematic sites database incorporating all new survey records and, where possible, existing sites data.

The survey effort would aim to complete approximately 350 systematic vegetation survey plots that sample previously un-represented or poorly-sampled environments and vegetation types in the survey area.

2. DATA COLLATION

2.1 Biotic and Abiotic Datasets

A significant amount of data exists for the study area, including abiotic and biotic datasets held by government agencies, consultancies, and individuals. The first stage in this project was to identify the datasets relevant to this study, such as

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GIS layers for climate, soil, geology, vegetation, plant species, remote sensing (satellite and aerial photography), topography, elevation, drainage, water bodies, landscapes, wetlands, infrastructure, and administrative boundaries (including land tenure). To assist this process, two documents were reviewed, namely: the Comprehensive Coastal Assessment Vegetation Data Audit report (NPWS, 2001) and the Data Audit of Vegetation Survey within the Central Coast LGAs (Bell, 2004). Requests were made to government agencies and consultants to acquire a number of specific datasets that would be used to guide the survey effort, including:

- Systematic vegetation survey data
- Land tenure information (including State Forest, National Park, Crown Land and Cadastre)
- Natural regions (eg. IBRA, Mitchell Landscapes)
- Roads
- Topographic maps
- Satellite data
- Aerial photography

All data requests were made for the data analysis area, which included a 10km buffer around the HCRCMA and LGA boundaries of the 14 HCCREMS member councils.

2.2 Preliminary Data Review

As a preliminary assessment of environmental heterogeneity and survey representation throughout the study area, a total of 4 environmental variables were intersected to yield an environmental stratification with 47 classes. These classes relate to unique combinations of mean annual rainfall, mean annual temperature, mean annual solar radiation and geology. Existing systematic vegetation survey sites were intersected with each of these units to identify the relative survey density of sites per map unit. The results of this work were presented to consulting botanists with extensive local knowledge to identify any additional survey records not already collated and to make recommendations on the environmental variables that are likely to be key drivers of vegetation patterns in the region. The final suite of systematic vegetation survey records identified through data audits, data collation and the expert review, are illustrated in Figure 2 and listed in Appendix 1.

2.3 Systematic Survey Data

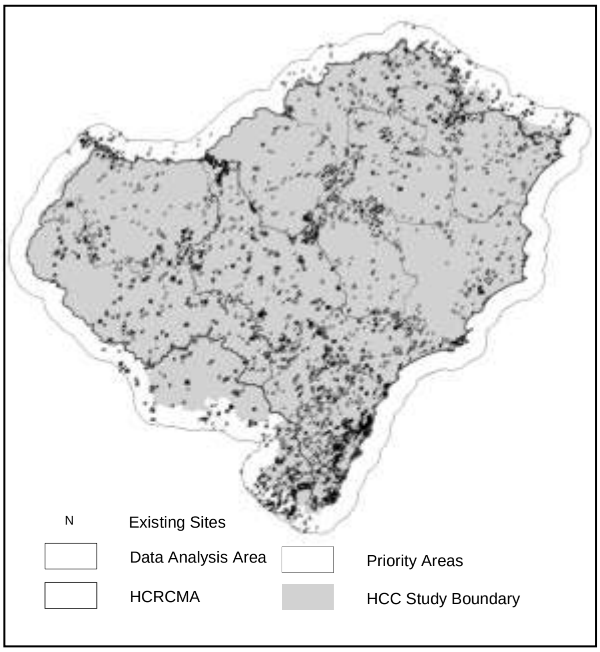
A total of 12 systematic vegetation survey databases were collated for this project and the locality data from them was extracted to provide summary information on the number and distribution of survey sites within the study area (Table 1). The floristic data from these databases are yet to be integrated, checked for duplicates, accuracy and nomenclature, and vetted for inclusion in any future vegetation community analysis and it is expected that this work will form part of the next stage of catchment-wide vegetation survey and mapping. Nonetheless, the following information is provided for context.

Table 1: Vegetation Survey Databases

No.	Source	Location
1	DEC (Western)	Dubbo
2	DEC (Northern)	Coffs Harbour
3	DEC (Central)	Hurstville
4	DEC (project specific)	Hurstville
5	Ecological Australia	Hunter Region
6	Maitland	Hunter
7	Travis Peake	Hunter Region
8	Steven Bell	Central Coast
9	Robert Payne	Hunter Region
10	Colongra Wetland Survey	Colongra Wetland
11	Woodlands Project	Hunter
12	LHCCREMS	Lower Hunter Central Coast

From these 12 databases, a total of 5,759 survey sites are recorded from 143 vegetation surveys within the data analysis area. These surveys include approximately 110,000 plant species records for at least 3,396 species. It should be noted that these figures are likely to include some duplicate records given that the data still requires validation. Future work should also refer to the Hunter Rare Plants Database (Bell et al., in prep) who list 20 communities and 5 plant populations of regional significance, and 1,217 species of conservation significance, including taxa listed on the NSW Threatened Species Conservation Act 1995 (TSC Act), the Australian Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the list of Rare or Threatened Australian Plants of Briggs and Leigh 1996 (ROTAP), or are considered to be of regional significance (eg. endemic, disjunct distribution or are at a distribution limit).

Figure 2: Existing Systematic Vegetation Survey Sites



3. SURVEY DESIGN

3.1 Standards and Techniques

3.1.1 Vegetation Surveys

Vegetation communities are typically identified through systematic surveys of vascular plant species and their relative cover and abundance scores within a predefined area, namely the survey quadrat. The standards that are applied in NSW usually involve a 20x20m quadrat size (or equivalent) and their locality is determined through a stratified random approach: namely, sub-divide the landscape into discrete areas that reflect different environments and within each area, randomly select a nominal number of site locations to survey (the total number is commonly dictated by the maximum number of sites that can be achieved within time and budget constraints). As a guide to the number of sites to survey, the Native Vegetation Mapping Project carried out by the former NSW Department of Land and Water Conservation previously applied a standard of 2000 sites per 1:100,000 topographic map sheet, although this number varied according to the extent and diversity of vegetation cover and the accessibility of the terrain and tenure.

3.1.2 Data Analysis

Once collected, the systematic vegetation survey data is entered into a database, and in NSW this is typically the YETI database managed and distributed by the NSW Department of Environment and Conservation (YETI is the acronym used for YET another vegetation survey database, also referred to as YAVSD, designed by Michael Bedward and Murray Ellis). The digital data is subsequently used in statistical analysis (either ordination and / or classification) to identify groups of sites, or groups of species, that are associated with each other or that co-occur in the landscape. These groups are often referred to as a 'community' or an 'association'.

3.2 Current Approach

3.2.1 Overview

The development of a methodology for conducting systematic vegetation surveys within the study area took into account a number of parameters, namely: environmental heterogeneity; regional (catchment scale), sub-regional and local scale vegetation patterns; the location of existing survey sites across the catchment; and the selection of appropriate site locations within the constraints of access, time and resources. These parameters are discussed in more detail below.

3.2.2 Environmental Plant Habitat

In order to better understand the plant habitat and environments of the region, the HCCREMS team produced a map of plant habitat that could be used for future analysis of vegetation patterns. This map (Figure 3) illustrates areas with similar environmental conditions in terms of the input variables of rainfall, temperature, slope, aspect, soil fertility and solar radiation. Unlike the traditional environmental stratification which relies on the arbitrary subdivision of environmental variables (refer section 2.2), this map was derived using an iterative "k-means" algorithm (Forgy 1965) running within a geographic information system (cf. Moore 2001; Mackey *et al.* 1989; Ferrier and Watson 1997; NPWS 2001, 2002, 2003).

3.2.3 K-Means

The k-means algorithm repeatedly searches the input variables for natural groups until an optimum is found between the within-group similarity and the between-group dissimilarity. The number of environmental domains (40 in this case) is specified in advance. As each of the six input variables was in the form of a data layer with a grid cell resolution of 100m (4,117,235 cells per layer), this number of domains represented a reasonable compromise between map detail, interpretability and computational efficiency. The environmental domains can be viewed as discrete plant habitats. The choice of environmental variables was based on research findings and expert opinion but was necessarily limited by the available spatial datasets.

Other variables may also have profound influence on plant distribution, however not all factors have been mapped or are available as spatial datasets. In addition, computational limitations meant that it was necessary to restrict the number of variables used in the analysis.

A total of eight analyses were run using the environmental variables listed above. These analyses tested the number of clusters that would ultimately be used in the final classification and ranged from 5 groups to 50 groups (the classifications were 10, 20, 25, 30, 35, 40, 45 and 50 groups). Each analysis was considered in turn and compared with each other in order to identify a suitable map scale that adequately captured the known environmental variation of the region.

3.3 Survey Effort

3.3.1 Prioritisation for Surveys

In order to adequately sample the environmental and floristic heterogeneity of the study area, site selection was targeted towards poorly sampled environments, ecosystems or otherwise poorly defined vegetation communities. In the absence of region-wide vegetation mapping, this was achieved on two levels: at a regional scale according to the plant habitat mapping; and at a sub-regional scale for the Central Coast (Gosford, Wyong and Lake Macquarie) according to best available vegetation mapping.

Existing systematic vegetation survey sites were reported against the environmental plant habitat map to identify poorly sampled environments at a regional scale (Figure 4). At the sub-regional scale, these sites were also reported against individual vegetation map units from the Lower Hunter Central Coast Regional Environmental Management Strategy mapping (Figure 6). These sub-regional survey priorities were determined based on the relative values of:

Very low priority	Map units with >= 25 sites
Low Priority	Map units with 11-24 sites
High Priority	Map units with 4-10 sites
Very High Priority	Map units with <= 3 sites

In addition, areas that have a relatively low site density (Figure 5) or have previously been identified as warranting additional survey work at the local scale (cf. Bell 2004; Peak, 2006) were reviewed for potential survey site localities. Furthermore, consulting botanists were provided with sufficient flexibility to survey opportunistic sites where they encountered unique vegetation types.

3.3.2 Site Density Analysis

The site density analysis in this instance has been employed to demonstrate diagrammatically the spread of sampling intensity across the study area. Two distinct representations of site density are presented: density by plant environments; and density by Euclidean spatial proximity. These two analyses are discussed in turn below.

A) ***Site density stratified by plant habitat classes.*** The sites data are reported against each class of the plant habitat map and the count of sites in each class is used as a surrogate of the sampling density. This technique has the obvious limitation that it ignores the areal extent of each map unit which may vary widely.

B) ***Site density calculated with regard to the Euclidean spatial proximity*** of each pixel coordinate to sites within a specified radius. Several radii were considered for this purpose. The goal of the analysis was to give an 'impression' of the site sampling intensity rather than an operational plan. For this reason, ultimately a relatively smooth function was chosen for the visual representation.

The reporting of the Point site data against the grid domain data was achieved using the ArcView extension, 'Point Analyst' (Point Analyst (grid) 3.0 © Dr. Rob Rempel 2003, Centre for Northern Forest Ecosystem Research (OMNR)). The 'capture point values' function was used and the output data was stored as part of the domain grid.

Figure 4: Poorly sampled environments

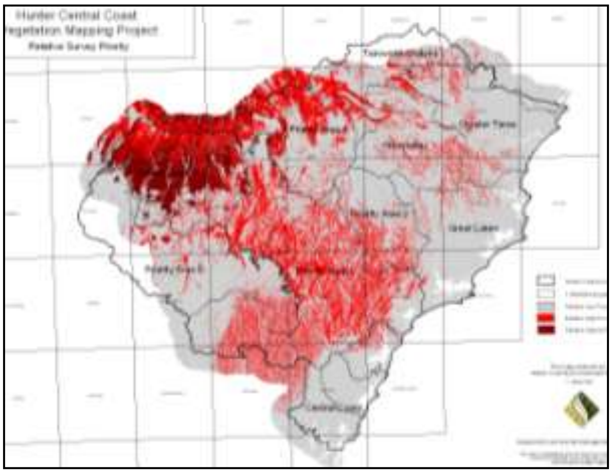


Figure 5: Site Density

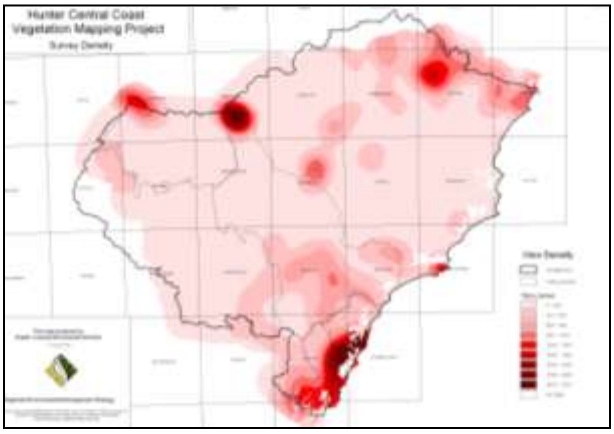


Figure 6: Survey priorities in the Central Coast

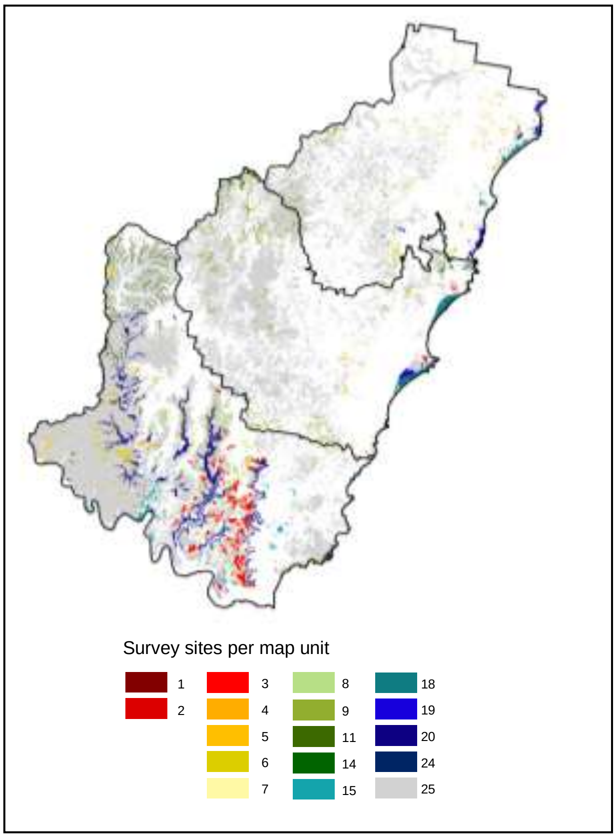


Figure 3: Plant Habitats of the Hunter, Central and Lower North Coast Region

Note: This map corresponds to LGA boundaries rather than CMA boundaries due to the scope of the contract to complete this work.

- Barrington Slopes
- Northern Range
- Richmond Range
- Coolah Tops
- Dissected Northern Range
- Dissected Sandstone (east)
- Goulburn Range
- Northern Coastal Range
- Richmond Spurs (west)
- Central Coast Slopes
- Central Coast
- Northern Valleys
- Gloulburn Ridge Slope
- Richmond Range High Slopes
- Dissected Sandstone (west)
- Barrington Tops
- Richmond Scarp
- Northern Range Ridgelines
- Dissected Sandstone (base)
- Dissected Plateau Slopes
- Barrington Ridgelines
- Northern Range
- North Coastal Flats
- Northern Plateau
- Ricmond Ridges
- Hunter River Valley
- Dissected Plateau Valley
- Hunter Valley Floor (east)
- Richmond Range Slopes (east)
- Richmond Range Slopes
- Northern Range
- Valley Floor (west)
- Goulburn Slopes
- River Valley Entrance
- Coastal Flats
- Mid Coast
- Northern Range Slope
- Mid Coastal Flats
- Dissected Plateau
- Northern Range Slopes

3.4 Site Selection

3.4.1 Random Site Locations

Survey site locations were randomly generated using an ArcView 3.2 extension. These random points were intersected with a number of GIS layers and selected for survey where the following parameters were met: the random point intersected with a high survey priority; the random point intersected with native vegetation cover; and the site was situated within 2km of an access road.

Sites that met these criteria were subsequently reported against tenure layers (eg. National Park Estate, State Forest, CLID) and divided into two datasets: crown land sites and private property sites. The crown land sites were allocated to the consulting botanists to initiate survey work whilst landholder liaison was undertaken to negotiate access to private property sites. Two phases of site selection were undertaken, as listed in Table 2. These sites were supplemented by opportunistic surveys based on recommendations from botanists with local expertise on poorly sampled vegetation types or geographic regions.

Table 2: Phase 1 and 2 of Vegetation Surveys

Phase 1 surveys	Phase 2 surveys
Existing sites as at 8 December 2004	Existing sites as at 16 March 2005 and including Phase 1 survey sites.
Focus on crown land sites	Private property sites from Phase 1 of site selection where the landholders permission to complete survey work has been granted.
Restricted to the Central Coast, Valley Floor and Merriwa Plateau	Crown land sites in priority areas

3.4.2 Site Allocation

Five botanical teams were contracted to complete 315 sites within the study area (Table 3). An initial meeting was convened with all project botanists to discuss details of the work, review the survey proforma, and standardize observational criteria. To provide further consistency between the survey teams, the project coordinator accompanied each team on survey work and clarified any discrepancies in data recording and provided advice and feedback on standardising observations. Systematic vegetation surveys were scheduled for 2004-05. Sites were allocated to each team of botanists according to their previous experience in specific landscapes (eg. valley floor, coastal vegetation).

Table 3: Consulting Botanists

Consultant	Botanist	Geographic Area
Ecological Australia	Bruce Mullins	Merriwa Plateau
Umwelt	Travis Peake	Valley Floor
Bangalay Botanical Surveys	Steve Chamberlain and Claire DeLacey	Valley Floor, Merriwa Plateau, other priority areas as agreed.
Eastcoast Flora Survey	Stephen Bell	Central Coast
RJ and MR Payne Pty Ltd	Robert Payne	Central Coast, other priority areas as agreed.

3.5 Survey Method

3.5.1 Quadrat Size

Each botanical survey team was supplied with the AMG coordinates for target and backup site locations to complete systematic vegetation surveys. The survey quadrat area measured 400m^2, usually 20x20m or an equivalent area where this dimension could not be achieved (eg. riverine communities). To assist in future monitoring of vegetation condition, each quadrat was permanently marked wherever possible (and where landholder permission had been granted) with a steel post positioned in the south-western corner of the quadrat.

3.5.2 Information Recorded

Surveys were systematic in that they recorded cover/abundance values for every vascular plant species present within the quadrat, along with the dominant species for each vegetation strata. Cover abundance values were based on the Braun-Blanquet system. As presented in Appendix 2, the complete set of attributes to be recorded at each site included:

- Plot identification
- Location details
- Site attributes
- Disturbance indicators
- Vegetation structure
- Canopy growth stage and structure
- Non-vascular ground cover
- Site profile / sketch
- Floristics with cover and abundance scores

3.5.3 Data Entry

On completion of the survey work, data was entered into the most recent version of the YETI database supplied by DEC. Fields that were not accommodated for in the YETI database (such as

non-vascular ground cover) were entered into an MS Excel Spreadsheet according to a standard template supplied by Hunter Councils Inc.

3.5.4 Voucher Specimens

Voucher specimens were collected for cryptic species, significant species, and for more commonly occurring species for the purpose of contributing to a regional herbarium. Specimens that could not be identified by the Consultant were lodged with the Royal Botanic Gardens for confirmation of species identification.

3.5.5 Summary Reports

A summary report from each botanist was required and was to include information on the overall findings of the survey work and general impressions of vegetation patterns in the survey region.

3.6 Data checking

Data supplied by each botanical team was checked by HCCREMS staff according to the procedure below.

1. Check that all survey proformas have been submitted
2. Check hard copy survey proformas for completeness and legibility. All fields should be entered with valid codes.
3. Check YETI database file and ensure that all sites have been entered and that all fields are complete with valid codes.
4. Check that the reference to the digital photos has been made. This can be in the photo file itself or a reference made to the photo file in the site comments.
5. Check Excel Supplementary data sheet. All fields should be complete and the codes should be valid as outlined in the contract for services.
6. A random check of 10% of sites involving a thorough (100%) check of all attributes on the hard copy survey form against both the YETI database and the supplementary spreadsheet. The results of this check were recorded and where necessary, the consulting botanist asked to make corrections.

3.7 Landholder Liaison

3.7.1 Unbiased Samples

The site localities selected for survey were ‘tenure blind’ as they were unbiased towards land tenure. To facilitate access to private property sites by the botanist, a systematic and thorough process of contacting landholders was carried out by project staff, with assistance from NSW Department of Lands and individual councils. The methods used for landholder liaison are listed below.

3.7.2 Landholder Contact Details

Lot & Deposited Plan numbers (DP) for randomly selected sites that were located on private property were entered into the NSW Department of Lands Local Government Portal database ‘Integrated Property Inquiry’ (IPI). This database provides the property address to determine the relevant Council boundary. After approval was obtained from the Local Council Privacy Officer, the Council property database was accessed to acquire the names and contact details of landholders and the data entered into an excel spreadsheet. In many instances, a white pages phone book search was carried out to obtain the phone number of the property owner.

3.7.3 Stage 1 Surveys

During the first stage of liaison approximately 81 landholders were contacted in priority areas 1 (Cessnock, Singleton, Muswellbrook and Maitland) and 2 (Merriwa and Upper Hunter). These residents were sent an information package consisting of:

- a letter outlining the project and how they could be involved,
- a information brochure about the Hunter and Central Coast Vegetation Mapping Project,
- an information brochure about the Department of Environment and Conservation’s Atlas database, and
- a consent form for the survey botanist to access the property to complete the survey work and for the on-supply or restriction of the survey results.

3.7.4 Stage 2 Surveys

The second stage of liaison involved follow up phone calls to landholders already sent information packages and to additional landholders in the Central Coast and Merriwa regions. Landholder responses and any updated contact details were recorded in an excel spreadsheet. Any information obtained during the phone call, eg specific requirements for accessing a site, were entered into the excel spreadsheet. This information was then supplied to the botanists.

4. SURVEY RESULTS

Whilst a comprehensive assessment of the survey results for the Hunter, Central and Lower North Coast is beyond the scope of this project, sites located in the Central Coast sub-region have been subject to a detailed analysis as part of the Regionally Significant Vegetation Mapping project (McCauley et al., 2006). Further, it is anticipated that the results from this survey work will form part of future efforts to survey and map the vegetation of the entire study area. In the meantime, some preliminary results are provided below regarding the survey effort, plant species recorded, vegetation communities sampled, and overall condition of the vegetation within the target survey areas.

4.1 Survey Effort

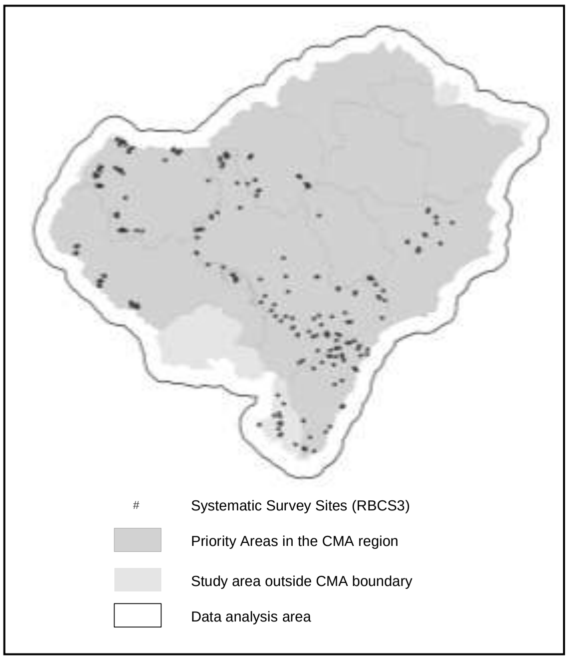
A total of 314 systematic vegetation survey sites were completed for this study. The geographic focus of these surveys were Priority Areas 1, 2 and the Central Coast (Table 4), although additional areas were included in the survey effort as they were poorly sampled by existing sites. These additional regional survey priorities included Great Lakes and Goulburn River regions (Figure 4).

Each field team supplied the results of the systematic survey work as a standard MS Access Database (the YETI database format as supplied by DEC). This information has been provided to the CMA and DEC in fulfilment of contract services and as part of the conditions specified in the NPWS scientific licence to collect plant material.

Table 4: Site frequency within Priority Areas

Area	No. Sites
PA1 – Hunter Valley	75
PA2 – Merriwa Plateau	77
PA3 – Dungog	5
PA4 – Upper Hunter	31
PA5 – Goulburn River	50
Central Coast	58
Great Lakes	18
TOTAL	314

Figure 4: Systematic Site Locations

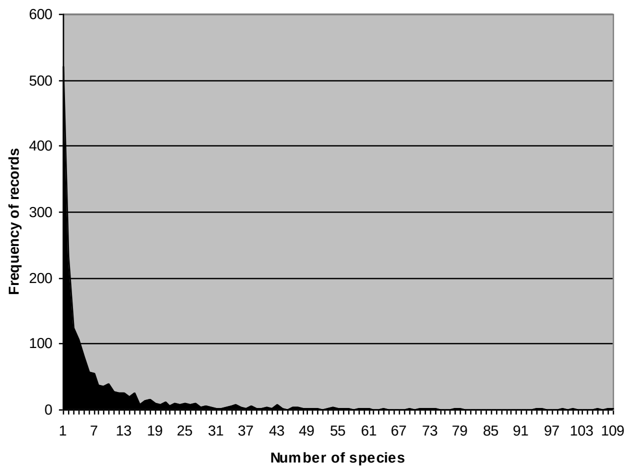


4.2 Plant Species

4.2.1 Species Recorded

A total of 1613 plant species representing 152 Families were recorded by the current surveys (Appendix 3). This number includes species, sub species, unknown species, forms and varieties. The vast majority of these species (65%) were only recorded from within 5 quadrats or less, with 32% of species only recorded from within a single quadrat (Figure 5). The most frequently recorded species included *Dichondra repens* (130 records), *Entolasia stricta* (99), *Glycine clendestina* (123), *Lepidosperma laterale* (93), *Lomandra longifolia* (104), and *Pratia purpurascens* (92).

Figure 5: Frequency of species number recorded



4.2.2 Significant Taxa

Based on a preliminary review of the species recorded within the quadrat samples, new localities have been found for at least 29 significant plant species, including species listed on the Threatened Species Conservation Act 1995 or the Environmental Protection and Biodiversity Conservation Act 1999, species listed as a Rare or Threatened Australian Plant (Briggs and Leigh, 1996), or the species locality extends the known range or limit of its distribution (Table 5). In addition, 21 species of Orchidacea were recorded, some of which may be endangered or vulnerable, (eg. *Chiloglottis* spp. and *Genoplesium* spp.) but all of which are protected under Schedule 13 of the National Parks and Wildlife Act 1974 (Table 6).

Table 5: New Records for Significant Plant Species

Species	Significance	Authority
Acacia fulva	2RC-	ROTAP
Acacia kulnurensis	2RC	ROTAP
Acacia obtusata	range extension	Mullins
Acacia terminalis	Endangered	TSC
Angophora inopina	Vulnerable	TSC, EPBC
Asterolasia buxifolia	Endangered	TSC
Boronia ruppii	Endangered	TSC
Callistemon citrinus	Vulnerable ROTAP	TSC
Callistemon linearifolius	Vulnerable, 2RCi	TSC, ROTAP
Callitris macleayanus	southern limit	Payne
Eucalyptus canonnii	Vulnerable	TSC
Eucalyptus carnea	Southern limit	Bell
Eucalyptus fergusonii subsp. *dorsiventralis*	2RC	ROTAP
Eucalyptus hypostomatica	3RC-	ROTAP
Eucalyptus parramattensis subsp. *decadens*	Vulnerable	TSC, EPBC
Grevillea montana	2VC	ROTAP
Grevillea paviflora ssp. *parviflora*	Vulnerable	TSC, EPBC
Hibbertia procumbens	Endangered	TSC
Homoranthus darwinioides	Vulnerable	TSC
Lastreopsis hispida	Endangered	TSC
Leucopogon confertus	Endangered	TSC
Lomandra fluviatilis	3RCa	ROTAP
Macrozamia flexuosa	2K	ROTAP
Monotaxis macrophylla	Endangered	TSC
Pimelea curviflora	Vulnerable	TSC, EPBC
Rutidosis heterogama	Vulnerable	TSC, EPBC
Sloanea woollsii	southern limit	Payne
Swainsona colutoides	Endangered	TSC
Tetratheca juncea	Vulnerable, 3VCi	TSC, EPBC, ROTAP

Table 6: New Records for ORCHIDACEAE

Acianthus fornicatus
Acianthus spp.
Chiloglottis spp.
Corybas spp.
Cymbidium suave
Dendrobium speciosum
Dendrobium tetragonum
Dipodium punctatum
Dipodium spp.
Eriochilus autumnalis
Genoplesium spp.
Glossodia major
Liparis reflexa
Microtis parviflora
Microtis spp.
Pterostylis longifolia
Pterostylis nutans
Pterostylis parviflora
Pterostylis sp. aff. *revoluta*
Pterostylis spp.
Sarcochilus hillii

4.3 Vegetation Communities

4.3.1 General Observations

A diversity of vegetation types were sampled by the current surveys, ranging from dry rainforest, to tall moist bluegum forest, dry open box woodlands, coastal heaths and wetlands. Whilst it is beyond the scope of this project to conduct an analysis of the vegetation communities that were surveyed, the results of this work will be subject to a detailed analysis as part of Stage 2 of the catchment-wide vegetation community mapping. In the meantime, the following information offers some general observations regarding vegetation communities of conservation significance, the incidence of exotic species, levels of disturbance, and overall vegetation condition. This information is also presented in Appendix 4. It should also be noted that the survey sites located in the Central Coast Region (namely, Gosford, Wyong and Lake Macquarie LGAs) have been incorporated into a sub-regional scale vegetation community classification for the Regionally Significant Vegetation Mapping Project (McCauley et al., 2006).

4.3.2 Communities of Significance

A total of 18 vegetation communities of significance or unusual occurrence were recorded by the field teams, including Endangered Ecological Communities (EEC), communities of restricted distributions, and poorly sampled communities. These communities are listed on the following page.

Significant Plant Communities Surveyed

1. ***Eucalyptus crebra – E.punctata – E.acmenoides – Allocasuarina torulosa* forest** occurs in the Central Coast as a band running along the contour and represents a vegetation type not previously defined (Bell, 2005).
2. ***Melaleuca nodosa* heath** has not previously been identified in the Lake Macquarie area and appears to be very restricted in its extent (Bell, 2005).
3. ***Eucalyptus racemosa – Corymbia gummifera – Banksia serrata* forest** with a heathy understorey dominated by *Xanthorrhoea glauca* is likely to qualify as an EEC but further investigation is required (Bell, 2005).
4. ***Melaleuca nodosa – M.decora* low closed forest** is a poorly sampled community in the region (Bell, 2005).
5. ***Eucalyptus agglomerata* forest** with an understorey of prickly shrubs is a community that is restricted in its occurrence (Bell, 2005).
6. ***Eucalyptus amplifolia – E. teretifolia*** is a community that has been poorly defined by previous classifications and additional work is needed to clarify its characterization and delineation in the landscape (Bell, 2005; also noted as significant by Peake, 2005).
7. ***Melaleuca nodosa – Banksia aemula – Eucalyptus parramattensis* subsp. *decadens*** is a community that has not previously been delineated and has a very limited occurrence in the region (Bell, 2005).
8. ***Eucalyptus sparsifolia – E. punctata – Backhousia myrtifolia*** occurs as a stunted form less than 1m high and has not previously been recorded in the region (Bell, 2005).
9. ***Eucalyptus squamosa* (mallee form) – *Corymbia eximia – Corymbia maculata*** with a heathy understorey. The co-dominance of *E. squamosa – C.eximia* is not known elsewhere (Bell, 2005).
10. ***Corymbia eximia*** as a dominant canopy species does not occur elsewhere in the Cessnock area on Permian sediments (Bell, 2005).
11. ***Eucalyptus tereticornis – Melaleuca quinquenervia – Angophora costata*** is a poorly sampled community (Bell, 2005).
12. **Umina Coastal Sandplain Woodland** is an Endangered Ecological Community (EEC) that was sampled in two plots (Payne, 2005).
13. ***Backhousia myrtifolia* / Dry Rainforest of the Hunter Valley**, considered of conservation significance and recently nominated as an EEC (deLacey and Chamberlain, 2005; Peake, 2005).
14. **Grassy White Box woodland** is an EEC that was recorded from a number of plots in the Upper Hunter (deLacey and Chamberlain, 2005).
15. **Lower Hunter Spotted Gum – Ironbark forest and woodland communities,** an EEC that was recorded at sites in the Lower Hunter (deLacey and Chamberlain, 2005; Peake, 2005).
16. ***Eucalyptus camaldulensis* woodland,** considered to be a significant vegetation community in the region (Peake, 2006).
17. ***Eucalyptus albens – E. moluccana – E. dawsonii* woodland,** considered to be a significant vegetation community in the region (Peake, 2006).
18. ***Casuarina cunninghamiana* riparian woodland,** considered to be a significant vegetation community in the region (Peake, 2006).

4.4 Vegetation Condition

4.4.1 Weeds

Weed species in the Upper Hunter are widespread throughout, although generally low abundance levels were recorded in rocky, inaccessible or drier sites. Problem weed species include Prickly Pear *Opuntia stricta* and Cobbler's Pegs *Bidens pilosa.* Within the ironbark and box woodlands, weed species are widespread but generally at low levels, the most commonly noted being *O. stricta* and species from the Asteraceae (eg. *B. pilosa* and *Conyza* spp.). Weed species are generally more prevalent in vegetation types occurring in areas of higher moisture content, such as river flat communities or open forests in areas of higher rainfall. Sites in the Lower Hunter are similarly affected with dense stands of *Lantana camara* present at some sites.

A number of sites within the Hunter Valley were heavily affected by dense occurrences of *L.camara*, wandering Jew *Tradescantia fluminensis* and a variety of groundcover species.

4.4.2 Feral Species

The most commonly noted feral species in the Upper Hunter sites was the Rabbit, particularly in the drier box-ironbark woodlands. In badly affected sites, the ground cover layer is occasionally almost completely denuded of herb and grass species. Feral goats also appear to be widespread and particularly common in the Stewart's Brook, Moonan Flat, Moon Brook and Lake Glenbawn areas. Most of the survey sites affected by these feral species are on steep slopes and feature easily eroded soils.

4.4.3 Grazing

A significant proportion of sites visited in the Upper and Lower Hunter Valley were subject to cattle grazing with numerous grazing leases present over crown land sites and poor fencing contributing to grazing pressures on reserved crown land.

4.4.4 Fire Regimes

Most sites in the Upper and Lower Hunter showed little evidence of recent fire. In contrast, sites in the Central Coast region were commonly recorded as showing evidence of recent fire and in some circumstances, were severely burnt.

4.4.5 Logging, Clearing, Vegetation Structure

Within the Upper and Lower Hunter Valley, most of the drier woodlands on steep, rocky or inaccessible sites showed little evidence of logging, with low levels of recent logging in most sites within the box-ironbark woodlands. Forests in the Carter's Brook area have been subject to more intense logging,

although within these areas there is good regeneration and large mature hollow-bearing trees. Minor levels of clearing are evident in some areas in the Upper Hunter, mostly at sites adjacent to existing pasture and on less rugged terrain.

4.4.6 Dieback

Some localized areas of tree dieback were recorded, namely along the western fringes of recent extensions to National Park Estate in Barrington Tops. Large areas of dead trees remain within private freehold lands at the western edge of Cater's Brook.

4.4.7 Other Observations

The absence of Eucalypt regeneration in the Upper and Lower Hunter Valley was notable in most areas sampled. Some sites in the Central Coast were modified by trail bike and mountain bike tracks, under scrubbing, mine subsidence, Bellbird activity, and ring barking.

4.3 Results of Landholder Liaison

4.3.1 Landholder Responses

Of the 88 landholders contacted, 23 granted access to their properties for vegetation survey, 5 landholders in priority area 2 and 18 in priority area 1. Within these holdings, 41 sites were surveyed, 18 in priority area 1 and 23 in priority area 2. Although a greater number of landholders were contacted in priority area 1, landholders in priority area 2 tended to own much larger estates that provided greater opportunity for surveying a range of environments. A regional comparison of landholder responses is shown below in Table 7 and Figure 6.

4.3.2 Landholder Concerns

A number of questions were raised by landholders, including:

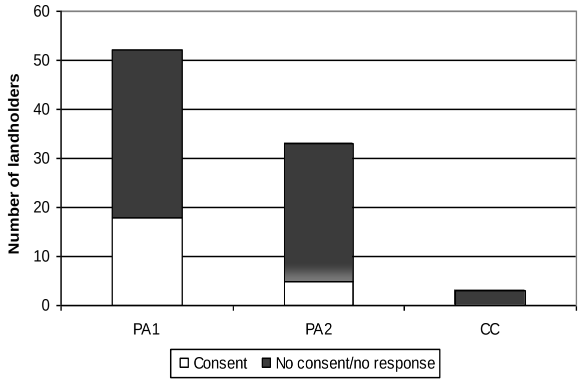
- How long the survey work would take;
- Who would be provided with the survey data;
- The possibility of finding threatened or endangered species which might lead to hindering the activities or plans of the landholder;
- Timing of the survey work;
- Why their property was chosen.

To address some of these concerns, the on-supply of data for some sites was restricted, the botanist was on occasion accompanied by the landholder, and a report on the survey results was sent to each landholder for their specific property.

Table 7: Summary of Landholder Responses

Region	PA1	PA2	CC	Total
Consent given	18	5	0	23
Number of Lot/DP	20	11	0	31
Number of sites secured	18	23	0	41

Figure 6: Response from Landholder Liaison



5. DISCUSSION

The following discussion reviews key findings from data collation, analysis, and field survey work. Comments are also made on the implications of these findings for future catchment-wide surveys and mapping.

5.1 Existing Data

5.1.1 Data availability and formats

The spatial datasets collated for this project were provided in either AGD66 or GDA94 projections. Given that the majority of data was projected as AGD66, this was the datum chosen for the working files on this project. In addition, data was supplied in a variety of formats, including Arcview vector and raster files, ArcInfo and MapInfo formats. Again, as the majority of data was supplied as Arcview files, this format was chosen for the working files. Future analysis of this data and the on-supply of resultant spatial layers would need to consider the needs of end-users and the standards currently adopted by NSW State and Local governments for data projections.

A number of datasets collated for this project were not accompanied by metadata or other supporting documentation. As such, expert knowledge was relied on to provide the information needed to work with some of the spatial layers. Some difficulties were also experienced with the acquisition of specific datasets due to the jurisdictions and responsibilities of data custodians and government agencies with local and regional offices. For example, there is currently no centralized repository for floristic sites data, which was ultimately sourced from individual consultants, project managers, and three separate offices of DEC, with significant overlap in the data each held. Whilst every attempt was made to source as much relevant data as possible, not all survey data was made available to this project, and future work should attempt to negotiate access to this data (eg. developers or their consultants and NSW State Forests, Appendix 1).

5.1.2 Systematic Vegetation Survey Data

Preliminary analysis of the systematic sites data collected for this project suggests that the study area is relatively well sampled, particularly within the Central Coast region and National Park areas of Towarri, Coolah Tops, Mount Royal, Crowdy Bay and Tapin Tops. However, the systematic sites data has not been integrated and is likely to contain a number of duplicate or anomalous records. Furthermore, if additional existing data become available (either from data not previously supplied or from new survey work that has recently been completed), survey priorities are likely to change accordingly. In particular, new surveys have recently been completed for assessments of EECs, development applications within the region, and vegetation mapping in Wollomi (pers com. Connolly 2006, Payne 2006 and Bell 2005). Before a catchment-wide analysis of the vegetation can be completed, this data should be integrated, checked for positional accuracy, duplicate records, botanical nomenclature, survey type and quadrat size, and standardised for cover/abundance scores. Once the sites are vetted and unacceptable data rectified or removed from the analysis dataset, further site selections can take place for catchment-wide surveys and subsequent vegetation community analysis.

5.1.3 Abiotic Data (Predictor Variables)

Whilst the focus of data collation was to acquire datasets relevant to site selection and stage 1 vegetation surveys and mapping, numerous datasets were also collated that could contribute towards future catchment-wide vegetation community mapping, including for example, climatic variables, geology, slope, and aspect. Whilst these data are considered factors that influence vegetation patterns in the region, the obvious omissions are disturbance history (particularly logging and fire history), hydrology, and a consistent soils layer with complete coverage of the study area. As such, additional analysis will be required to generate a suite of predictor variables that can be used for catchment-wide mapping, and in this regard, consultation with DNR and DEC may provide the project scope for completing such work.

5.2 Vegetation Surveys

5.2.1 Data Standards

A range of quality control measures were put in place for the collation and management of systematic vegetation survey data including the use of a standard field survey proforma, attendance at a ‘calibration’ field day by each survey team, the collection of voucher specimens, a 10% random check of the data submitted by each survey team (for all attributes including AMG coordinates), and where necessary, the correction of survey records and confirmation of plant identifications from the Royal Botanic Gardens. The systematic survey data is currently stored in the standard YETI database as the RBCS3 survey (Regional Biodiversity Conservation Strategy phase 3) and additional work is required to integrate all sites data for further analysis. In addition, the voucher specimens should be lodged with the Hunter Regional Botanic Gardens and further liaison is required to secure the ongoing management of this important resource.

5.2.2 Contribution to knowledge

The analysis of environmental variables that are considered key determinants of vegetation patterns within the study area identified a variety of plant habitats based on aspect, rainfall, solar radiation, slope, substrate fertility, and temperature. In the absence of a region-wide vegetation map, site selection for systematic surveys was largely based on this analysis in order to achieve a representative sample of extant vegetation patterns. Whilst further analysis is required to gauge the success of achieving such a sample (particularly when all of the existing sites are taken into consideration), contextual findings suggest that the survey sites are well placed given that they are located in areas not previously visited by local botanists, identified new populations of significant taxa, and sampled a number of significant vegetation communities.

The low levels of sample density and species records within systematic survey datasets are not unusual (cf. NPWS 2002a and 2002b), and for this survey, 32% of species were only recorded from within a single quadrat. Similarly, the entire systematic sites database amounts to a sample of 0.0052% of the study area, a relatively well-sampled region but nonetheless one with many areas yet to be surveyed.

This survey also collected additional attributes for growth stage, habitat values, and disturbance indicators. Whilst this data is often neglected in the analysis of vegetation communities, it offers insight to the condition of extant vegetation and provides a benchmark for monitoring vegetation change.

5.3 Future Survey Priorities

The aim of future systematic vegetation surveys should be to achieve a representative and random sample of vegetation types in the region, among other things. This project provides some useful tools to assist achieving this aim, including a map of vegetation formation, extant vegetation, and plant habitats. However, these tools are intended for use at the regional scale and will not necessarily address local scale priorities (eg. species and communities of conservation significance). As such, a targeted survey effort would be required to address such priorities.

6. CONCLUSIONS

There is a significant amount of information on the natural environments, flora and vegetation for the Hunter, Central and Lower North Coast region of NSW. This data includes GIS spatial data for predictor variables, systematic vegetation survey datasets, administrative boundaries, and remotely sensed imagery. The utility of this data to the next stage of vegetation community mapping is currently limited by the varying formats, coverage and resolution, particularly with regards to the soils data and systematic sites database. Furthermore, additional predictor variables will be required for hydrology (eg. flood frequency, periodicity of inundation) and disturbance history (eg. logging and fire), as these factors are considered to be significant determinants of vegetation patterns in the region.

Additional work is also required for the integration and validation of existing systematic sites data prior to the identification of suitable site locations for catchment-wide surveys. This work will need to take into account botanical nomenclature, cover / abundance schemes, sample size, survey type, duplicate records, currency and overall accuracy. In this regard, a collaborative effort between the NSW Department of Environment and Conservation and the Hunter-Central Rivers CMA may provide efficiencies and avoid duplications.

In identifying priority areas for future catchment-wide surveys, a number of spatial layers are now available to guide site selection, including extant vegetation, vegetation formation and plant habitat mapping. However, in order to achieve non-biased samples, sites should be randomly selected across all land tenures, including State Forest, National Park, Crown Reserve and Private Property. To facilitate such a 'tenure blind' sample, a landholder liaison strategy is strongly recommended in order to achieve the best possible project outcomes. This strategy should specify appropriate measures for the identification of property details, correspondence with land holders, follow-up action, on-supply of survey results, and opportunities for establishing long-term monitoring sites.

In concluding, these surveys collected a vast amount of data on the vegetation of the region, including species composition, vegetation structure, habitat parameters, and condition indicators. The majority of this data may remain unexplored given the propensity to focus on species composition as determinants of vegetation communities. However, there is a unique opportunity to gain insight to the regions ecology, health, and habitat values through exploratory analyses of these additional observations.

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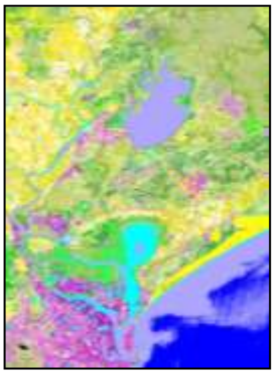
CHAPTER 3



A Rapid Approach to Vegetation Survey: Remote sensing ground truth for vegetation and land cover mapping

Angela McCauley[1]

This chapter describes an approach to rapid vegetation survey and land cover mapping that can aid assessments of species diversity, vegetation condition, and habitat assessment. In this study, the rapid vegetation survey method has been used to assist site selection for remote sensing ground truth and the subsequent assessment and analysis of regional vegetation patterns (refer chapter 5).

Title illustration: Portion of an unsupervised classification of a SPOT5 scene showing the shallow waters of Fullerton Cove (light blue), mangrove vegetation of Kooragang Nature Reserve (green), Stockton Beach (yellow), Newcastle (pink and purple), Grahamestown Dam (mauve), and the Pacific Ocean (dark blue).

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1. INTRODUCTION

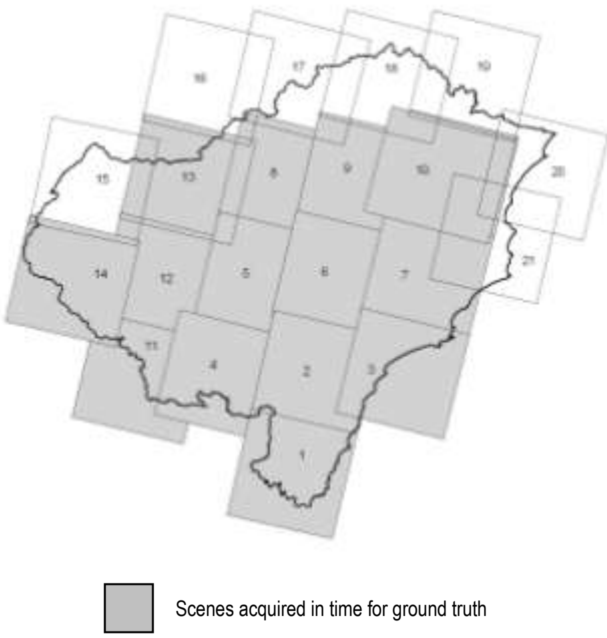
1.1 Background

Vegetation mapping based on remote sensing (either aerial photography or satellite imagery) to delineate vegetation patterns relies on a field-based component (ground truth) to validate the vegetation units identified. The large survey area encompassed by the Hunter, Central and Lower North Coast region, combined with time and resource constraints, necessitated a rapid survey approach whereby field observations could be recorded in a consistent and timely manner to generate a sufficient dataset to guide the attribution of catchment-wide vegetation mapping. This mapping was based on SPOT5 satellite imagery that was recently acquired for the state of NSW as a joint purchase between the Australian Federal and NSW Governments. This imagery was captured between November 2004 and August 2005 and a total of 21 scenes provide complete coverage of the study area (Appendix 5). Only 14 of these scenes were available in time for the field survey component of this project and as such, no ground truth has been completed for the northern and north-eastern most scenes (Figure 1).

1.2 Project Objectives

The specific objectives of the rapid vegetation survey effort were to sample broad land cover types and vegetation patterns that were evident in the SPOT5 satellite data, to maximise the number of sites that could be surveyed within project constraints, and to maximise the geographic coverage of the study area in an attempt to sample the full range of vegetation diversity likely to be present. The outcomes from this work would result in approximately 1,000 rapid sites distributed throughout the survey area that sampled a range of vegetation attributes that relate to their spectral reflectance patterns such as canopy cover, dominant growth form, vegetation type, vegetation density, structural complexity, understorey type, and disturbances.

Figure 1: SPOT5 scenes available for ground truth



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2. SURVEY METHODS

2.1 Preliminary SPOT5 classification

Preliminary SPOT5 image analysis was completed for each of the 14 scenes that had coverage of the study area. For purposes of data management and cross-referencing survey results, each scene was assigned a number, 1 through to 14 (Figure 1). An unsupervised classification of the SPOT5 scene was completed to produce a raster file with a minimum of 70 map units. Each unit was assigned a unique identifier that related to the scene number (eg. 112 for scene 1, map class 12). These outputs were visually assessed with reference to the SPOT5 colour mosaic backdrop in order to determine if the map unit delineated vegetation or other land cover classes, and to assign an appropriate interpretative map label to each class (Appendix 6).

2.2 Site Selection

Sites were selected for rapid vegetation survey based on a random sample of sites within the study area. The precise location of the site was however adjusted to ensure the site intersected with vegetated areas and that access could be achieved (ie. avoid water bodies, cliff lines and private property). In this regard, opportunistic sites were also provided for to maximise the survey effort. Such sites were labeled with the letter ‘r’ to denote a random location (this was chosen in preference to the letter ‘o’ for opportunistic as it is easily confused with zero). The site identification is prefaced by ‘MU’ for ‘map unit’ and is based on the scene and map class being sampled, eg. the site labeled as MU112_t1 denotes the site is located within scene number 1, map class number 12 and is the first target site. Digital photographs taken at the site also have the same site identification reference in the file name.

The total number of sites selected for survey was based on the total area of each map unit to achieve a minimum of:

- 3 sites for each potential vegetated map unit;
- 4 sites if the map unit measured 100 – 1000 ha;
- 5 sites if the map unit was 1000 – 10,000 ha; and
- 6 sites if the map unit was >10,000 ha.

In addition, sites were located within 2km of an access road and within contiguous areas of the same map unit, preferably at least 30m from the map unit boundary. Sites were also aggregated within close proximity to each other in order to minimise travel time wherever possible.

2.3 Standardised Data Collation

Field teams completed a trial survey to ensure consistency between different observers and in data recording. Observations were made and recorded on a standard survey proforma (Figure 2) and into a hand-held pocket PC; both formats were cross-checked to ensure correct data recording. The information recorded at each survey site included 114 attributes according to the following:

- Site details (including AMG coordinates from GPS), aspect, tenure and a general site description.
- Vegetation type (Appendix 7).
- Vegetation description.
- Vegetation cover.
- Dominant species and cover in each strata (or genus level where species cannot be readily determined).
- Growth forms and ground cover types (cf. Walker and Hopkins, 1990).
- Level and type of disturbance (eg. clearing, logging, erosion, feral species, fire, weeds and grazing).
- Growth stage of the canopy.
- Habitat parameters, such as tree hollows, bark types, presence of beyonettes and bare branches.
- Substrate type and any other general observations relevant to the site.
- At least two high resolution digital photographs.

The data was supplied to Hunter Councils as an excel spreadsheet and as hard copy proformas. To ensure data entry accuracy and completeness, a random cross-check of 10% of the data with the original survey proforma was performed and rectified as necessary.

2.4 Site Location and Observation

Target sites were located by entering way points into a Garmin12 differential global positioning system (GPS) and driving as close to the destination as possible. The site was then located by traversing to the target area until a GPS reading within 10m of the map coordinate was achieved. Once at the site, a temporary marker was placed at the centre point, and all observations within a 10m radius of the centre point were recorded on the standard field proforma. A nearby alternative site location would be chosen by the surveyor if the original supplied site was inaccessible.

Figure 2: Rapid Vegetation Survey Proforma

Rapid Vegetation Survey Proforma

Survey ID: ....
Site ID: .... Date: ....
Surveyor: .... API: .... Photo ....
E _ _ _ _ _ _ N _ _ _ _ _ _ _ +/- _ _ _ m _ _ _ASL
Datum / Projection: .... Aspect: ....
Tenure / Name: ....
Veg / Site Description ....
....
Specht: ....

Emergent…...% Canopy…...% Mid…...% Understorey…...% Groundcover…...%

Species (*if sampled)	Cover	Strata	Ht.	*Circ.*	*Dist.*
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

Community: ....

0 = Not Present 2 = Occasional (5-25%) 4 = Very Common (50-75%)
1 = Rare (<5%) 3 = Common (25-50%) 5 = Abundant (>75%)

Tree .... Heath .... Fern....................................
Shrub .... Grass .... Woody Vine ....
Mallee .... Sedge / Rush .... Wiry Vine..........................
Cycad .... Palm .... Grass Tree ....
Fungi .... Lichen .... Moss/Bryo ....
Herbs .... Algae .... Lithophytes ....
Epiphytes .... Parasites .... Rock ....
Litter .... Logs .... Bare ....
Debris.................. Other ....
....

Clearing............... Logging / Old..................... / Recent.................
Erosion .... Ferals .... Fire ....
(Epicormic……..Scar…….Coppice…….. Scorch……… Charred……..)
Weeds..................... Grazing............................. Other ....

Regen %.............. Mature %.............. Senesc. % ....
Hollows (S)......... (M)........................ (L) ....
Beyonettes .... Bare Branches .... Other ....
Smooth .... Stringy..................... Papery ....
Box...................... Ironbark .... Tessellated......................
Corky .... Other ....
Notes (eg. substrate) ....
....

3. PRELIMINARY ANALYSIS

3.1 Objectives

To assist the final analysis of satellite data (Chapter 4) and the interpretation of survey results, preliminary analysis was completed for the first block of scenes as exploratory analysis (scenes 1, 2, and 3 covering the Central Coast sub-region). A series of vegetation attributes were derived from the field data based on the likelihood that these attributes would influence spectral reflectance patterns.

These attributes include:

1. Emergents
2. Density Index
3. Moisture Index
4. Standardised vegetation description
5. NVIS
6. Growth Stage
7. Condition Index
8. Height of Upper Strata
9. Structural Complexity Index

3.2 Emergents

Emergents are considered to represent a height differences between vegetation strata, namely emergent strata, canopy strata and sub-strata. Where a difference of >= 5m is detected, this will be considered as a structural difference in the vegetation and hence, an emergent strata present. The presence of emergents at each site was identified by applying the following rule set to the data:

The difference between emergent height and canopy height [Emergent_Ht_m] - [Canopy_Ht].

- Where emergent or canopy height had a score (was present).
- Where the difference in height values was >=5m.

The difference between canopy height and substrata height [Canopy_Ht]-[Substrata_Ht].

- Where canopy or substrata height had a score (was present).
- Where the difference in height values was >=5m.
- Where canopy cover score is =< 20% and the canopy cover score is =< the substrata cover score.

Emergents with a cover score of >=20% and no canopy were excluded.

3.3 Vegetation Density

Vegetation density is considered to be a function of form, cover and strata. Accordingly, the following rule set was applied in the derivation of a density index. A unique list of species for the Central Coast was generated. Each species was allocated a density score based on foliage and crown characteristics. Where the taxa was unknown, the density score was assigned to a broad vegetation type (Table 1).

Table 1: Density Scores and Values

Density	Density
Very sparse	1
Sparse	2
Moderate	3
Dense	4
Very dense	5

Density calculations were based on:

d x csp = dsp

(dsp + dsp + dsp) / n = dst

(dst + dst + dst + dst + dst) * p = sds

d = density assigned to each individual species
csp = cover score for each species
cst = cover score for each strata
dsp = density score for each species
n = number of species in each strata
p = number of strata at each site (all 5 strata)
sds = site density score

3.4 Vegetation Wetness Index

Vegetation moisture is considered to represent the level of moisture taken up by the plant species present at a site. Some taxa are typically associated with moist environments (eg. rainforest) or boggy sites (eg. Typha swamp), whilst others are associated with dry exposed sites (eg. Spotted Gum woodland). In many circumstances however, the individual strata reflect different types of moisture availability and hence, it is not straightforward to merely assign a moisture index for a site based on one strata alone. An expert review process was used to assign a level of moisture indicated by the complement of different plant types in all strata (Table 2).

Table 2: Moisture Levels and Vegetation Wetness

Moisture Level	Vegetation Wetness Index	Examples
Very dry	1	Foredune vegetation
Dry	2	Banksia heath
Moderately Dry	3	Angophora Eucalypt forest with a mixed understorey
Moderate	4	Melaleuca thicket with Eucalypt emergents
Moderately Wet	5	Wet sclerophyll Eucalypt forest
Wet	6	Rainforest with Eucalypt emergents
Very Wet	7	Typha wetland

3.5 Standardised Vegetation Description

Two standardised vegetation descriptions were assigned by expert review: a Specht classification and a descriptive classification. The Specht classes were relatively straightforward based on the form and cover of the uppermost strata (Appendix 7). The process for standardising vegetation descriptions involved reviewing the dominant species in each strata and creating a description that characterised the vegetation, comparing this with the description recorded by the field teams, and adjusting the final labels until the total number of unique descriptors was reduced as much as possible without losing information.

3.6 NVIS

A hierarchical vegetation classification was developed by the National Land and Water Resources Audit in an attempt to standardize vegetation mapping, namely the National Vegetation Information System or NVIS (Land and Water Australia, 2001). Whilst NVIS classes range from 1 (broad class) to 6 (sub-association), the aim of the current work was to achieve a broad description and as such, level III in the hierarchy was chosen as the most appropriate class. Field data was assigned to the standard NVIS classes by expert review based on form, height, and dominant species in each strata (Table 3).

Table 3: NVIS Hierarchy

NVIS Level	NVIS Description	Description
I	Class	Dominant growth form of the ecologically dominant stratum.
II	Structural formation	Height of the ecologically dominant stratum.
	Structural formation	Cover of the ecologically dominant stratum.
III	Broad floristic formation	Broad floristic code usually dominant land cover genus of the uppermost or dominant stratum.
IV	Sub-formation	Dominant genus of the understorey / substrata.
	Sub-formation	Dominant genus of the ground cover.
V	Association	Dominant growth form, height, cover and species (three species) of the three traditional strata.
VI	Sub-association	Dominant growth form, height, cover and species (five species) of all layers / strata.

3.7 Growth Stage

Growth stage was collected in the field as a relative canopy cover percentage for each of the three main growth stages for typically Eucalypt and related species:

- Regeneration [Regen],
- Mature [Mature], and
- Senescence [Senesc].

The sum of the three fields = 100%. The rule set that was applied to the data is listed in Table 4.

Table 4: Rule set for assigning Growth Stage

Regen (%)	Mature (%)	Senec (%)	Description	Growth stage score
>=95			Re-growth	1
>=80			Young	2
	>=80		Mature	3
<80	<80	<80	Multi age	4
		>=80	Old	5
		>=95	Very Old	6

3.8 Condition Index

The condition index is a relative score, essentially the sum of the scores for 'adverse circumstances' in each plot (fires, feral species, weeds, etc) scaled amongst the plots so that plots with no scores for adversities have a condition of 100%. The condition score = the sum of the following fields:

- Clearing
- Logging (old)
- Logging (recent)
- Erosion
- Ferals
- Fire
- Epicormic
- Scar
- Coppice
- Scorch
- Charred
- Weeds
- Grazing
- Other disturbance
- Hollows (small)
- Hollows (medium)
- Hollows (large)
- Beyonettes
- Bare branches
- Other habitat

Condition Index Calculations:

Condition (%) = (the maximum condition score – condition score) / maximum condition score x 100

3.9 Height of Upper Strata

The height of the each strata (m) was recorded in the field for each site. For this analysis, the height of the upper-most strata present at each site was used, with precedence given to the tallest stratum in the following order: emergent, canopy, sub-strata, understory then ground cover.

3.10 Structural Complexity Index

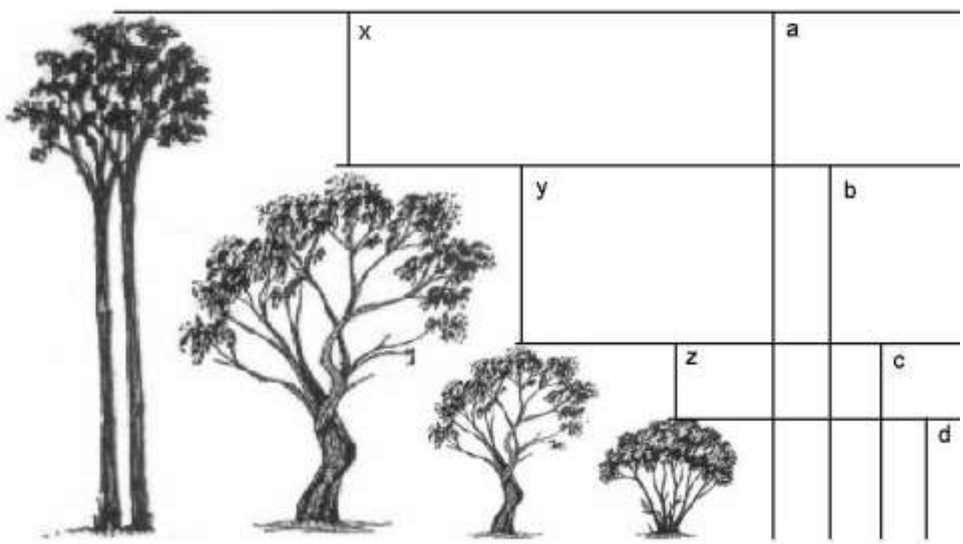
The structural complexity index is considered to represent the complexity in terms of height between each strata. The greater the distance between each strata, the higher the structural complexity index for any given site.

a = height of emergent strata
b = height of canopy strata
c = height of substrata strata
d = height of understory strata
p = the number of strata at each site (excluding ground cover)

$$a - b = x$$
$$b - c = y$$
$$c - d = z$$
$$(x + y + z) * p$$

Using the above equation sites with only an understory were not identified as being different from sites with only a ground cover. Sites with an understory only were assigned a structural complexity of 1.

Figure 3: Strata used to derive structural complexity



4. RESULTS

4.1 SPOT5 Scene Classifications

A total of 14 SPOT5 scenes covering the Hunter and Central Coast region have been classified to produce broad vegetation and land cover maps for each scene. The resultant map units were reviewed relative to the SPOT5 colour backdrop and assigned an interim interpretive label for the purposes of rapid survey site selection. An example of one of these classified scenes is presented in Figure 5 along with the interpretive map units listed in the map legend. Whilst all these scenes were interpreted for vegetation cover, time constraints precluded an assessment of all land cover classes for every classified scene. Furthermore, the interpretive map labels have not been standardised, again due to time constraints. Nonetheless, this process provided the necessary information needed to target rapid vegetation surveys predominantly within vegetated areas that have similar reflectance patterns. In this regard, the classifications provide a 'stratification' of satellite data for ground truth that will subsequently be used to guide catchment-wide vegetation mapping (Chapter 4).

4.2 Rapid Surveys

4.2.1 Overview

A total of 922 rapid vegetation survey sites were completed throughout the Study Area, sampling 229 unique vegetation map units within scenes 1 through to 14 (Figure 4). Surveys were completed between September 2005 and February 2006. In most circumstances, one rapid site could be completed within approximately 15 minutes, although the travel time to and from the site varied depending on accessibility. The survey effort was maximised by the proximal location of the sites on route to other target sites.

The results of the rapid surveys also include a digital photo library with over 2000 photographs that cross-reference to the site identifications and therefore can be geo-referenced. A summary of the survey results is provided in the tables below for vegetation descriptions, growth stage, and disturbance, whilst a comprehensive list of all site attributes is included in Appendix 8.

4.2.2 Vegetation Types

Whilst a range of vegetation types were sampled, the main types were open woodland (45%) and woodland (24%). Other vegetation types surveyed included isolated trees, grassland, heathland, shrubland, mangroves, and rainforest (Table 5 and photographs on pages 32 and 33).

Figure 4: Rapid Vegetation Survey Sites

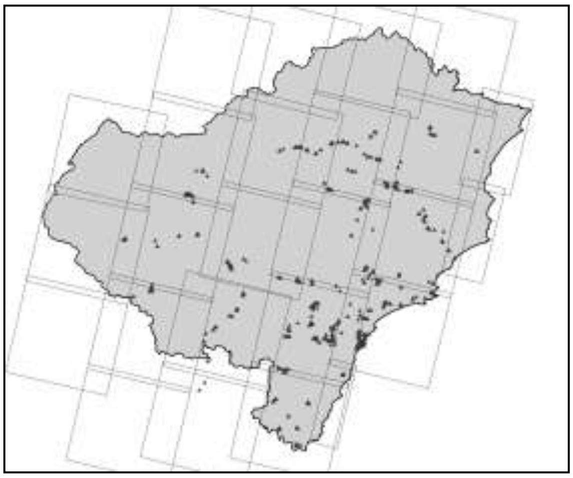
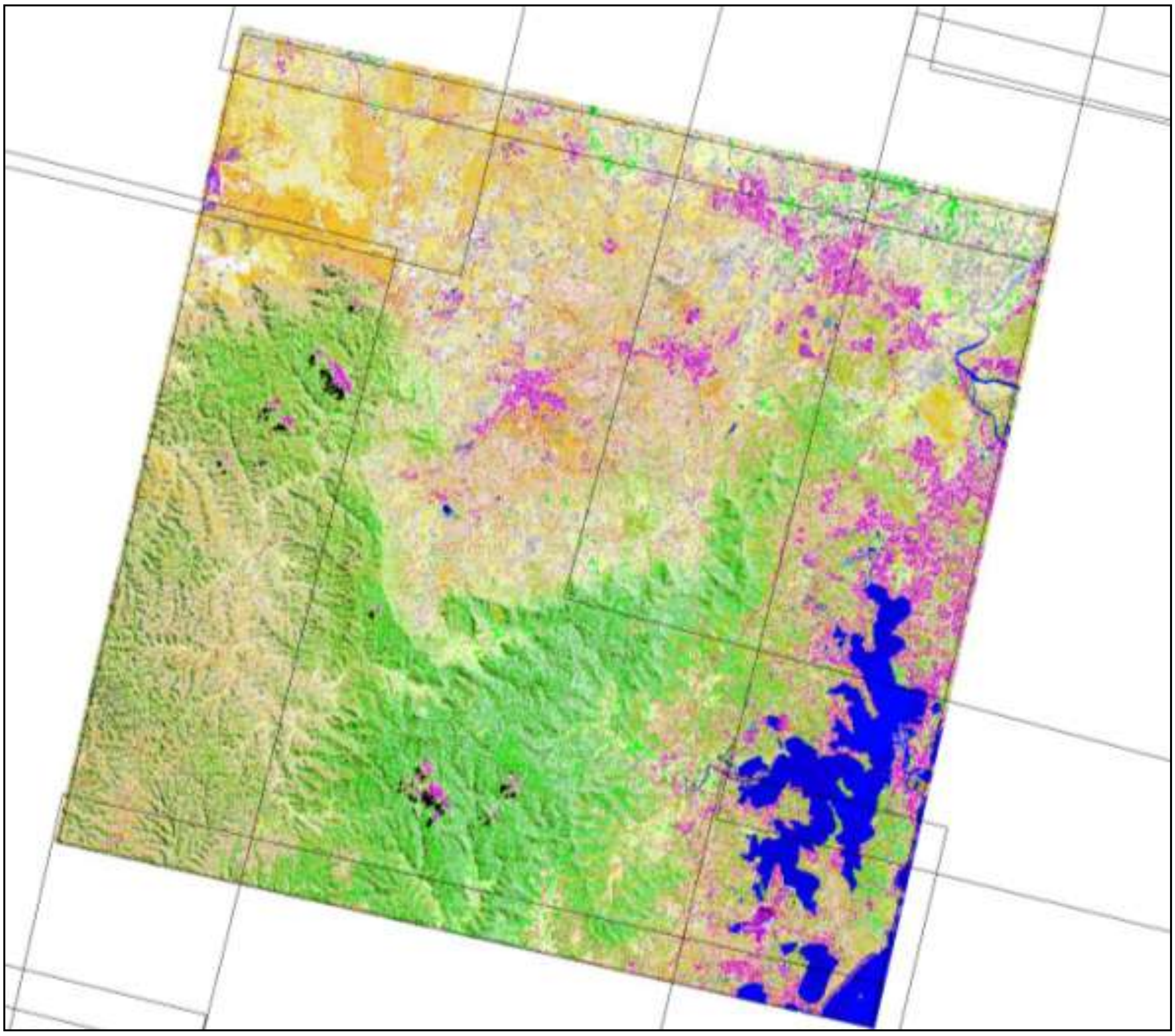


Table 5: Main Types of Vegetation Sampled

Vegetation Description	Sites	%
Open Woodland	417	45.2
Woodland	220	23.9
Open Forest	47	5.1
Isolated Trees	29	3.1
Forest	27	2.9
Grassland	17	1.8
Closed Shrubland	12	1.3
Sod Grassland	9	1.0
Rushland	9	1.0
Open Grassland	8	0.9
Heathland	8	0.9
Open Shrubland	7	0.8
Woodland / Open forest	6	0.7
Sod Grassland	5	0.5
Closed Heathland	5	0.5
Water	3	0.3
Shrubland	3	0.3
Mangrove	3	0.3
Closed Sod Grassland	3	0.3
Woodland / Open Woodland	2	0.2
Woodland (Acacia dominant)	2	0.2
Wetland Complex	2	0.2
Shrubland	2	0.2
Rainforest	2	0.2
Open Woodland (Acacia dominant)	2	0.2
Isolated Grass	2	0.2
Fernland	2	0.2
Closed Rushland	2	0.2
Closed Grassland	2	0.2
Cleared Land	2	0.2
Casuarina Open Forest	2	0.2
Acacia Woodland	2	0.2
Total*	864	93.7

* The remaining sites list a further 58 vegetation descriptions, however these only contribute a relatively small percentage to the overall sample.

Figure 5: Classified Scene No. 2 (scene number 389416_150305)



Crops
Rocky Eucalypt Scrub / Vegetation edge
Sparse Eucalypt / minor scrubby Pasture
North Slope Scrub
Eucalypt
Dry Eucalypt
Eastern Eucalypt
Eucalypt
Dry Eucalypt
Moist Coast Forest 2
Moist Coastal Forest
Exposed Ridge Edge Vegetation
Dry Slope Scrub
Protected Ridge Edge Vegetation
Fragmented Vegetation / North-facing Scrub
Sheltered Eucalypt
Sheltered Eucalypt 2
Sheltered Eucalypt 3
South-facing Gully Vegetation
Sparse Vegetation
Very Fragmented Vegetation
Native Grasses?

Surf?
Shallow Water / Coal Sludge?
Very Shallow Water / Coal Sludge?
Shallow Water
Water
Water
Water / Minor Cloud Shadow / Coal
Water / Minor Cloud Shadow
River Edge / Minor Cloud Shadow / Coal
Coal / Road / Shadow
Shadowy Vegetation? / other
Cloud Shadow / Shadowy Gully

No Data

Building / Excavation / Glare
Building / Urban
Building / Urban
Building
Bare Ground / Building Glare / Urban
Mine / Coal / Road / Urban
Urban Road / Cleared
Urban / Road / Coal
Building
Building / Urban
Building
Bare Ground / Building Glare / Urban

Almost bare pasture
Native Grasses2?
Native Grasses?
Pasture1
Pasture2
Pasture3
Pasture4
Pasture5
Pasture6
Almost bare ground
Native Grasses? / Pasture
Bare Ground / Excavation

NOTE: Cloud cover is included in the non-vegetated classes

Site Photographs of Vegetation Types Sampled (site reference in brackets)

1. Isolated trees on sandstone outcrop (r01b_251005_02)

2. Callitris open woodland (mu1339_t1_02)

3. Grassland with scattered trees (mu236_t3_01)

4. Ironbark open woodland (mu1252_t2_01)

5. Grassland (mu1335_t3_01)

6. Paperbark forest (mu335_t4_01)

Site Photographs (….continued)

7. Riparian vegetation (mu657_t2_01)

8. Coastal heath (pilot_r95_02)

9. Rainforest (mu934_t5_01)

10. Mangrove vegetation (mu347_t1_01)

11. Wet sclerophyll forest (mu1040_t3_02)

12. Wetland (mu353_t1_02)

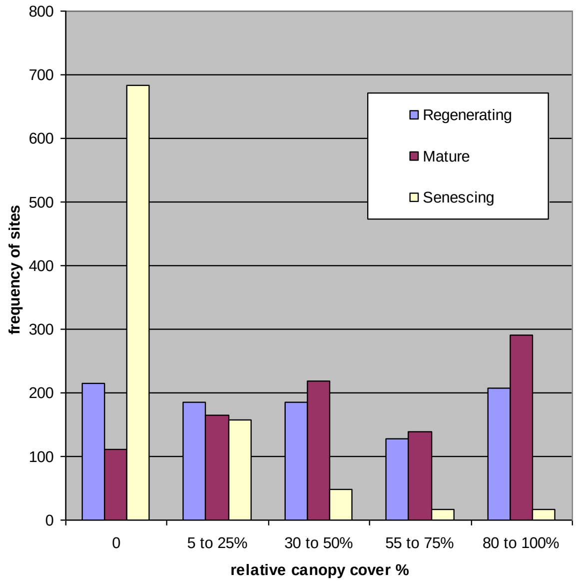
4.2.3 Growth Stage

The growth stage of canopy trees for regenerating, mature and senescing forms, was recorded as 5% increments at every site where trees were present. This information has been compressed into 5 classes to illustrate the main trends in the data (Table 6 and Figure 6). In summary, the main canopy component (>50% relative ccp) comprised regenerating trees at 336 sites, mature trees at 429 sites, and senescing (old growth) trees at 33 sites.

Table 6: Canopy Growth Stage

% Canopy	Number of Sites		
	Regen	Mature	Senesce
0	215	111	683
5 to 25%	186	164	157
30 to 50%	185	218	49
55 to 75%	128	139	16
80 to 100%	208	290	17

Figure 6: Growth Stage



4.2.4 Disturbance Types

Evidence of environmental perturbations relating to erosion (E), grazing (G), weeds (W), fire (F), and logging (old – Lo and recent – Lr), were recorded at each rapid survey site as an abundance score or otherwise as a % of the area affected (Table 7). The vast majority of sites showed no evidence of these events, although weeds were common to abundant at a large proportion of sites (17%) and evidence of fire was often recorded.

Table 7: Disturbance Types

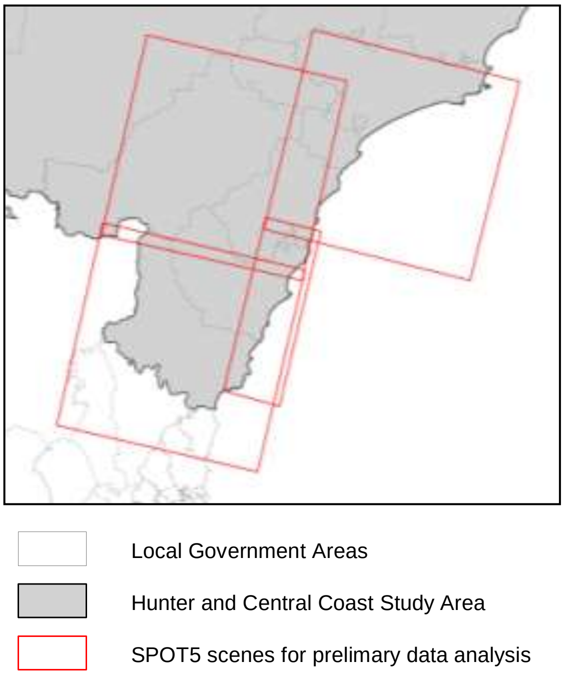
Disturbance	E%	G%	W%	F%	Lo%	Lr%
Not present	67.8	88.3	60.8	51.2	83.9	86.4
Rare (<5%)	18.1	3.9	12.5	34.5	9.7	6.8
Occasional (5-25%)	10.4	2.5	9.8	9.2	4.7	4.4
Common (24-50%)	3.4	2.5	9.5	4.4	1.6	1.6
Very Common (50-75%)	0.2	1.7	4.2	0.5	0.1	0.3
Abundant (>75%)	0.1	1.1	3.1	0.1	0	0.3

4.3 Preliminary Data Analysis

4.3.1 Analysis Area

A preliminary analysis of rapid survey data was completed for sites located within the Central Coast area (Figure 7) as an input to sub-regional scale vegetation mapping (refer to Chapter 4). The results of this analysis include standardised vegetation descriptions, growth stage, and structural complexity, which are discussed in turn below. Other indices were also generated for NVIS, height of the upper strata, and condition. Where attributes could be readily derived, sites outside of the Central Coast area were also assigned the relevant scores and this data has been included in the digital database.

Figure 7: Area for Preliminary Analysis



4.3.2 Standardised Descriptions

A total of 170 unique vegetation descriptions were derived for a total of 577 rapid survey sites (Appendix 9). Of these, the most frequently recorded vegetation types were Eucalypt woodland with a grassy understorey, Eucalypt woodland with a sclerophyll understorey, Eucalypt woodland with a shrubby understorey, Tea Tree thicket with emergents, Grassy paddocks, Banksia heath with emergents, and Eucalypt open woodland with a shrubby understorey (Table 8).

Table 8: Standardised Vegetation Units

Standardised Vegetation Description	Site Freq.
Eucalypt woodland with grassy understorey	26
Eucalypt woodland with sclerophyll understorey	17
Eucalypt woodland with shrubby understorey	17
Tea Tree Thicket with emergents	17
Grassy Paddocks	16
Banksia heath with emergents	13
Eucalypt open woodland with shrubby understorey	13
Angophora - Eucalypt woodland with mixed understorey	11
Eucalypt open woodland with grassy understorey	9
Eucalypt forest with mixed understorey	7
Eucalypt open woodland with sclerophyll understorey	7
Mangroves	7
Turpentine forest or woodland	6
Weed thicket	6
Wetland	6
Angophora - Eucalypt woodland with sclerophyll understorey	5
Rainforest with Eucalypt emergents	5
Casuarina forest	4
Eucalypt woodland with grass trees	4
Eucalypt woodland with mixed understorey (lillys)	4
Isolated Eucalypt trees with grassy understorey	4
Melaleuca thicket with Eucalypt emergents	4

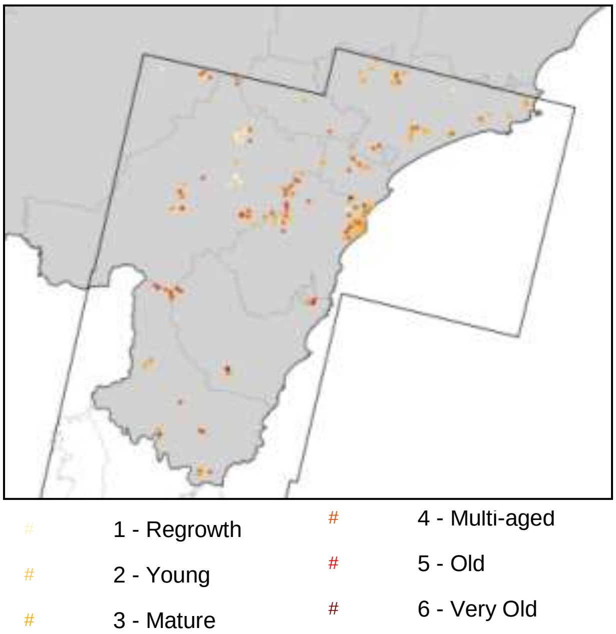
4.3.3 Growth Stage

Vegetation growth stage was derived for a total of 344 sites, although 13 of these had no growth stage recorded (Table 9). The majority of these sites supported either mature or multi-aged forests and woodlands (69%), with old growth vegetation only being recorded at 5 sites (1.5%). The distribution of these sites reported by growth stage is illustrated in Figure 8.

Table 9: Derived Growth Stages

Growth Stage	Site Frequency	% of Sites
Not recorded	13	3.9
Regrowth	38	11
Young	49	14.2
Mature	104	30.2
Multi-aged	135	39.2
Old	3	0.9
Very Old	2	0.6

Figure 8: Distribution of Sites by Growth Stage



4.3.4 Structural Complexity

Structural complexity scores were generated for all rapid survey sites, with scores ranging from 0 to 148. Whilst nearly 20% of sites had a score of 0, 35% of sites (322) fell in the mid range of 20 to 60 (Figure 9). The distribution of sites illustrating structural complexity scores is illustrated in Figure 10.

Figure 9: Structural Complexity and Site Frequency

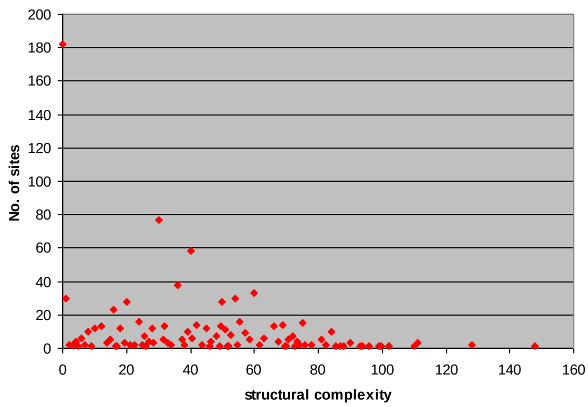
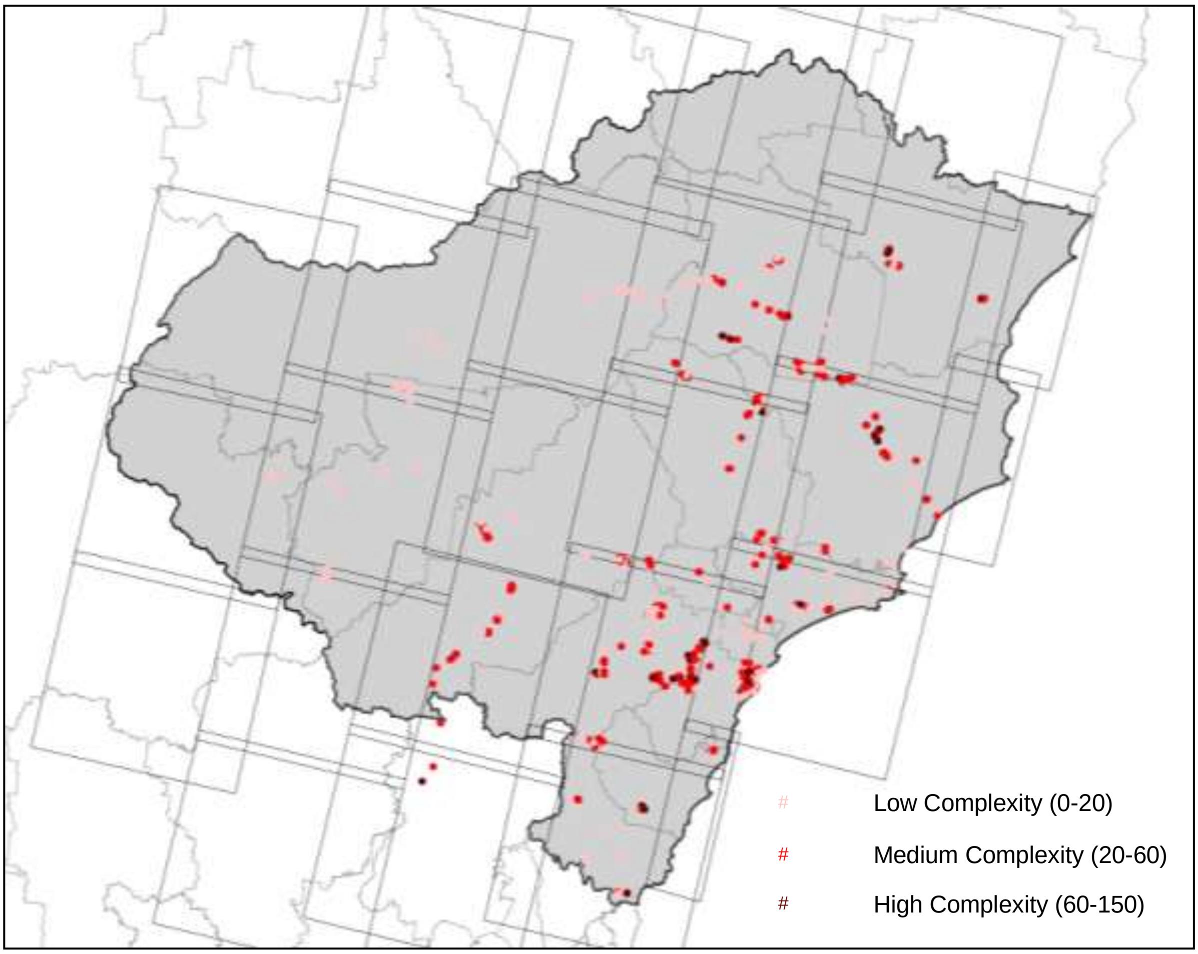


Figure 10: Relative Structural Complexity



5. KEY FINDINGS

5.1 SPOT5 Data

From the 21 SPOT5 scenes that provide complete coverage of the study area, a total of 14 scenes were classified and interpreted for the purpose of assisting rapid survey site selection. The remaining 7 scenes were received from DNR late in the project and as such, were not available in time for the analysis. Time constraints also precluded the interpretation of all land cover classes for each of the classified scenes, and instead, priority was assigned to interpreting extant vegetation classes given this was the focus of the survey effort.

Notwithstanding the incomplete nature of the individual SPOT5 scene analysis, this data warrants further consideration as it provides sub-regional scale map data (in contrast to the catchment-wide mapping that is presented in the following section). This mapping is particularly useful for the delineation of extant vegetation at the 10m pixel resolution and could be used for targeting specific land cover classes, such as wetlands, rainforest, and riparian vegetation.

5.2 Rapid Vegetation Survey

The rapid vegetation surveys sampled a wide range of environments throughout the study area, covering 14 scenes and yielding 922 survey sites. An abundance of data can be recorded using this technique, which takes around 15 minutes to complete one site (excluding travel time). This data includes observations on vegetation type, structure, composition, diversity, habitat value, and disturbance indicators. Whilst sites were selected from within areas that exhibited relatively homogenous patterns in the classified SPOT5 scene, some map classes were located in extremely inaccessible areas (eg. private land, steep terrain) or otherwise occurred as isolated pixels within a heterogeneous land cover pattern. This limitation may be overcome by generating a smaller number of map classes in the initial classification.

Unfortunately, due to time constraints, a detailed analysis of the rapid survey results was not completed for this study. Instead, the data has been used to inform catchment-wide mapping and vegetation mapping for the Central Coast sub-region. To assist this work, some preliminary analysis was completed for growth stage, disturbance types, and structural complexity.

5.3 Future Work

Clearly, there is an abundance of information generated from the rapid vegetation surveys and mapping of individual SPOT5 scenes, although at this stage, only a small portion of this data has been used in elucidating vegetation patterns and ecological process for the regions plant diversity. The following recommendations are therefore made in order to complete work that was constrained by time and resources, or that can otherwise be undertaken in order to identify some key areas where this data can be further utilised:

1. Complete an unsupervised classification of the remaining 7 SPOT5 scenes, interpret the resultant map units and complete rapid surveys in these areas.
2. Conduct further analysis of rapid survey results to elucidate vegetation patterns, disturbance regimes, habitat potential, and vegetation condition. This analysis could also include the same attributes that were also recorded during systematic vegetation surveys completed for this study.
3. These survey results could be used to inform individual scene classifications to produce higher resolution catchment-wide mapping or sub-regional scale data products. This data could also be used to assist the delineation of specific land cover classes via the application of supervised classification techniques.

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Walker, J. and Hopkins, M. S. (1990). **Vegetation.** In McDonald, R. C.; Isbell, R. F.; Speight, J. G.; Walker, J.; and Hopkins, M. S. (1990). Australian Soil and Land Survey Field Handbook. Second Edition (pp. 58-86). Inkata Press, Sydney. ISBN 0-909605-64-5.

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CHAPTER 4

Mapping Vegetation Cover and Vegetation Formation from SPOT5 Satellite Imagery

Anders Siggins, Kimberley Opie, Darius Culvenor, Neil Sims and Glenn Newnham [1]

This chapter details the methods used to map vegetation cover and formation based on the analysis and classification of SPOT5 satellite imagery and rapid field assessment techniques. The results of the mapping are discussed and maps are presented in the attached CD.

Title illustration: The SPOT5 satellite.

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1. INTRODUCTION

The objective of the vegetation mapping project component is to create a range of classified map products for the Hunter, Central and Lower North Coast Region of NSW from SPOT 5 satellite data. This section describes the methods used to create a seamless mosaic of 22 separate images, captured between November 2004 and August 2005, the techniques used to classify the mosaic for the purposes of identifying a range of vegetation cover types across the study area, and a description of the landcover characteristics of the classes identified within the images.

The major steps used in this project are:

1. Radiometric correction to minimise the influence of solar, atmospheric and sensor artefacts on the image data,
2. Masking unwanted parts of the images from the analysis,
3. The use of a range of methods to seamlessly join adjacent images to one another,
4. Unsupervised and supervised classification procedures to discriminate key landcover types throughout the study area, and
5. The assignment of a vegetation description to each class based on field data.

The main limitations of this mapping work were directly related to analysing 22 separate SPOT5 scenes as one mosaic. As the 22 scenes were collected over significant seasonal variation, comparing similar vegetation communities across two different scenes relied heavily on the presence of field data in those regions. Over 900 detailed field data records were collected for the study, but time and effort practicalities resulted in large regions of the catchment having no field data samples. This scale difference between the field data and image data substantially complicates the process of identifying the landcover characteristics in each class shown in the classified maps.

2. MATERIALS AND METHODS

2.1 Satellite Image Data

This project uses digital image data captured by the SPOT5 satellite. This imagery was purchased as part of a New South Wales State Government state-wide coverage of SPOT5 imagery that will ultimately be made available for widespread use by organisations such as local councils and catchment management authorities.

In general, SPOT5 imagery can be described as having moderately fine spatial resolution, which enables identification of a high level of detail at the landscape scale, but low spectral resolution as it records radiance in a small number of spectrally broad wavelength bands (Table 1). The low spectral resolution of SPOT5 imagery limits the range of landcover types that can be identified within it and the accuracy with which landcover types can be differentiated from one another.

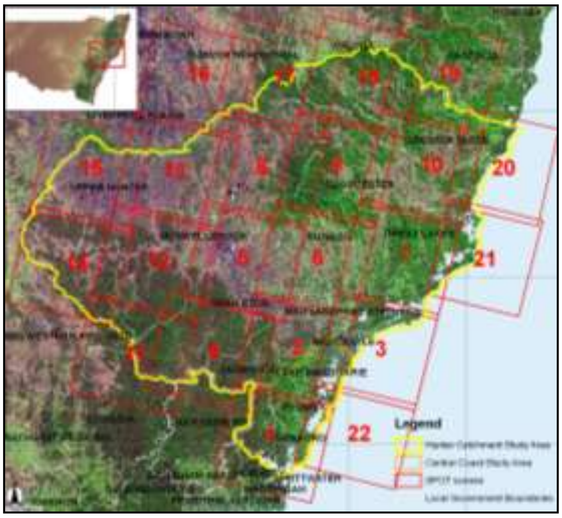
The acquisition and pre-processing of these images was managed by Raytheon. Pre-processing included orthorectification to account for topographic variations in the spatial registration of the images to a map grid, and image calibration to reduce the influence of solar, atmospheric and sensor characteristics on the image data. Full coverage of the study area required 22 full SPOT5 scenes captured over a period between November 2004 and August 2005 (Figure 1).

[1] ENSIS (formerly Forestry and Forest Products, CSIRO), Clayton South VIC 3169

Table 1: Spatial and spectral characteristics of SPOT 5 images.

Spectral Bands and spatial resolution	Two panchromatic (5 m) bands combined to generate a single 2.5 m resolution band Three multispectral bands at 10 m resolution One short-wave infrared at 20 m resolution
Spectral Range	Pan: 0.48 – 0.71 µm Green: 0.59 – 0.59 µm Red: 0.61 – 0.68 µm Near infrared (NIR): 0.78 – 0.89 µm Short-wave infrared (SWIR): 1.58 – 1.75 µm
Image Swath	60 km x 60 km-80 km (dependent on view angle)
Raw Positional Accuracy	< 50 m (1 σ) on flat terrain without ground control points
View angle	+/- 31.06 degrees

Figure 1: Coverage of SPOT5 Scenes



Note: The Hunter, Central and Lower North Coast study area illustrated with an overlay of the SPOT5 scene boundaries.

2.2 Seamless Mosaic Creation

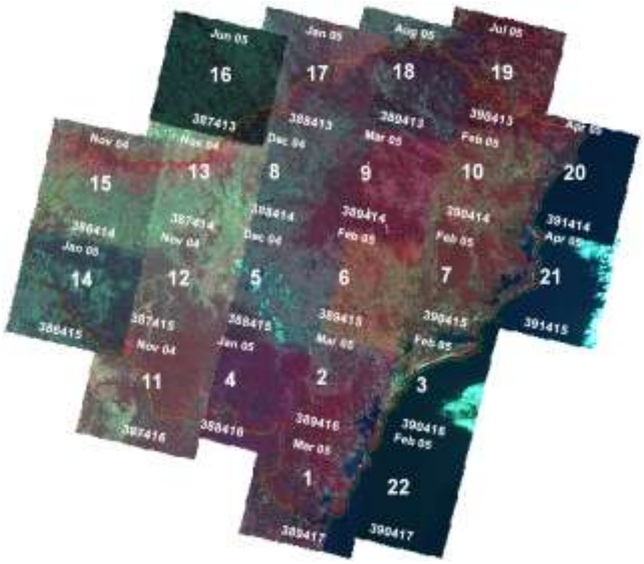
The long period of time over which the images were captured means that each image has a different spectral character (Figure 2). These differences are caused by variations in atmospheric conditions including moisture and particulate levels, sun angle and brightness differences. In addition, the landscape itself is constantly changing in response to climatic and seasonal changes, and more gradually due to weathering etc. The overall effect is to create a patchwork of different image brightness levels across the study area.

A requirement for this study was the creation of seamless data classifications. This was achieved using the following procedures:

- Each image was corrected for the influence of solar illumination and sensor orientation variations based on image capture time, date, and sensor orientation parameters for each scene (provided by Raytheon; Appendix 10).
- Dark-pixel subtraction was applied to each scene to minimise spectral offsets caused by atmospheric path radiance.
- Empirical line correction was performed on mismatching scenes as required, where substantial brightness differences between images remained.
- Image cropping was applied to scenes lying on the edge of the study boundary and a buffer of 1,500 m applied. This buffered boundary was used for the final map production in order to avoid map slivers or inconsistencies with other map coverages or extents (Note: the 10km buffer that was applied to data collation was not used in this analysis due to the unmanageable file sizes that would have been generated by the raw SPOT5 imagery).
- A mosaic of the 22 scenes was created in ENVI 4.2 image processing software (Research Systems Inc., 2005).

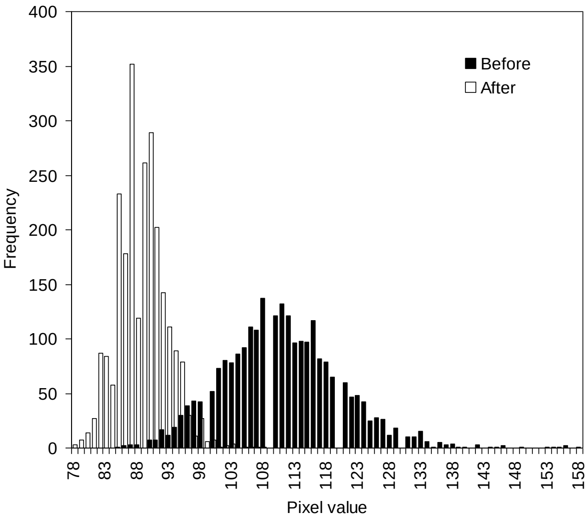
Interrogation of the image mosaic indicated that the colour matching algorithm used to join images in ENVI tended to reduce the spectral variance of the images. This was particularly evident in Band 3 (NIR, Figure 3). This reduced data range may affect the separability of classes during classification due to the 8-bit quantisation of data. Data ranges for each band in the final image mosaic were normalised by stretching pixel values in each band from 0-255.

Figure 2: SPOT5 Image Mosaic



NOTE: SPOT5 image mosaic showing scene numbers and collection dates for the images used in this project. The catchment boundary is shown in red and a 1.5km buffer around the catchment is shown in green

Figure 3: Compressed range of data values following creation of the image mosaic.



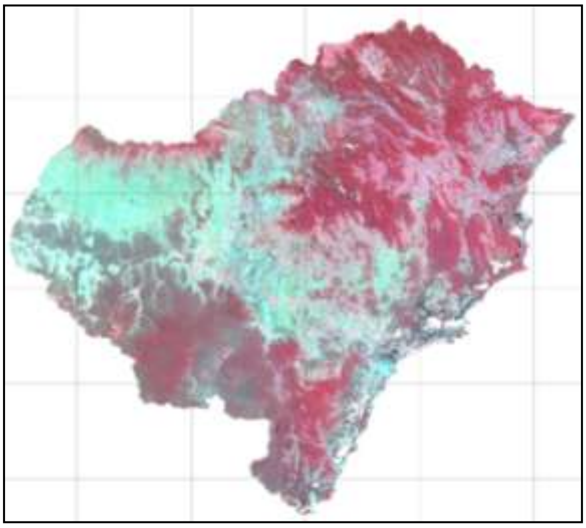
In practice, creating a seamless mosaic from these images is a time-consuming, iterative process in which parameters for image brightness adjustment are repeatedly refined until there is no visible separation between images. For example, the priority set for the overlap region between two scenes had a significant effect on brightness discontinuity of the boundary. In other cases, results were improved by mosaicing two problematic scenes independently and then joining this to the larger mosaic. The resultant seamless mosaic is shown in Figure 4.

2.3 Field Data

The entire field dataset for the catchment was unavailable at the beginning of the study, and field data were provided in two stages for analysis. The first datasets covered the Central Coast region and was supplied in the form of a table containing 344 sites. Each site has detailed form and species information that needed to be aggregated into a broader vegetation index before SPOT5 image analysis could begin. In order to provide a standardized vegetation description for each of the sites, the 344 sites were grouped into 22 unique land cover descriptions (refer to Chapter 3).

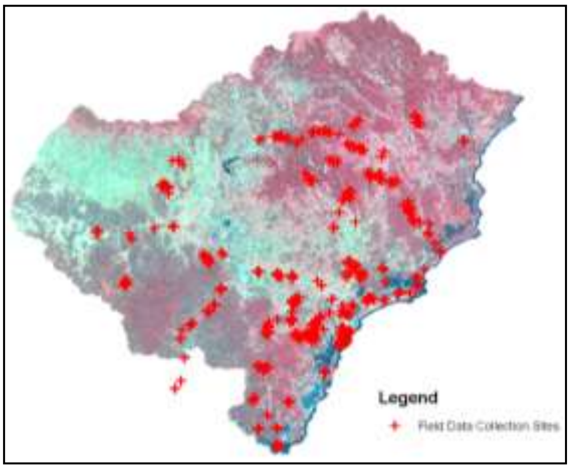
The second dataset included descriptions of the dominant and subdominant species in each of five vegetation strata, cover proportions, height and structure of vegetation at 922 sites across the entire study area. Site attributes for which field data were collected in this project are listed in Appendix 11. The location of these survey sites is illustrated in Figure 5.

Figure 4: Mosaic of SPOT5 Scenes for the Study Area



NOTE: This seamless mosaic of 22 SPOT5 scenes provide coverage of the Hunter, Central and Lower North Coast study area.

Figure 5: Field data collection points



Of the 922 sites, there were 800 unique vegetation descriptions, and considerable filtering was required to standardize and reduce the number of descriptions to a level suitable for use in classification. To reduce the number of field classes, computer algorithms were written to simplify the highly detailed descriptions. The derived class names usually included vegetation type descriptions (e.g. Open Woodland, Forest, Closed Shrubland, Isolated Trees), canopy type (species) descriptions, and a description of either the sub-canopy or understorey strata (e.g. *Eucalyptus* Woodland with Bracken Fern Understorey; Open Coachwood Forest with Privet Understorey). This resulted in 359 unique land cover descriptions.

2.4 Image Classification

Classification was performed for both stages of the project; at the sub-regional scale for the Central Coast and for the entire Hunter, Central and Lower North Coast study area.

2.4.1 Central Coast (Stage 1)

The Central Coast area extends north from the Hawkesbury River/Broken Bay to Nelson Bay/Port Stephens. Classification of the Central Coast region required parts of the mosaic originating from four SPOT5 images (Scenes 1, 2, 3 and 22 in Figure 2). Classification was performed using all SPOT5 bands and two additional spectral indices derived from these band mosaics; the Normalised Difference Vegetation Index, (NDVI) which has been associated with plant vigour and biomass (Tucker, 1979), and the Shortwave Infrared Water Stress Index, (WSI) which has been associated with canopy water stress (Fensholt et al, 2003). Only areas of water were masked from the image for classification. A 'k-means' classification was applied to these data for the purpose of interrogating the resulting classes.

A field dataset was produced that listed the locations and vegetation descriptions for various points within the catchment. Field data points were spatially located within the mosaic and a region of 100 metres by 100 metres, centred on each field data point location, was used to determine the local image classes associated with that vegetation description. Image classes were then weighted by the inverse of their geographic distance from the field data point and the accumulated weights for each class were used to assign the probability that the class represented the vegetation description for that field data point. The highest probability class was then assigned with the vegetation description for that data point.

Relatively high redundancy in the data (344 field data points describing 22 vegetation descriptions) allowed an iterative process to be developed for assigning final vegetation descriptions to classes. In the first instance, if a single class was consistently assigned a particular vegetation description with a high probability in all instances then that vegetation description was considered appropriate. If more than one class was confidently assigned the same vegetation description then these classes were merged. A new classification was then produced, masking out any confidently-assigned classes. This process was performed over a number of iterations and all remaining classes given the vegetation description with the greatest accumulated probability.

A number of merging functions were used to increase class assignment confidence. First, classes were merged that had very similar vegetation descriptions and were judged to be indistinguishable given the inherent limitations of the SPOT5 dataset. Second, classes were merged where the spectral class separability did not give sufficient confidence in the discrimination of the vegetation descriptions. Consultation with Hunter Councils produced a final list of descriptions based on the vegetation descriptions obtained from image class statistics and local field knowledge.

Mangrove areas were addressed separately, using a supervised classification of the raw SPOT5 bands and a digital elevation model (DEM). Training data for the classification was derived directly from the data in known areas of mangrove cover. This mangrove class was added to the vegetation description with priority over previously assigned class descriptions.

2.4.2 Catchment Scale (Stage 2)

For the entire study area, a k-means classification was applied to the mosaic data and the 100 metre by 100 metre region around each field data point again analysed, using the same weighting procedure, to determine probabilities of classes corresponding to the vegetation description of the field data. Due to the size of the catchment mosaic, the iterative procedure developed for the Central Coast sub-region was shortened to keep processing time within practical limits. Unlike the Central Coast region, areas identified by the woody vegetation mask as being non-woody vegetation, as well as mangrove areas identified using supervised classification of the mosaic and DEM, were not included in the classification process. This was done to ensure that the resulting classification would produce image classes with the least 'mixed' vegetation.

The variability of land cover types across the catchment also added an additional layer of complexity to the classification. There were large regions across the catchment that were not represented in the field data. Consequently, it is assumed that various other important land cover types were not represented in the field dataset. This reduces confidence in the final classification descriptions. As a means of partially addressing this issue, at each iteration non-vegetated classes were identified using visual interpretation of the data. Water bodies, along with flooded mangrove regions, were also identified and an appropriate description assigned. Classes with assigned vegetation descriptions, non-vegetated classes and water classes were then masked out, and the classification and class description assignment procedure performed again over the rest of the mosaic. Classes that remained unnamed after the final iteration were then assigned the vegetation description with the greatest accumulated probability. Once again, the merging of classes was performed via subjective assessment of vegetation description similarity and lack of spectral class separability in order to increase class description confidence.

3. RESULTS

3.1 Masking

Masks created from the SPOT imagery were used to eliminate non-vegetated areas from the mosaic, to focus the classification only on the regions of interest. First, a water mask was created to eliminate inundated areas from the scene (Figure 6). The mask was created by applying a threshold to the NIR wavelengths, which have a very low reflectance from deep clear water. Pixels below a certain value were identified as water, and others dry. This mask clearly identifies areas of relatively deep, clear water, but some areas of shallow or highly turbid water remain.

A non-woody vegetation mask was created from an unsupervised classification of the SPOT5 mosaic (Figure 7). This mask includes areas identified as water, and urban or pasture areas. Non-woody vegetation areas occupy approximately 50 percent of the study area.

Figure 6: Water Mask for the Study Area

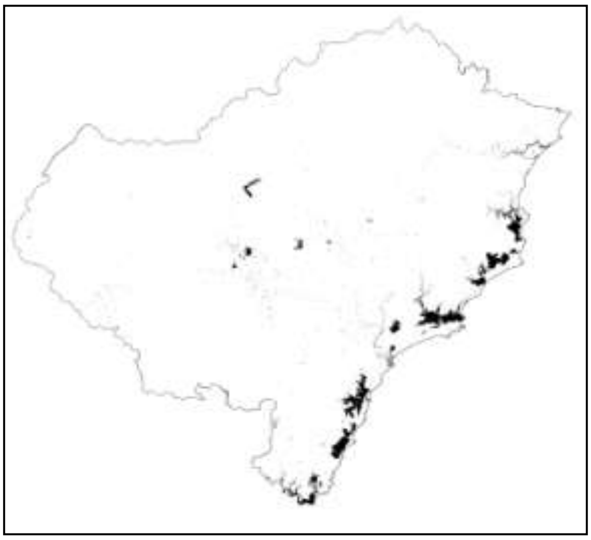
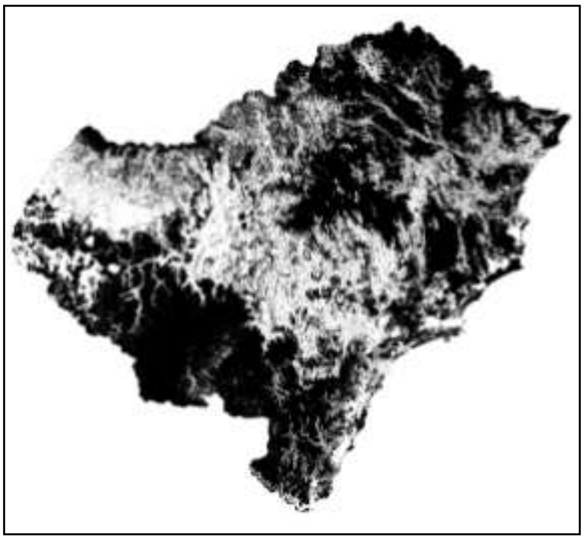


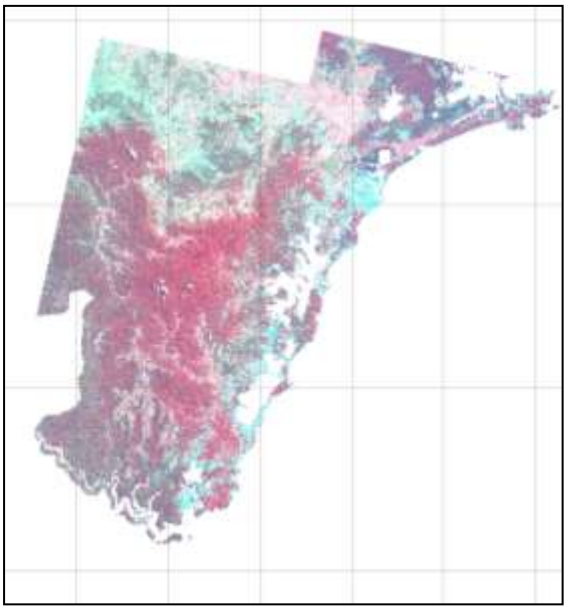
Figure 7: Woody Non-Woody Mask for the Study Area



3.2 Central Coast Classification

The SPOT5 mosaic over the Central Coast region had no visible seams and very small areas of localised clouds (Figure 8). This area contains a wide range of landcover types including cities, grasslands, forests, and several areas of rushes, mangroves and sedges near estuaries and wetlands.

Figure 8: SPOT5 Image Mosaic for the Central Coast



NOTE: SPOT5 image mosaic over the Central Coast region with the non-vegetation and water mask applied

The Central Coast mosaic was classified into 40 classes which were grouped into 22 landcover types based on the apparent spatial coherence of each class, and on class separability metrics (Jeffries-Matusita distance) calculated in ENVI. This classification indicates that the Central Coast sub-region is dominated by Eucalypt Woodlands and Grasslands, with localised areas of mangroves (Figure 9). Landcover descriptions at each field sampling location in the Central Coast study area are provided in Appendix 12.

3.3 Catchment Scale

The catchment-scale mosaic (Figure 4) was classified into 100 classes using a mask which removed areas of water and non-woody vegetation for the classification process. The resulting image classes were then allocated a vegetation description by considering the statistical relationship between that image class and the field data (using the same process as described for the Central Coast region), local knowledge of specific areas (Wollomi Sandstone, Goulbourn River, and Barrington Tops), and landscape elements such as riparian zones or slope aspect. The final vegetation descriptions were

then grouped into 49 vegetation types (Figure 10). At this scale, the study area is dominated by Eucalypt Open Woodlands and Mixed Woodlands with smaller areas of Rainforests. Landcover descriptions at each field sampling location are provided in Appendix 13

4. DISCUSSION

4.1 Overview

Satellite remote sensing is the only way to economically provide information about the landscape composition and structure of large areas at fine resolution. Digital image data from satellites such as SPOT5 have found a wide range of applications in resource and environmental research, and are commonly incorporated into the monitoring and mapping programs of many institutions. Image data are now commercially available from a large number of sensors with diverse spectral and spatial characteristics, and each sensor has it's strengths and weaknesses. The Hyperion satellite, for example, provides hyperspectral image data (more than 200 spectral bands) which provides enormous potential for spectral discrimination of features on the land surface, such as differing nutrition levels in plant foliage (Coops, 2002). Hyperion images are small, however (about 8km EW by 42km NS) and the data are extremely noisy and prone to influence from atmospheric conditions. MODIS, in contrast, provides daily coverage of most parts of the globe, but has large pixels between 250m and 1000m in size.

The advantages of SPOT5 imagery include its relatively fine spatial resolution, moderately large scene size (Table 1) and high signal to noise ratio. In addition, the NSW state wide coverage acquired by the NSW government makes these images widely available to many institutions that may not previously have used satellite image data. The main limitation of SPOT5 imagery is its low spectral resolution, having only 4 multispectral bands. This is amongst the lowest spectral resolution of the commercially available multispectral satellite sensors, the effect of which is to limit the number of landcover types that can be identified in the images and the accuracy with which they can be delineated. This project looked at several other technical issues that were encountered during the project which also influenced the processing methods and the character of the outputs from this work. These issues are described below.

4.2 Woody versus non-woody

To apply the method developed in the Central Coast classification to the entire catchment, it was necessary to limit the classification results to areas identified as being composed of woody vegetation. This was done to reduce the effect of unevenly distributed field data points in sparse vegetation areas, and to maximise the spectral variation between the 100 classes across the woody vegetation. Due to the variation in spectral characteristics of the vegetation across the 22 SPOT5 scenes, it was very difficult to accurately separate some woody vegetation areas in one part of the mosaic from some non-woody vegetation areas in another part of the mosaic. Visual analysis of the final woody vegetation mask showed that there were some minor inconsistencies, notably in the drier western areas of the catchment, where some vegetation had the same spectral characteristics as dark soils in the east (Figure 11).

Irrigated agricultural paddocks in the central section of the catchment were also difficult to separate from moist vegetation in the northeast.

4.3 Seams in the mosaic

The spectral character of satellite images of the earth is influenced by a wide range of factors, including atmospheric and solar conditions, sensor calibration and true changes in the condition of objects on the land surface. These factors can make two images of the same part of the earth captured on different dates appear very different, and classification of those images may produce widely different results. The mosaic created in this project contains a large number of images, captured over a long period of time and in different seasonal and climatic conditions. Consequently, it is highly unlikely that the mosaic will be entirely free of seam artefacts.

Processing to remove seams between images in the mosaic included correction for atmospheric, solar and sensor artefacts in each image, and image calibration balancing during the addition of each new image into the mosaic. While these procedures minimise the appearance of seams between images, they also affect the spectral characteristics of the images, which can alter the results of classification.

One process in particular, edge smoothing, was used to reduce visual image artefacts associated with integrating multiple images into the mosaic dataset. One consequence of this technique is that it 'grades' pixel values in the overlap zones between adjacent images. This can increase the spectral similarity (thus reducing the separability) of different landcover types near to the edges of each scene. Conversely, edge smoothing may create a new class in the overlap zone due to the interpolation of pixel values. This was evident in the

mosaic created in this project and, though these 'seam classes' occupied relatively few pixels, their spectral distinctiveness from the remainder of the pixels in the image meant that about 10% of the total number of classes identified during classification contained only pixels in the merge zones. These pixels have been included in the Non-Vegetation mask and it may be possible to refine future classification procedures to better account for these processing artefacts.

4.4 Scale differences between the image and field data

In addition to the limited spectral resolution of the SPOT5 images, the other principle limitation of this project resulted from differences in scale between the data measured in the SPOT5 images and the data measured in the field at each sampling site. The spatial resolution of the SPOT5 sensor is 10m in the visible and NIR range, which means that each data point recorded by the sensor is an integration of the reflectance of every component of the land surface within that 10m by 10m pixel area. In contrast, the field data provided for this project included highly detailed descriptions of the vegetation characteristics within a very localised area surrounding sampling points. When viewed quantitatively, this field data can indicate very different landcover characteristics between adjacent sampling points. The high level of detail recorded by the field crews is also indicated by there being more than 900 unique identifiers of landcover type amongst the plots sampled throughout the study area. This level of detail is not discernable within the SPOT5 imagery (nor probably within image data from any commercially available sensor) and serves primarily to complicate the task of identifying the true landcover characteristics within each image class. Consequently, substantial effort was allocated to transforming intricate field descriptions into useful categories that could be used as class descriptions over the catchment.

We recommend that field data for future studies of this kind should consider the resolution and field of view of the sensor being used when the level of detail and range of landcover features to be sampled is being determined. Features beneath dense vegetation canopies will be largely invisible to a sensor looking straight down, for example.

Often, the best classifications are achieved by identifying areas of homogeneous landcover types in the field, which encompass distinctive vegetation community types and soil characteristics, and then using those 'training areas' to seed statistical models of the spectral character of the data at the commencement of classification. Ideally, several training areas will be located for each class into which the image is being identified, which provides a more robust statistical basis for the detection and separation of classes. This 'supervised classification' technique is best suited to areas where the character of the landcover is known, where the landscape is not especially complex and where training sites are available for all landcover types in the study area. Unsupervised classification techniques, such as were primarily used in this project, are best suited to large and complex landscapes where the landcover characteristics are poorly known, such as was the case in this project.

5. CONCLUSION

Satellite remote sensing is the most economical and accurate means of acquiring information about landcover characteristics over large areas at fine-scale. With the increased availability of satellite data, such as via the NSW state wide purchase of SPOT 5 imagery, the range of applications, and the accuracy of results, is likely to increase. The range of spatial and spectral characteristics of satellite image data is also increasing, and each data type is best suited to particular applications.

SPOT 5 data provides a moderately high level of spatial detail at the landscape scale, but has a relatively small spectral resolution compared to many other commercially available satellite image data products. This limits the range of landcover types that can be identified using SPOT imagery, and the potential to discriminate between them. These results have been affected by the limitations of the image data, and the mismatch in scales between the data recorded by the SPOT sensor and field data describing landcover characteristics throughout the study area. While it is important to consider the limitations of the techniques used when interpreting these results, the maps produced in this project represent amongst the best possible results using this imagery and field data, and with current best practice image processing techniques over this large area.

6. RECOMMENDATIONS

6.1 Revised extant vegetation layer

A revised woody non-woody (extant) vegetation layer could be generated either from the classification of blocks of data clipped from the SPOT5 mosaic (preferably that reflect like-environs or a similar capture date) or alternatively from individual SPOT5 scenes. The results of these classifications could then be merged to produce a seamless vegetation coverage. A revised vegetation layer would address the issues of:

- The omission of remnant and scattered vegetation cover
- The inclusion of water bodies with the vegetation units
- The inclusion of agricultural areas with vegetation units

6.2 Revised Classification

A 100-group classification based on the revised extant vegetation layer could be re-run to identify the vegetation types currently omitted from the catchment mapping.

6.3 Cloud Cover

Vegetated areas that are obscured by cloud cover need to be identified by alternative means, either from a SPOT5 scene with a different capture date, aerial photography or existing mapping.

6.4 Supervised Classifications

Targeted (or supervised) classifications for specific and problematic vegetation types could be completed to aid the delineation of:

- upland swamps (eg. Barrington)
- rainforest
- riparian vegetation
- coastal wetlands.

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Research Systems Inc. (2005) **ENVI: The Environment for Visualising Images,** Version 4.2. Boulder, Colorado.

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ACKNOWLEDGEMENTS

This project was undertaken in close collaboration with Hunter Central Coast Regional Environmental Management Strategy team, in particular, Angela McCauley and Martin Stuart. Valuable input was provided by Ensis staff Dr. Jacqui England and Jonathan Brabner.

Figure 11: Woody vegetation delineation problems in catchment west. Mosaic (a) and mask (b). Note: Dark areas in mask represent woody vegetation

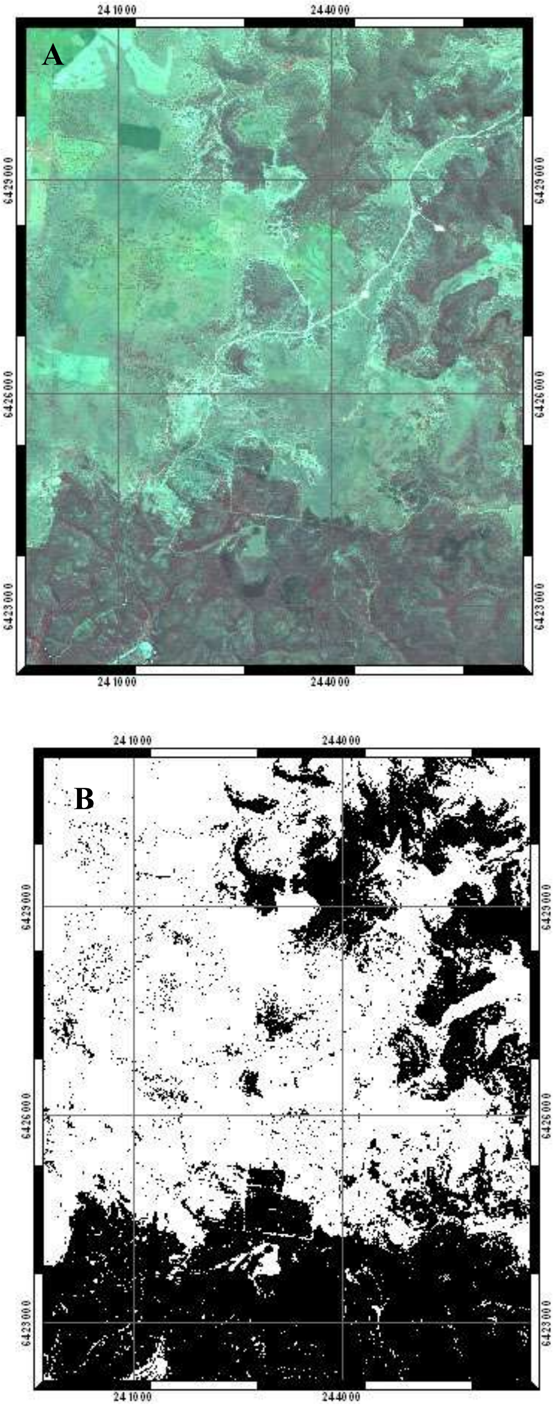
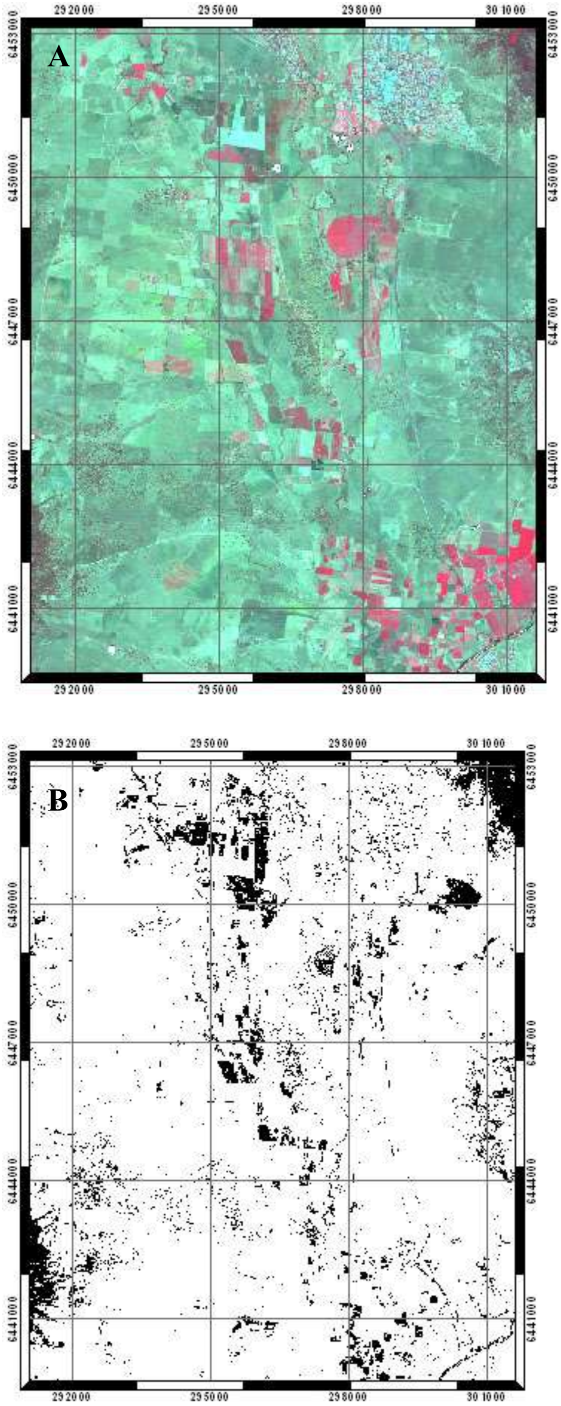


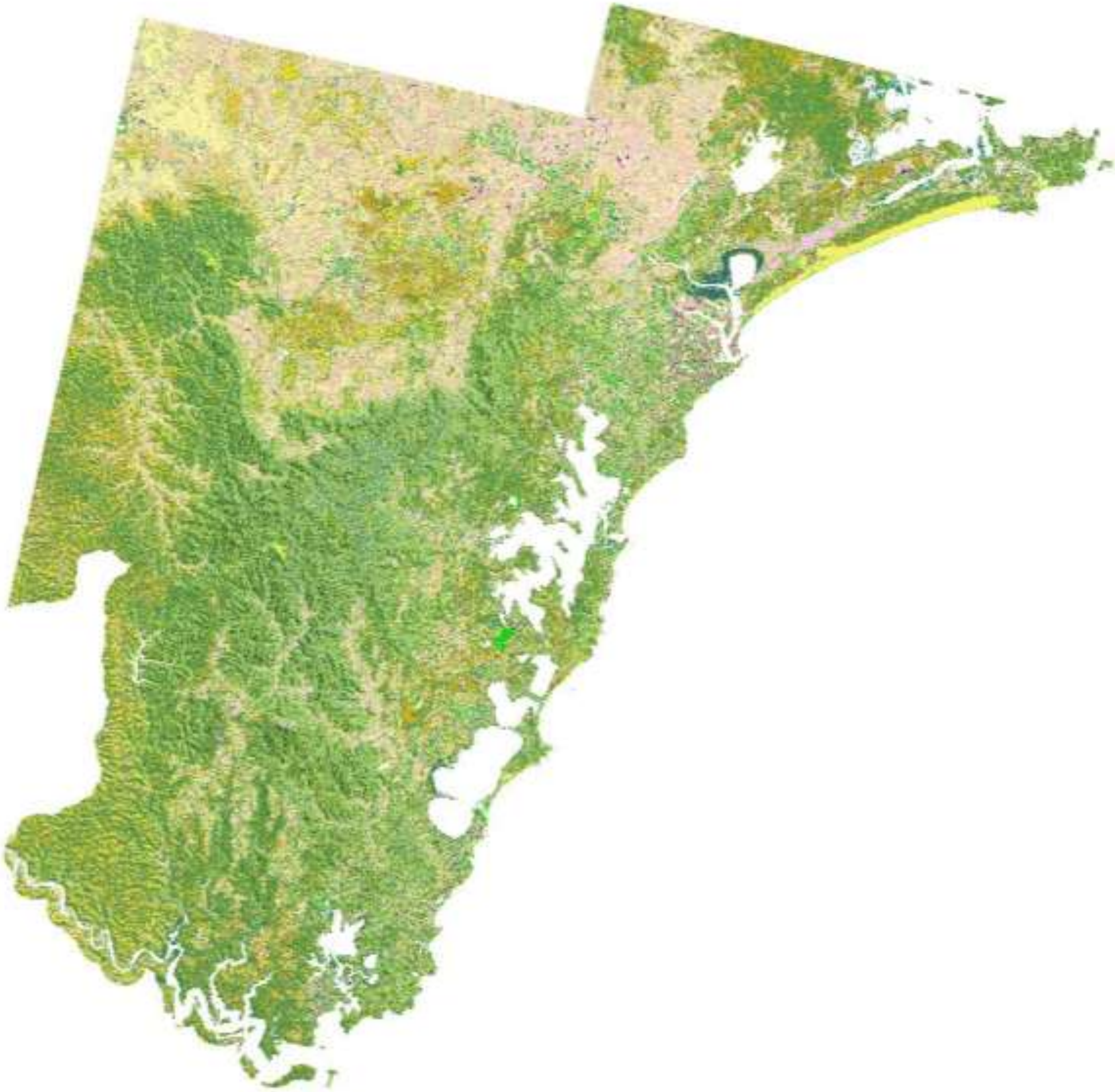
Figure 12: Woody vegetation delineation problems in centre of catchment. Mosaic (a) shows dark soil and irrigated paddocks in dark green and red respectively, and mask (b). Note: Dark areas in mask represent woody vegetation.



These irrigated paddocks represent a very small area of the catchment, and should not adversely affect the proportion of woody vegetation estimated across the catchment. At the catchment scale, the loss of drier vegetation may be seen as acceptable, however, when analysing only those areas affected, it may prove to be an important underestimation of woody vegetation.

Analysis of the Central Coast region's woody mask suggests that by creating woody masks for smaller areas, the inconsistencies associated with assessing vegetation across such diverse spectral variation would be avoided. The mosaic could be segmented into smaller areas, separating the mosaic into distinct vegetation regions (such as the drier west, the moist centre, and the wetter coastal regions) or possibly operating at the SPOT scene scale for highest possible accuracy. These smaller regions would then be analysed to create the woody vegetation masks and the separate masks combined into an overall woody mask of the complete catchment.

Figure 9: Land Cover of the Central Coast



0
1-Non-veg
2-Swampy vegetation and wetlands
3-Dry euc forest on ss plateau & coastal flats
4-grassland or grassy swamp
5-foredune veg and shrubland (incl. some non-veg)
6-urban, built-up
7-grassy paddocks and isolated eucalypts
8-non veg (grassland or pasture)
9-sparse veg and grassland
10-non veg (grassland or pasture)
11-non veg (grassland or pasture)
12-non veg (grassland or pasture)
13-foredune / grassy foredune
14-open Eucalypt woodland with heath / sedge understorey
15-Moist euc forest on southerly aspects
16-Wet sclero forest / rainforest
17-Eucalypt woodland with mixed understorey
18-Dry eucalypt and banksia heath
19-Isolated Eucalypt emergents
20-Saltmarsh, scattered mangroves
21-Foredune/ urban built-up
22-Euc-mela swampy woodland, typha wetland
23-Tea tree thicket with emergents and swamp
24-Saltmarsh / grassy swamp
25-Wet sclerophyll forest
26-Eucalypt forest with mixed understorey
27-Dry Eucalypt forest on northerly and NE aspects
28-Sand with scattered veg, weed thicket
29-Euc woodland with banksia and tt heath
30-Open Euc woodland and sparse dry euc
31-Isolated trees
32-Eucalypt open woodland on dry sandstone ridges and disturbed coastal flats
33-Grassland and isolated trees
34-non-veg (cleared, grassland, pasture)
35-non-veg (cleared, grassland, pasture)
36-non-veg (cleared, grassland, pasture)
37-Coastal heath
38-Wet sclero woodland
39-Mangroves

Figure 10: Vegetation Descriptions at the Catchment Scale

1 - Dry sclerophyll open woodland scattered trees
2 - Dry sclerophyll forest & Woodland
3 - Dry sclerophyll open forest and woodland on sandstone
4 - Dry sclerophyll woodland & open woodland
5 - Dry sclerophyll woodland on sandstone
6 - Dry forest and woodland complex
7 - Dry sclerophyll woodland on sandstone and rocky outcrop
8 - Dry sclerophyll heathy sandstone complex
9 - Dry sclerophyll woodland and open woodland with shrubby u/s on ss ridge, slopes coastal flats
10 - Dry shrubby forest / woodland
11 - Eucalypt and Angophora woodland complex
12 - Scattered trees and shrubs, mostly cleared
13 - Sheltered dry eucalypt forest and woodland with shrubby u/s
14 - Beech forest, rainforest, mixed forest
15 - Rainforest / mixed forest
16 - Moist open forest and woodland
17 - Wet sclerophyll forest / mixed forest
18 - Wet sclerophyll forest and woodland
19 - Wetlands, mangrove / saltmarsh
20 - Weedy forest / improved pasture
21 - Grassland / reedland / coastal heath
22 - Eucalypt / mixed woodland +/- weed scrub on northern slopes
23 - Moist eucalypt forest / shadow
24 - Rainforest and moist forest in riparian zones and south facing slopes
25 - Rainfores and riparian vegetation
26 - Mixed forest on fertile slopes, coastal foothills & riparian zones
27 - Moist sclerophyll forest and woodland in sheltered sandstone valleys and dry northern inland slopes
28 - Moist woodland and open woodland along the coast and inland slopes
29 - Moist woodland and grasslands / rush
30 - Dry eucalypt forest and woodlands on sandstone ridgelines and coastal foothills
31 - Dry sclerophyll scrub on sandstone
32 - Dry open forest and woodland of the northern ranges on north-facing slopes
33 - Dry open forest and woodland on north-facing slopes and ridges
34 - Dry sclerophyll open woodland on sandstone ridges, tallus slopes and coastal foothills
35 - Dry open woodland and sclerophyll scrub
36 - Dry sclerophyll forest and woodland on sandstone ridges and coastal plains
37 - Dry sclerophyll heathy woodland on sandstone
38 - Dry sclerophyll woodland on rocky sandstone slopes, lowlands or sandy coastal flats
39 - Dry sclerophyll woodland and open woodland on rocky ss slopes, lownads or sandy coastal flats
40 - Dry sclerophyll woodland on rocky slopes and ridges and on coastal lowlands
41 - Dry sclerophyll woodland with northerly aspects
42 - Dry sclerophyll woodlands of the northern range
43 - Dry shrubby woodland on sandstone
44 - Sclerophyll wodland and shrubland
45 - Low fertility dry forests / woodlands and heath
46 - Low fertility dry forests / woodlands in sheltered gullies and southern slopes
47 - Open sclerophyll heathy woodland
48 - Woodland and open woodland along the coast and inland slopes
49 - Mangroves

CHAPTER 5

Results of Vegetation Survey and Mapping in the Hunter, Central and Lower North Coast Region of NSW

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This chapter summarises the results of the Hunter, Central and Lower North Coast Vegetation Survey and Mapping project, including a review of the overall achievements that have been reached. Key findings of the survey and mapping work are presented and recommendations are made for further work, particularly regarding the imminent catchment-wide vegetation community mapping for the region.

Title illustration: SPOT5 colour image showing Newcastle (grey with white clouds), Fullerton Cove and the Hunter River (blue), Kooragang Nature Reserve (dark green areas surrounding the Hunter River and Fullerton Cove), Stockton Beach (white), and the Tomago Sandbeds (green area behind the Sandbeds).

1. OVERVIEW

1.1 Overall Achievements

The vegetation survey and mapping project for the Hunter, Central and Lower North Coast Region of NSW has reached a critical milestone in achieving the objectives of the Hunter and Central Coast Regional Environmental Management Strategy and the HCRCMA Catchment Action Plan in moving towards catchment-wide data products and contributing the first stage of data towards mapping the vegetation communities of the region.

The application of SPOT5 satellite imagery to regional-scale vegetation mapping is a relatively new approach that offers an alternative to traditional aerial photograph interpretation in providing information about the landscape composition and structure of large areas at relatively fine resolution. Digital image data from satellites such as SPOT5 have found a wide range of applications in resource and environmental research, and are commonly incorporated into the monitoring and mapping programs of many institutions (cf. Boorowa Regional Catchment Committee, 2003; Yang and Thomas, 2003).

In meeting the overall project objectives, a landscape-wide and tenure-blind gap analysis has been completed; poorly sampled environments and vegetation map classes have been identified and systematic vegetation surveys completed within priority survey areas; the survey data has been checked and entered into the standard YETI survey database; maps of extant vegetation and vegetation formation have been produced for the study area; and ground truth surveys have been completed. These project results provide useful baseline data in their own right, but also provide the inputs needed for the next stage of vegetation community mapping for the Hunter, Central and Lower North Coast Region of NSW.

1.2 Application of Project Outcomes

The results of this project include vegetation survey and map data that provide information on the location, connectivity and patch size of remaining vegetation in the region in addition to site-based assessments of floristic composition, condition and habitat values. This data can be used to monitor vegetation change over time; guide the location of restoration projects (and hence strategic investments for on-ground works); contribute to assessments of key habitats and corridors; provide input to vegetation community classification schemes; and provide baseline data to assist future conservation assessments in the region. It is envisaged that the next stage of vegetation survey and mapping in this region will build upon what has been achieved in the current project and complete additional systematic surveys to produce a comprehensive, catchment - wide vegetation survey database that will be subject to a detailed analysis of vegetation communities and predictive modelling. Both the survey site locations and vegetation community mapping can be guided by the maps presented in this study.

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1.3 Specific Project Outputs

The outputs of the Vegetation Survey and Mapping project for the Hunter, Central and Lower North Coast Region of NSW are as follows:

a) 314 additional floristic survey sites that target previously unsampled vegetation types or poorly sampled environments.

b) Permanent site markers located within the systematic plots for long-term monitoring of vegetation change and condition.

c) Vegetation cover mapping at 20m resolution that provides complete coverage of the study area.

d) Land cover and vegetation formation mapping at 10m resolution that provides coverage of the Central Coast.

e) Vegetation formation mapping at 20m resolution that identifies broad vegetation types.

f) 922 rapid vegetation survey sites that sample a range of vegetation types and record information on vegetation structure, condition, diversity, growth stage, and disturbance indicators.

These project outcomes are discussed in more detail in the following sections, along with key research findings and implications for future work.

2. SITE ASSESSMENTS

2.1 Purpose of Field Surveys

Site based assessments provide the 'ground truth' for guiding the attribution of any map that represents 'real world' entities. Without ground truth, maps become a 'best guess', and without maps, our knowledge is restricted to a few known point localities. Clearly, vegetation mapping for the study area has relied on both the results of vegetation surveys and our ability to extrapolate and interpolate these observations across a landscape.

Two types of site assessments were completed for this project; rapid ground truth surveys and detailed systematic vegetation surveys. Each survey type differs in its objective: systematic surveys provide the floristic information for characterising a vegetation community within a 20x20m sample size; whilst rapid surveys provide an assessment of vegetation type, condition and habitat parameters within an approximate 10m radius of a point in order to assist the interpretation of remotely mapped vegetation patterns. The time required to complete a systematic sample is approximately 2-3 hours, whilst a rapid site can be completed within around 15 minutes. Notwithstanding these differences, the sample size is similar (400m^2 for systematic sites and 314m^2 for rapid sites) and consistent attributes have been recorded for vegetation type, dominant species in each strata, growth stage, and evidence of disturbance. This data has the capacity for additional analyses of habitat values, vegetation condition, and species diversity.

2.2 Sample Size and Representation

Within the study area, there are approximately 6073 existing systematic vegetation survey plots and a further 922 rapid survey sites, bringing the total site-based assessments to 6995. Whilst this might reflect a relatively well surveyed region, this survey intensity still only represents around 0.0052% of the analysis area. As such, it is important to use knowledge of vegetation patterns, numerical analyses and unbiased survey techniques to achieve a representative sample of the regions plant diversity in producing vegetation maps for the region. To facilitate such a sampling strategy, the plant habitat mapping presented in Chapter 2, along with the recently completed vegetation formation mapping, can be used to assist site selection and to target vegetation types that are considered relatively poorly sampled.

2.3 Outcomes of Systematic Surveys

2.3.1 Survey Areas

A total of 314 systematic vegetation survey sites were completed for this study. The geographic focus of these surveys were Priority Areas 1, 2 and the Central Coast, although the Great Lakes and Goulburn River regions were also included in the survey effort as they were identified as relatively poorly sampled within the study area.

2.3.2 Plant Species

A total of 1613 plant taxa representing 152 Families were recorded by the current surveys. This number includes species, sub species, unknown species, forms and varieties. The vast majority of species (65%) were only recorded from within 5 quadrats or less, with 32% only recorded from within a single quadrat.

2.3.3 Species of Conservation Significance

New localities have been found for at least 29 significant plant species, including species listed on the Threatened Species Conservation Act 1995 or the Environment Protection and Biodiversity Conservation Act 1999, species listed as a Rare or Threatened Australian Plant, or the species locality extends the known range or limit of its distribution.

2.3.4 Communities of Conservation Significance

A total of 18 vegetation communities of significance or unusual occurrence were recorded by the current surveys, including Endangered Ecological Communities (EEC), communities of restricted distributions, and poorly sampled communities.

2.4 Outcomes of Rapid Surveys

A total of 922 rapid vegetation survey sites were completed throughout the Study Area, sampling 229 unique vegetation map units across 14 SPOT5 scenes. The types of vegetation surveyed included Eucalypt woodland and forests with varying types of understorey, Turpentine forest, weed thicket, wetland, rainforest, mangrove, grassland, heathland, shrubland, mangroves, Casuarina forest, and Melaleuca forest. The rapid survey results also include a digital photo library with over 2000 photographs that cross-reference to the site identifications.

Whilst detailed analysis of the sites data is yet to be undertaken, preliminary results were generated for growth stage, disturbance types, and structural complexity. These results suggest that, for treed vegetation, growth stage is dominated by regenerating and mature trees, with the majority of sites recording multi-aged stands and rarely older forests. The vast majority of sites surveyed showed no obvious evidence of disturbance events, although weeds were prevalent at a large proportion of sites and evidence of fire was commonly recorded. Structural complexity scores ranged from 0 to 148, with around half the sites in the low to mid range, suggesting a diversity of vegetation strata.

Further analyses of this data could contribute to an assessment of habitat values and vegetation condition. For example, an analysis of structural complexity by vegetation type and disturbance regimes may prove useful for 'benchmarking' the condition of specific vegetation types.

Future work should also include surveys across the remaining 7 scenes that have not yet been sampled, the integration of the rapid survey results with the individual SPOT5 scene classifications, and a more detailed analysis of the survey results for the entire study area.

3. VEGETATION MAPPING

3.1 Map Scale and Intended Use

3.1.1 Maps as Representations

Field data is collected or observed at a scale of 1:1, that is, there is a direct measurement of on-ground attributes. In transferring this information into a map format that covers more than just the point of observation, say for example a 1:25,000 scale map, some type of data compression and extrapolation typically takes place for the purpose of communication and understanding. This process inevitably results in some inaccuracies or mis-representation of the actual on-ground entities. In order to reduce the level of inaccuracy, the current trend is to increase the number of site assessments and reduce the scale of mapping, although these factors are ultimately limited by the constraints of time and resources and the intended use of the map being created.

3.1.2 Suitable Applications

Clearly all maps will have strengths and weaknesses depending on the balance of these parameters, and it is important to be mindful of the limitations of any data product, the scale of mapping, and its intended use prior to its application. For example, conservation priorities assessed within one local government area will differ from the conservation priorities assessed across an entire Bioregion – the data inputs might be the same but the area under consideration has changed, therefore distribution patterns will also change, as will area calculations of the relative conservation values. Similarly, vegetation community mapping produced at a regional scale will provide information on where assemblages of species are likely to occur based on survey sites, plant-environment relationships, and vegetation patterns. Such mapping does not replace the need for site-based assessments in order to establish the presence or absence of an endangered ecological community or threatened plant population in areas that have not previously been surveyed.

3.1.2 Vegetation Community Maps

Vegetation community mapping techniques are currently based on systematic vegetation surveys (where all vascular plant species and their cover-abundance are recorded), the statistical analysis of this data to produce a classification of vegetation communities, and the interpolation of these communities across a geographic area using predictive modelling techniques. Many factors can influence the resolution and accuracy of the resultant map product, such as the adequacy of the sample dataset (is it representative, random or biased?); the ability to generate predictor variables that represent determinants of vegetation patterns (eg. disturbance regimes and soil types); the scale of the predictor variables; and the spatial accuracy of the sites data and other GIS data layers.

3.1.3 Map Scale of Project Outputs

This project has addressed the first stage of vegetation community mapping by completing vegetation surveys in poorly sampled environments and by producing vegetation maps as an input to the modelling process. The mapping is intended for use at the regional scale for the Hunter, Central and Lower North Coast of NSW, and at a sub-regional scale for the Central Coast. These map outputs are discussed below, along with a brief description of local scale mapping in order to provide context.

3.2 Local Scale Mapping

Local scale mapping is typically required for on-ground management of specific sites or areas of conservation value, including for example, assessments of development applications and the delineation of areas supporting Endangered Ecological Communities or rare plant populations. This mapping relies on detailed site-based assessments, sometimes combined with high resolution imagery, such as 1:6,000 scale photography or 2.5m Quickbird satellite imagery. No local scale mapping was completed for this project.

3.3 Sub-regional Scale Mapping

Sub-regional scale mapping typically involves stereoscopic aerial photograph interpretation (API) combined with extensive ground truth surveys (where time and resources permit), and the digital capture of map linework using scanning and orthorectification techniques. The map scale is dependant on the scale of aerial photography and in NSW, the standard scale has been 1:25,000 (this scale of photography has been captured nominally every 7 years by the NSW Department of Lands and is readily available to most vegetation mapping practitioners). Local governments have also contracted aerial photography at a larger scale to effect on-ground management and assets management. Vegetation mapping produced from this photography is often in the order of 1:16,000 scale.

The vegetation formation mapping completed for the Central Coast sub-region as part of this study was based on the analysis of three SPOT5 scenes. The SPOT5 data comprises a 2.5m resolution panchromatic band and 10m resolution multi-spectral bands. This data is considered useful for land cover mapping, including agricultural lands, urban areas, water bodies, roads, disturbance (eg. open cut mines, recent logging), the delineation of broad vegetation types, and targeted (supervised) mapping of specific land cover units such as wetlands, riparian vegetation, and rainforest.

The SPOT5 mosaic over the Central Coast sub-region had no visible seams and very small areas of localised clouds. This area contains a wide range of landcover types including cities, grasslands, forests, and several areas of rushes, mangroves and sedges near estuaries and wetlands. The classification of the SPOT5 data indicates that the Central Coast is dominated by Eucalypt Woodlands, Forests, and Grasslands, with localised areas of mangroves, coastal heath, and rainforest.

The interpretive vegetation maps generated from the classification of individual SPOT5 scenes also provide a sub-regional view of vegetation patterns, and for this project, were used to assist site selection for ground truth surveys. This mapping provides additional detail on vegetation cover compared to regional scale mapping and could be further refined by incorporating the results of ground truth surveys, standardizing map unit descriptions, and the supervised classification of specific vegetation types (eg. wetlands, mangrove vegetation and rainforest).

3.4 Regional Scale Mapping

Within NSW, a number of regional scale vegetation mapping projects have been completed, using a range of techniques including 1:25,000 scale API, 1:50,000 scale API, and Landsat satellite imagery (eg. CRAFTI, M305, EBDB, woody-non woody mapping and bioregional assessments). This scale of mapping is relatively coarse, delineating broad land cover types, extant vegetation or vegetation formations. For API-based mapping (as is the case with other map scales), the mapping pathway will dictate the resolution of the map output by specifying a minimum polygon size for delineating vegetation patterns, which is ultimately dependant on the time available and the size of the area being mapped (a 20ha minimum polygon size would be reasonable for most regional scale API mapping).

The regional scale mapping completed for this study considered that satellite remote sensing was the only way to economically provide consistent information about the landscape composition and vegetation structure of such a large area at a relatively fine resolution. Given the substantial dataset generated by the SPOT5 imagery for such a large study area, the output resolution was re-sampled from 10m to 20m resolution, still retaining a relatively high resolution map output. The products generated from the analysis of SPOT5 data included a mosaic of the multi-spectral bands and from this, a vegetation mask (woody-non woody), a water mask, and a map of vegetation formation. Due to the variation in spectral characteristics of the vegetation across the 22 SPOT5 scenes, it was very difficult to accurately separate some woody vegetation areas in one part of the mosaic from some non-woody vegetation areas in another part of the mosaic. Visual analysis of the final woody vegetation mask showed that there were some minor inconsistencies, notably in the drier western areas of the catchment, where some vegetation had the same spectral characteristics as dark soils in the east. This mask includes areas identified as water and urban or pastures areas. Woody vegetation areas occupy approximately 50 percent of the study area.

The vegetation description for the classified SPOT5 data were generated by considering the statistical relationship between the image class and the field data, local knowledge of specific areas (Wollomi Sandstone, Goulbourn River, and Barrington Tops), and landscape elements such as

riparian zones or slope aspect. The final vegetation descriptions have been grouped into 49 vegetation types. At this scale, the study area is dominated by Eucalypt Open Woodlands and Mixed Woodlands with smaller areas of Rainforests and Mangrove vegetation.

The regional-scale mapping could be refined by completing supervised classifications of specific vegetation types (eg. wetlands, rainforest and mangroves), generating an extant vegetation map from sub-regional scale mapping, and re-running a regional classification using a larger number of classes.

4. RECOMMENDATIONS

4.1 Data Management

- Whilst every attempt was made to source as much relevant data as possible for this project, not all survey data was made available. Future work should attempt to negotiate access to data not previously supplied or from new survey data that has recently been completed.
- Local governments hold a significant amount of data that is potentially useful for regional scale projects. In this regard, Hunter Councils Inc. could facilitate data exchange and consistency in data formats for the compilation of such spatial information.
- There is currently no centralized repository for floristic sites data, which was ultimately sourced for this project from 12 separate databases. It is recommended that the CMA, DEC and Hunter Councils coordinate the integration and on-going management of vegetation survey data for the region.
- Due to the variety of formats and projections of data collated for this project, the standards chosen for the resultant project outputs are compatible with ESRI suite in both AGD66 and GDA94. The future supply of digital data should meet the standards recently adopted by NSW State and Local Governments, namely GDA94.
- A number of datasets collated for this project were not accompanied by metadata or other supporting documentation. As such, expert knowledge was relied on to provide the information needed to work with some of the spatial layers. Efforts should be made by NSW government agencies to utilize the CANRI web site for storage and on-supply of digital data with accompanying metadata statements that comply with ANZLIC guidelines.
- Any future analysis of SPOT5 data for regional scale mapping will require sufficient data storage and computing capabilities for working with substantially large datasets. This is particularly the case for vegetation community modelling given the additional data inputs for predictor variables.

4.2 Systematic Vegetation Surveys

- Additional work is required for the integration and validation of existing systematic sites data prior to the identification of suitable site locations for regional-scale survey and mapping. This work will need to take into account botanical nomenclature, cover / abundance schemes, sample size, survey type, duplicate records, currency and overall accuracy.
- In identifying priority areas for future systematic vegetation surveys, a number of spatial layers are now available to guide site selection, including extant vegetation, vegetation formation and plant habitat mapping.
- In order to achieve non-biased samples, sites should be randomly selected across all land tenures, including State Forest, National Park, Crown Reserve and Private Property.
- A landholder liaison strategy is strongly recommended in order to achieve the best possible project outcomes for future survey work. This strategy should identify appropriate measures for the identification of property details, correspondence with land holders, follow-up action, on-supply of survey results, and opportunities for establishing long-term monitoring sites.
- For consistency with data recording, the observation fields used for this project should be applied to future systematic vegetation surveys using a standardised survey proforma.

4.3 Vegetation Community Mapping

4.3.1 Predictor Variables

The Hunter region has an extended history of human modification of the landscape and this history is reflected in current land cover and vegetation patterns. Clearing, grazing, fire, logging and under scrubbing, all contribute to vegetation change and heterogeneity of the vegetated landscape. In addition to stochastic events, vegetation patterns become fragmented and difficult to discern. These factors, in addition to soil type and the regions hydrology, are considered to be key determinants of vegetation patters in the region and are therefore important variables for consideration in the modelling of vegetation communities. As such, additional work is needed to generate GIS layers for these predictor variables.

4.3.2 Environmental Heterogeneity

Vegetation community modelling for the next stage of mapping in the Hunter, Central and Lower North Coast region will need to address the challenges posed by the substantial analysis dataset of the

SPOT5 multi-spectral mosaic and other predictor variables, the environmental heterogeneity at the sub-regional scale, and the limitations of the catchment-scale vegetation formation mapping. To address these issues, consideration should be given to segregating the study area into more manageable sub-regions for analysis purposes (this segregation could be based on either the date of SPOT5 image capture or grouping similar environments); the development of a higher resolution vegetation formation map that incorporates the individual SPOT5 scene classifications at 10m resolution, supervised classifications for specific vegetation types (eg. wetlands, mangrove vegetation and rainforest), and other sub-regional scale vegetation map products; completing targeted (fine scale) API for specific areas (eg. coastal locations); and generating additional predictor variables, such as proximity to coast and topographic layers sourced from a high resolution DEM (held by some local governments for some coastal areas).

4.4 Future Research Priorities

- Follow-up surveys should be completed at the sites established as long-term monitoring plots. These surveys could be conducted on a semi-regular basis (say, every 2 years) and then analysed to identify any long term trends in vegetation change (say, after a 10 year period).
- Vegetation survey and mapping for the Hunter, Central and Lower North Coast of NSW is intended to address regional scale data requirements and will not necessarily address local scale priorities (eg. species and communities of conservation significance). As such, a targeted survey effort is recommended in order to address such priorities.
- The surveys completed for this project have recorded a vast amount of data on the vegetation of the region, including species composition, vegetation structure, habitat parameters, and condition indicators. It is recommended that this data be subject to detailed analysis in order to gain insight to the regions ecology, health, and habitat values.
- The knowledge gleaned from such research activities is used wisely by our community and policy makers to make informed land use planning decisions to create a healthy and sustainable environment for future generations and that these actions continue to act in the true spirit of custodianship.

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