A method for deriving maps of landscape alteration levels from vegetation condition datasets

Martin Mutendeudzi and Richard Thackway

March 2010

© Commonwealth of Australia 2010

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the Commonwealth available from the Department of Communications, Information Technology and the Arts. Requests and inquiries concerning reproduction and rights should be addressed to the Commonwealth Copyright Administration, Intellectual Property Branch, Department of Communications, Information Technology and the Arts, GPO Box 2154, Canberra ACT 2601 or at www.dcita.gov.au/cca.

The Australian Government acting through the Bureau of Rural Sciences has exercised due care and skill in the preparation and compilation of the information and data set out in this publication. Notwithstanding, the Bureau of Rural Sciences, its employees and advisers disclaim all liability, including liability for negligence, for any loss, damage, injury, expense or cost incurred by any person as a result of accessing, using or relying upon any of the information or data set out in this publication to the maximum extent permitted by law.

Postal address:
Bureau of Rural Sciences
GPO Box 858
Canberra, ACT 2601

Website: www.brs.gov.au
Email: info@brs.gov.au
Telephone: +61 2 6272 4282
Facsimile: +61 2 6272 4747
Publication sales: 1800 020 157

Acknowledgements

The authors would like to acknowledge the valuable contributions from several people. Sue McIntyre (CSIRO) encouraged the Bureau to explore methods for converting condition datasets, derived using the VAST framework, into maps of LALs. Researchers at numerous vegetation condition related workshops and conferences, including those held in Burnie, Perth, Sydney and Hobart in 2006 and 2007, encouraged the Bureau to undertake further research into methods for deriving LALs. Dominic Sivertsen, Ross Peacock and Megan McNellie (NSW DECC) provided the input condition dataset required to create the VAST condition class datasets. Several staff at the Bureau including, Jodie Smith, Mijo Gavran and Ian Frakes who prepared the final VAST datasets used in this report and Greg Hood and Emma Lawrence who provided statistical advice on the interpretation of the results for the LALs. Ken Turner (NSW DECC) offered suggestions on how to improve the Shoalhaven VAST condition class dataset. Mark Parsons, Georgina Kelley and John Davidson reviewed the draft report.
Table of Contents

Executive Summary ............................................................................................................................. v
Introduction ........................................................................................................................................... 1
  Regional study areas ........................................................................................................................ 4
Method.................................................................................................................................................. 8
  Step 1 ............................................................................................................................................... 8
  Step 2 ............................................................................................................................................... 8
  Step 3 ............................................................................................................................................... 10
  Step 4 ............................................................................................................................................... 11
  Step 5 ............................................................................................................................................... 12
  Step 6 ............................................................................................................................................... 12
  Step 7 ............................................................................................................................................... 12
Results .................................................................................................................................................. 13
  LALs - Shoalhaven dataset ............................................................................................................. 13
  LALs - Bogan Gate dataset ............................................................................................................. 18
  LALs - Australia wide dataset .......................................................................................................... 22
Discussion .......................................................................................................................................... 27
  Scale ............................................................................................................................................... 27
  Comparing LALs between different study areas ............................................................................. 27
  Application of derived LALs ............................................................................................................. 28
  Limitations of LALs ........................................................................................................................... 28
Conclusions ......................................................................................................................................... 30
References ........................................................................................................................................... 31
Appendix 1.......................................................................................................................................... 34
  RGB* values for VAST condition classes ....................................................................................... 34
  RGB* values for derived LAL classes .............................................................................................. 34
Appendix 2.......................................................................................................................................... 35
  Rules and steps implemented in compiling the national VAST dataset ........................................ 35
List of Figures

Figure 1: Location map showing the two study areas: Shoalhaven, South-east NSW and Bogan Gate, Central Western NSW ................................................................. 4
Figure 2a: Shoalhaven study area – VAST condition classes ..................................... 5
Figure 3a: Bogan Gate study area – Vegetation or VAST condition classes ............... 7
Figure 4: Process summary for a particular window size radius, i.e. 250, 500 and 1000 metres .................................................................................................................. 9
Figure 5: A framework for classifying landscapes based on the description of four landscape alteration states associated with increasing amount of habitat and decreasing levels of habitat connectivity .......................................................... 10
Figure 6: Continental VAST condition classes .......................................................... 12
Figure 7a: LALs derived using a 250 metre moving window radius ............................ 14
Figure 8a: LALs derived using a 500 metre moving window radius ............................ 15
Figure 9a: LALs derived using a 1000 metre moving window radius ......................... 16
Figure 10: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the Shoalhaven study area .......... 17
Figure 11a: LALs derived using a 250 metre moving window .................................... 18
Figure 12: LALs derived using a 500 metre moving window ...................................... 19
Figure 13a: LALs derived using a 1000 m moving window ....................................... 20
Figure 14: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the Bogan Gate study area .......... 22
Figure 15a: LALs derived using a 2.5 kilometre moving window ............................... 23
Figure 16a: LALs derived using a 5 kilometre moving window .................................. 24
Figure 17a: LALs derived using a 10 kilometre moving window ............................... 25
Figure 18: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the continent ...................................... 26

List of Tables

Table 1: The Vegetation Assets, States and Transitions classification ......................... 3
Table 2: Estimated proportions of habitat modification classes within each LAL derived from Figure 5 ................................................................. 10
Table 3: VAST condition class look-up table ............................................................. 11
Executive Summary

A method for deriving maps and statistics that describe landscapes with increasing fragmentation and decreasing vegetation condition is outlined. The method is based on the McIntyre and Hobbs (1999) conceptual model of landscape alteration levels (LALs) and requires access to an appropriate vegetation condition dataset describing increasing levels of modification of vegetation types due to human land use and land management practices. Landscapes are classified into four categories (intact; variegated; fragmented; and relictual) based on the level of habitat intactness or alteration. The McIntyre and Hobbs model is widely known and understood and assists conservation biologists and natural resource managers to address the full spectrum of human impacts observed across agricultural and fragmented landscapes.

The GIS enabled LAL method was developed using FRAGSTATS software, and two fine regional scale Vegetation Asset States and Transition (VAST) datasets, in two distinct environments. To illustrate the utility of the GIS enabled LAL method the method was then applied to a national vegetation condition dataset. Scale of the output is intrinsically linked to the resolution of the input dataset and the size of the moving window. The responsiveness of the classification to scale was evaluated by employing three moving window sizes.

The report discusses potential applications of the derived LAL maps in developing sustainable land management practices. The maps and statistics derived using this method can provide a useful first pass filter for use in on-ground and regional applications such as identifying areas for more detailed investigations and to better understand the underlying causes of fragmentation and the condition of native vegetation. The products may also be useful in designing regional vegetation management plans, investment strategies and management action plans. Further, the products can assist with analysing the spatial patterns and processes operating in the landscape to facilitate discussions between stakeholders on what interventions may be needed to re-establish ecological functions. However, the LALs described and mapped using this approach only reflect the structural or physical characteristics of landscapes, not their functional properties.
Introduction

Landscape alteration can occur as a consequence of natural processes, such as drought, wildfires and long-term climate change. However, in recent decades there has been an increasing need for information about anthropogenic patterns and processes which alter landscapes. Activities such as clearing native vegetation for agricultural expansion and urbanisation have become the most important cause of habitat loss and fragmentation (Hobbs and Hopkins 1990, Novacek and Cleland 2001; Lindenmayer and Fischer 2006). Fragmentation can induce long term changes in habitat composition through processes such as the richness reduction that is frequently associated with habitat loss (Hill and Curran 2001; Ramos et al. 2008), the invasion of species from the vegetation surrounding the fragments (Fox et al. 1997), or differential recruitment along an edge-centre gradient (Laurance et al. 1998; Harper et al. 2005). Such habitat degradation eventually reduces biodiversity (Ramos et al. 2008; Novacek and Cleland 2001; Sala et al. 2001; Lindenmayer and Fischer 2006).

Conserving the original vegetation remnants is considered important as a public–private benefit as these are often the last reservoirs of threatened species and are a potential focus for species dispersion and recovery (Turner and Corlett 1996). However, land managers charged with the task of identifying the most appropriate and cost effective areas to be conserved often have limited dedicated resources to enable the development of local and regional trade-offs. Spatial products, such as datasets and maps that characterise sites, patches and landscapes in terms of disturbance or alteration levels, can help land managers and other stakeholders identify priorities for detailed investigations and improve understanding of the underlying causes of habitat alteration. Additionally, being able to describe vegetation modification classes and Landscape Alteration Levels (LALs) in a consistent way will enable land managers to compare landscape changes in both space and time, thereby monitoring the effectiveness of their programs or intervention.

Land management decisions that affect the structure, floristics and/or regenerative capacity of vegetation depend on the goals and values and the desired outcomes of land management plans and land management practices (e.g. habitat for selected species, maximising water yield, food or fibre production, amelioration of erosion and farm forestry for carbon sequestration; Maltby et al. 1999). At the site level, a desired ‘state’ of the vegetation can be achieved by managing and regulating biophysical conditions, including water and nutrient inputs, and physical and biological relationships (Trudgill 1977; Maltby et al. 1999), for example, by managing fire or grazing pressure (Noss and Cooperrider 1994).

Without additional information on vegetation modification, or the degree of vegetation change, it is not possible to adequately address the links between management intervention and vegetation structure and floristics or the impacts on natural resources, including biodiversity (Hobbs and Hopkins 1990, McIntyre and Hobbs 1999; Thackway and Lesslie 2006).

The method and the resultant reporting products outlined in this report will enhance the capacity of regional bodies and land managers to place in context the status and condition of vegetation at different scales within regions. Tools such as this one aim to help stakeholders measure intermediate natural resource management outcomes and to discuss trade-offs between conservation of biodiversity, protection of native vegetation remnants and commercial production. As such, these tools are relevant to monitoring and reporting of vegetation outcomes under the Australian Government’s Caring for our Country initiative and other community based programs.

Methods are being developed to describe vegetation condition classes in order to understand and address spatial patterns at varying scales, levels and effects of management intervention, assess natural resource condition, and to maintain and/or restore habitat (EMR 2006). Spatial and temporal information is also needed to support the development of sustainable production
A method for deriving maps of landscape alteration levels from vegetation condition datasets (Thackway and Lesslie 2005).

One method to describe and map native vegetation condition classes is the Vegetation Assets, States and Transitions (VAST) framework (Thackway and Lesslie 2006; Thackway and Lesslie 2008). VAST is based on the assumption that changes in the state of vegetation modification can be effected through land management practices. These condition classes are summarised in Table 1. Management interventions that are aimed at restoring and maintaining vegetation communities must be informed by knowledge of the extent and duration of past disturbances, cultural conditions that have shaped the landscape, species availability and species resilience and assembly rules (Hobbs and Norton 1996; Thackway and Lesslie 2008).

The VAST framework is able to translate and compile a wide range of data and information developed from vegetation assessments including survey and mapping, modelling and monitoring. The VAST framework was developed to utilise existing datasets that are compiled at a range of scales including site, local, regional and national levels. Provided these datasets and expert knowledge are available to inform the VAST diagnostic attributes, along with information about the benchmarks, they can be classified into the VAST states (Thackway and Lesslie 2006; Thackway and Lesslie 2008).

Meeting the challenge of sustainable management of vegetation for production and conservation and rehabilitating degraded ecosystems requires maps derived from conceptual landscape models. Lindenmayer and Fischer (2006) discuss several conceptual models that have been proposed to study and characterise landscapes in terms of their alteration and dynamics. The authors sub-divide the conceptual landscape models into species-based and pattern-based models. The contour model, described in Fischer et al. (2004), where the landscape is represented as a map of habitat suitability contours overlaid for different species, is an example of a species-specific gradient model.

We recognise three types of landscape pattern-based conceptual models:

a) Island model (Shafer 1990). The underlying premise is that fragments of the original vegetation surrounded by cleared or highly modified land are analogous to oceanic islands in an “inhospitable sea” of unsuitable habitat (Haila 2002; Lindenmayer and Burgman 2005).

b) Patch matrix-corridor model (Forman 1995). In this model landscapes are conceived as mosaics of three components:
   - Patch – relatively homogenous non-linear areas that differ from their surroundings.
   - Corridors – strips of a particular patch type that differ from the adjacent land on both sides.
   - Matrix – the dominant and most extensive patch type in a landscape.

c) Habitat-variegated or landscape continuum model (McIntyre and Barret 1992, McIntyre and Hobbs 1999). This model reflects the often diffuse nature of the boundaries between patches and the background matrix, accommodating the objections by many researchers to the sharp boundaries and discrete classes prevalent in most landscape conceptual models (Harrison 1991).

The habitat-variegated model was developed using ecological processes and incorporates gradual spatial changes or gradients in habitat quality (McIntyre 1994; McIntyre and Hobbs 1999). The model has the advantage that it takes into account small habitat elements that might otherwise be classified as ‘unsuitable habitat’ in the background matrix (Tickle et al. 1998). Although originally proposed for semi-cleared grazing and cropping landscapes in rural eastern Australia, the model was extended to include tropical and temperate rainforests (McIntyre and Hobbs 1999). This model has been widely accepted by researchers, research and development managers and institutions as a useful way of communicating ideas about landscapes relating to research, management, policy development and administration (Williams 2005).
Table 1: The Vegetation Assets, States and Transitions classification

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas where native vegetation does not naturally persist and recently naturally disturbed areas where native vegetation has been entirely removed. (i.e. open to primary succession)</td>
<td>Native vegetation community structure, composition, and regenerative capacity intact - no significant perturbation from land use/land management practice</td>
<td>Native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice</td>
<td>Native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice</td>
<td>Native vegetation replacement - species alien to the locality and spontaneous in occurrence</td>
<td>Native vegetation replacement with cultivated vegetation</td>
<td>Vegetation removed - alienation to non-vegetated land cover</td>
<td></td>
</tr>
<tr>
<td>Diagnostic criteria</td>
<td>Complete removal of in-situ regeneration capacity except for ephemerals and lower plants</td>
<td>Natural regeneration capacity unmodified</td>
<td>Natural regeneration capacity persists under past and/or current land management practices</td>
<td>Natural regenerative capacity limited / at risk under past and/or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice.</td>
<td>Regeneration potential of native vegetation community has been suppressed and in-situ resilience at least significantly depleted. May still be considerable potential for restoration using assisted natural regeneration approaches</td>
<td>Regeneration potential of native vegetation community likely to be highly depleted by intensive land management. Very limited potential for restoration using assisted natural regeneration approaches</td>
<td>Nil or minimal regeneration potential. Restoration potential dependent on reconstruction approaches</td>
</tr>
<tr>
<td>Vegetation condition class (objective)</td>
<td>Nil or minimal</td>
<td>Structural integrity of native vegetation community is very high</td>
<td>Structure is predominantly altered but intact e.g. a layer/stratum and/or growth forms and/or age classes removed</td>
<td>Dominant structuring species of native vegetation community significantly altered e.g. a layer/stratum frequently and repeatedly removed</td>
<td>Dominant structuring species of native vegetation community removed or predominantly cleared or extremely degraded</td>
<td>Dominant structuring species of native vegetation community removed</td>
<td>Vegetation absent or ornamental</td>
</tr>
<tr>
<td>Vegetation condition class (objective)</td>
<td>Nil or minimal</td>
<td>Compositional integrity of native vegetation community is very high</td>
<td>Composition of native vegetation community is altered but intact</td>
<td>Dominant structuring species present - species dominance significantly altered</td>
<td>Dominant structuring species of native vegetation community significantly altered</td>
<td>Dominant structuring species of native vegetation community removed</td>
<td>Vegetation absent or ornamental</td>
</tr>
<tr>
<td>Examples</td>
<td>Bare mud; rock; river and beach sand; salt freshwater lakes; rock slides; lava flows</td>
<td>Old growth forests; native grasslands that have not been grazed; wildfire in native forests and woodlands of a natural frequency and/or intensity</td>
<td>Native vegetation types managed using sustainable grazing systems; selective timber harvesting practices; severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity</td>
<td>Intensive native forestry practices; heavily grazed native grasslands and grassy woodlands; obvious thinning of trees for pasture production; weedy native remnant patches; degraded roadside reserves; degraded coastal dune systems; heavily grazed riparian vegetation</td>
<td>Severe invasions of introduced weeds; invasive native woody species found outside their normal range; isolated native trees/shrub/grass species in the above examples</td>
<td>Plantations, horticulture; tree cropping; orchards; reclaimed mine sites; environmental/amenity plantings; improved pastures (incl. heavy thinning of trees for pasture); cropping; isolated native trees/shrub/grass species in the above examples</td>
<td>Water impoundments; urban and industrial landscapes; quarries and mines; transport infrastructure; salt scalded areas</td>
</tr>
</tbody>
</table>

This report outlines a method for classifying landscapes with increasing fragmentation and decreasing vegetation condition based on the McIntyre and Hobbs (1999) conceptual model of LALs. We outline the method used to realise the LAL conceptual model and use maps of vegetation condition and the FRAGSTATS software to describe and map LALs in a GIS environment.

We illustrate the utility of the GIS enabled LAL method by applying the LAL method to a national scale vegetation condition dataset. We briefly discuss how the two components of landscapes, namely vegetation condition classes and LALs, can be used to facilitate discussions between stakeholders on what interventions may be needed where to re-establish ecological functions and to help inform the development of regional vegetation management plans, investment strategies and management action plans.

Regional study areas
The two locations (Figure 1) chosen for methodology development were selected for the following reasons:

a) reliability in terms of scale and accuracy of the vegetation condition (VAST) datasets
b) contrast of environments in terms of vegetation type, land-use pattern and climate.

Figure 1: Location map showing the two study areas: Shoalhaven, South-east NSW and Bogan Gate, Central Western NSW

Shoalhaven – South-east NSW
The Shoalhaven study area is located within the coastal lowlands, escarpment and undulating highlands and tablelands of southeast New South Wales (NSW) between latitudes 34° 30’ S and 35° 39’ S and longitudes 149° 38’ E and 150° 51’ E (Figure 1). It covers a total area of approximately 983 000 ha (9830 square kilometres). The major geological and terrain landscapes include fertile coastal shale dominated plains bounded by infertile, incised sandstone scarps and plateaux in the eastern and central parts of the region, and undulating tablelands in the west, comprised mainly of granitic and meta-sedimentary substrates.

Figures 2a and 2b show that land clearing, primarily for agriculture and to a lesser extent urban development, has had a significant impact on the extent and condition of the remnant native vegetation in the study area since European settlement with approximately 30 per cent or 294 000 ha cleared. The native vegetation of the study area is described in detail by Tindall et al. (2004).
Further, Tindall et al. (2004) describe the climate for most of the study area as temperate, featuring warm summers and cool winters on the coast and mild/warm summers and cold winters on the ranges and tablelands.

Land use in the study area is dominated by nature conservation (31 per cent) and grazing of modified pastures (28 per cent), with the remaining area consisting of other minimal uses (stock routes, defence, residual native vegetation and rehabilitation area (21 per cent), production forestry (seven per cent) and residential areas (five per cent). With regard to forest cover, approximately 63 per cent of the study area is covered by native forests. Open and woodland eucalypt forests predominate and together compose approximately 84 per cent of the forest cover.

In terms of the vegetation condition classes described in Table 1, residual VAST class I forms the matrix in the central and southern parts of this study area (Figures 2a and 2b). The western, northern and north-east parts of the study area are dominated by replaced (advective – IV or managed – V). Areas of transformed – VAST class III comprise approximately the same proportion as replaced (advective – class IV or managed – class V) but are more scattered. There are small scattered areas of condition classes modified – VAST class II and removed – class VI (Figure 2b). It should be noted that the condition class, naturally bare – VAST 0, has a small areal extent and a patchy distribution. As a result for the mapping and analysis purposes of this report, naturally bare – VAST 0, has been grouped with residual VAST class I. This is represented as an asterisk (*) in Figures 2a and 2b.

Figure 2a: Shoalhaven study area – VAST condition classes
The Bogan Gate study area is located in the central western region of NSW, between latitudes 32°00' S and 33°30' S and longitudes 147°00’ E and 148°00’ E as shown in Figure 1. It covers a total area of approximately 1 577 000 ha or (15 770 square kilometres). Figures 3a and 3b show that land clearing, primarily for agriculture and to a much less extent urban development, has significantly affected the extent and condition of the remnant native vegetation in the study area since European settlement, with approximately 50 per cent or 788 500 ha cleared. The patterns and distribution of native vegetation across the study area have changed considerably since European settlement (Lewer et al. 2003).

The climate of this study area is described by Lewer et al. (2003) as semi-arid. BRS catchment scale land-use mapping data (January 2007) indicates that the predominant land-use types are grazing of modified pastures (54 per cent of study area) and cropping (34 per cent). Approximately 22 per cent of the study area is covered by native forests, of which eucalypt woodlands comprise about 83 per cent.

In contrast to the Shoalhaven study area, replaced (adventive – IV or managed – V) forms the matrix (dominant and most extensive patch type in the landscape) of this study area and is interspersed with somewhat large patches of condition classes modified – VAST class II and transformed – VAST class III. Patches of removed – class VI condition classes comprise minor proportions (Figures 3a and 3b). It should be noted that the condition class, naturally bare – VAST 0, has a small areal extent and a patchy distribution. As a result, for the mapping and analysis purposes of this report, naturally bare – VAST 0, has been grouped with residual VAST class I. This is represented as an asterisk (*) in Figures 3a and 3b.
Figure 3a: Bogan Gate study area – vegetation or VAST condition classes

Figure 3b: Bogan Gate study area – proportions of vegetation or VAST condition classes
Method

The regional vegetation condition datasets for this project, Figures 2a and 3a, were derived in collaboration with the NSW Department of Environment and Climate Change (DECC) at 1:100 000 scale. Vegetation mapping reports, field survey notes and input from the DECC vegetation mapping team members provided the primary knowledge to determine the VAST condition classes for these datasets (McNellie, M pers. comm., 21/01/08).

These regional datasets were used to establish a methodology for deriving LALs at different scales. The process and main steps of this methodology are described in detail below and summarised in Figure 4.

Step 1

This step involved evaluating and standardising the vegetation condition datasets provided by DECC to ensure compliance with the VAST classification described in Table 1. The step produced appropriate 100 metre resolution raster vegetation condition datasets through:

a) intersecting each vegetation condition dataset with BRS datasets to improve the delineation of the Naturally Bare (VAST 0) condition class, which was considered to be poorly mapped

b) converting the Bogan Gate vegetation condition dataset from vector to a raster format (100 metre cell size GRID).

Step 2

In this step the vegetation condition datasets produced in Step 1 were separately entered into the FRAGSTATS (McGarigal et al. 2002) Version 3.3 software program to calculate a compositional metric which measures the proportion of the various vegetation condition classes or patch types. The metric was calculated using a moving square window approach, which can be imagined as a window of fixed size passing over every grid cell of the input dataset. Area proportions for the various vegetation condition classes are calculated during the process. For each processing cell, the calculation considers all grid cells that are completely contained within the radius\(^1\) of the moving window. The radius refers to the distance from the centre of the focal cell to the side of the square window. Computation is performed until a value has been derived for every grid cell location and for every vegetation condition class of the input dataset. Metric values were calculated separately for three moving window sizes for each vegetation condition dataset. The moving window sizes, chosen through consultation with a panel of ecologists from BRS and DECC and taking into consideration the scale of the datasets, were of radius 250, 500 and 1000 metres for the regional datasets.

Subsequent operations, specifically steps 3 to 6 inclusive (see Figure 4), were each carried out three times, one for each window size.

\(^1\) In square moving window analysis, radius refers to the shortest distance between the focal cell and the side of the square window in an orthogonal direction. The radius is measured in cell widths (e.g. 2 cells wide) and rounded where the nominated radius is not perfectly divisible by the cell size.
Step 1: Prepare the vegetation condition datasets (VAST classes 0, I, II, III, V, VI)

Step 2: Calculate areas by VAST class (Proportion of vegetation condition within moving window area at each grid cell location)

Step 3: Combine VAST class grids (Overlay and then sum the proportions of vegetation condition classes 0-III)

Step 4: Develop and apply threshold rules to combined grid

Step 5: Generate derived landscape alteration levels map and statistics

Step 6: Evaluate map (Statistics and visual appearance)

Step 7: Accept

Figure 4: Process summary for a particular window size radius, i.e. 250, 500 and 1000 metres
Step 3

The outputs from Step 2 were a series of 100 metre resolution grids which ascribed proportions of vegetation condition classes to each grid cell and, for each moving window radius. The challenge for Step 3 was to interpret the McIntyre and Hobbs (1999) landscape conceptual model, illustrated in Figure 5, in terms of the vegetation condition class proportions ascribed to the grid cells. Table 2 shows the estimated relative proportions of vegetation modification classes within each LAL derived from McIntyre and Hobbs (1999). This table shows what we interpreted to be the minimum average or mean proportions and/or ranges of the native vegetation component, including Naturally Bare or VAST 0, required for each LAL by the conceptual model.

Table 2: Estimated proportions of habitat modification classes within each LAL derived from Figure 5

<table>
<thead>
<tr>
<th>LAL</th>
<th>Native Habitat modification states</th>
<th>Non-native Habitat modification states</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unmodified¹,² %</td>
<td>Modified and retained¹,² %</td>
</tr>
<tr>
<td>Intact</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Variegated</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Fragmented</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Relictual</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

1 Estimated proportions of habitat modification classes within each LAL estimated from McIntyre and Hobbs (1999), Figure 5.
2 Mean sum of native vegetation condition class, including Naturally Bare (VAST 0), in each LAL provided by McIntyre and Hobbs (1999) in Figure 5.
3 We assumed that the habitat modification classes in Figure 5 correspond to the vegetation condition classes in the VAST framework as follows: Unmodified (VAST 0 & I), Highly modified (VAST II), Modified and retained (VAST III), and Destroyed (VAST IV, V & VI).

Figure 5: A framework for classifying landscapes based on the description of four landscape alteration states associated with increasing amount of habitat and decreasing levels of habitat connectivity. (Based on McIntyre and Hobbs (1999).)
The relative proportions of the vegetation modification classes within each LAL from Table 2 and their correspondence with vegetation condition classes were used as a guide. First, the vegetation condition class compositional metric grids were overlaid and combined into a single grid for each moving window size. The outputs of the overlay and the combination process were single grids for each moving window size in which the proportions of the original vegetation condition classes could be determined at any cell location of the input dataset in the one grid. Second, a new attribute (Sum of VAST 0-III Proportions) was created for each of the combined grids and populated with the sum of proportions of VAST 0, I, II and III vegetation condition class. This additional attribute is very important to the interpretation of the McIntyre and Hobbs (1999) landscape conceptual model since it represents and describes the native vegetation and naturally bare components of the landscape.

**Step 4**

The aim of Step 4 was to find suitable thresholds for outputs from Step 3. This involved determining the actual proportions of the vegetation condition classes required to achieve our interpretation of the McIntyre and Hobbs (1999) model. An iterative process was employed and was implemented through the use of a look-up table (Table 3). The first iteration used relatively high thresholds of VAST 0, I, II and III condition classes and the Sum of VAST 0-III. The thresholds were varied in subsequent iterations if they were deemed unsuitable during evaluation in Step 6. ArcMap was used for this process and the process was performed in a way that ensured that there were no class overlaps, i.e. the derived LAL classes were mutually exclusive. This was achieved by excluding grid cells from further processing once they had been allocated a derived LAL during processing for a particular moving window size.

To help the reader interpret the relationships between vegetation condition classes and LALs, two different pallets of colour were used to represent:

- vegetation condition class. This colour set is used in Figures 2a, 2b, 3a, 3b and in the results section below in maps (Figures 7b to 9b, 11b to 13b, and 15b to 17b). Red, green and blue values for the vegetation condition classes (VAST) are given in Appendix 1.
- LALs shown in Table 2. This colour set (red, green and blue) is used below in the results section in maps (Figures 7a to 9a, 11a to 13a and 15a to 17a) and graphs (Figures 6, 10 and 14). RGB values for each colour for the LALs are given in Appendix 1.

The methodology emphasised setting thresholds of minimum areas for the native vegetation or naturally bare condition class components, that is, proportions of VAST 0, I, II and III condition classes and/or the sum of the proportions for these states (i.e. Sum of VAST 0-III Proportions).

Table 3 contains the threshold values that were found appropriate for the two study areas at the three moving window sizes employed.

**Table 3: VAST condition class look-up table**

<table>
<thead>
<tr>
<th>Derived Landscape Alteration Level</th>
<th>Area proportion of VAST condition state within moving window threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VAST 0 or 1</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Intact</td>
<td>&gt;80%</td>
</tr>
<tr>
<td>Variegated</td>
<td>&gt;20%</td>
</tr>
<tr>
<td>Fragmented</td>
<td>&gt;1%</td>
</tr>
<tr>
<td>Relictual</td>
<td>Remaining unallocated grid cells</td>
</tr>
</tbody>
</table>

Note: There is no VAST condition class IV in the two regions.
Step 5
This step produced maps showing the spatial configuration of the derived LALs along with the basic statistics (area-weighted mean, minimum and maximum values of vegetation condition class proportions) for each derived LAL. Maps and statistics were produced for each iteration and moving window size.

Step 6
In this step the statistics from Step 5 were evaluated to determine whether the thresholds used satisfied the amounts of native vegetation condition and/or naturally bare states specified in our interpretation of the McIntyre and Hobbs (1999) landscape conceptual model (Figure 5). The corresponding map was used primarily to determine whether a particular set of thresholds produced a visually coherent or logical LAL map for the study area. If the statistics and the maps were deemed unsatisfactory, new thresholds were set and the process repeated from Step 4.

Step 7
When the results from Step 6 were deemed satisfactory the iteration stopped and the results were accepted.

To illustrate the utility of the GIS enabled LAL method to other vegetation condition datasets we applied the LAL method to a 1 km GRID resolution national scale vegetation condition dataset using three moving window sizes (2.5 km, 5 km and 10 km). These moving window sizes are identical, in terms of the ratio of the dataset grid size to the moving window size, to the moving windows sizes applied to regional datasets.

The national VAST dataset was compiled by Lesslie et al. (2008) by integrating multiple scale datasets including national and catchment scale land-use, Moderate Resolution Imaging Spectroradiometer (MODIS) land-cover type and the Australian Land Disturbance Database (ALDD). A sequence of steps and rules summarised in Appendix 2 were used to compile the national VAST dataset and the final product is available as a 1 kilometre grid resolution dataset.

Figure 6: Continental VAST condition classes (Based on VAST2, Lesslie et al. (2009))
Results

The results from the two regional and the national dataset show that the LALs proposed by McIntyre and Hobbs (1999) conceptual model can be successfully derived using the GIS enabled LAL method described above.

The results for each LAL dataset are described separately and presented as pairs, i.e. map and graph, to show the effect of changing the size of the moving window on the spatial configuration and the composition of vegetation condition classes which are found within each LAL class i.e. Intact, Fragmented, Variegated and Relictual. The maps show the spatial configuration of the derived LALs while the corresponding graphs show the weighted average composition or area proportion (per cent) of each vegetation condition class within a derived LAL e.g. Intact.

A graph is also presented for each dataset or study area to show the response of the percent of area allocated to each LAL to changing the moving window size. These graphs illustrate how descriptions of the study areas in terms of the dominant LALs are influenced by changes to the moving window size.

LALs – Shoalhaven dataset

Figures 7a, 8a and 9a show the spatial configuration of the LALs derived using moving windows of radius 250, 500 and 1000 metres respectively in the Shoalhaven study area. Figures 7b, 8b and 9b are the corresponding graphs which show the variation of the weighted average proportions of vegetation condition classes (VAST) with change of moving window size, for each derived LAL.

A number of patterns are discernible from the map series when the moving window radius is increased, these include:

- increasingly smooth boundaries of the derived LALs
- disappearance of small unconnected and isolated fragments of the derived LALs, the Relictual LAL in particular
- considerable shrinking of Relictual patches
- expansion and increased connectivity of Fragmented LAL patches to form larger contiguous areas
- Intact and Variegated areas appear relatively more stable except in areas where these derived LALs appear disaggregated at the 250 metre moving window radius.

When the LAL maps are interpreted in conjunction with the corresponding vegetation condition (VAST) map, it is apparent that the influence of small and/or disaggregated vegetation condition classes in determining the type of derived LAL in their immediate vicinity is increasingly diminished as the radius of the moving window is increased. This effect is particularly evident in areas north-east of Braidwood where the Shoalhaven study area vegetation condition map (Figure 2a) shows disaggregated small remnants of Residual (VAST I) and Modified (VAST II) vegetation condition class. However, the presence of the derived Intact LAL in these areas was observed in the derived LAL maps only at the 250 metre moving window radius. A similar pattern is exhibited by the remnant areas of Residual and Modified vegetation condition classes between Goulburn and Moss Vale.

Figures 7b, 8b and 9b are graphs associated with the maps described above. The graphs show the weighted average proportion of individual vegetation condition classes within a derived LAL for the three moving windows. The general pattern of the graphs is similar across the three window sizes with some variations, mainly minor, in the vegetation condition classes proportions. The weighted average vegetation condition classes proportions of the derived Intact LAL show the least variation with window size increase, a feature consistent with the tight or narrow thresholds set for this LAL as required by the conceptual model.

Larger variations in the weighted average proportions of vegetation condition classes with changes in moving window size are observed for the other derived LALs which use larger threshold ranges, also as required by the conceptual model. The derived Relictual LAL shows the largest variations.
250 metre moving window radius

Figure 7a: LALs derived using a 250 metre moving window radius

Figure 7b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 250 metre moving window radius
A method for deriving maps of landscape alteration levels from vegetation condition datasets

500 metre moving window radius

Figure 8a: LALs derived using a 500 metre moving window radius

Figure 8b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 500 metre moving window radius
1000 metre moving window radius

Figure 9a: LALs derived using a 1000 metre moving window radius

Figure 9b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 1000 metre moving window radius
Figure 10 shows the effect of increasing the size of the moving window radius on the percentage of the study area allocated to each derived LAL. The gradients of the curves are a measure of the responsiveness of the derived LALs to changes in the size of the moving window. In the Shoalhaven study area, Fragmented is the most responsive (steepest gradient) of the four derived LALs, and the only one to exhibit a positive trend. At 250 metre moving window radius, the study area is dominated (approximately 38 per cent) by the derived the Intact LAL. However, as the moving window radius is increased, the Fragmented LAL becomes more dominant. The increase in the proportion of the Fragmented LAL occurs at the expense of the Intact and Relictual LALs whose proportions drop by approximately 4.5 per cent each. This shift in dominance occurs in areas where there is large heterogeneity in the input vegetation condition dataset, particularly where the Managed or VAST V vegetation condition class forms the matrix of the landscape while the other condition classes exist as small disaggregated patches. The Variegated LAL shows the least responsiveness to a change in moving window radius in this study area.

Figure 10: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the Shoalhaven study area
LALs – Bogan Gate dataset

Figures 11a, 12a and 13a show the spatial configuration of the LALs derived using moving windows of radius 250, 500 and 1000 m respectively in the Bogan Gate study area. The following trends or patterns are discernible from the maps:

- increasingly smooth boundaries of the derived LALs
- disappearance of small disaggregated patches of the Intact, Variegated and Relictual and shrinkage of the larger patches of these derived LALs
- Fragmented LAL patches or network expands very rapidly to become the dominant matrix and the patches of the other derived LALs become increasingly isolated.

Figures 11b, 12b and 13b are graphs associated with the maps described above. The graphs show that the weighted average proportions of the vegetation condition classes in the derived Intact LAL vary least. Larger variations occur in the Variegated and Fragmented LALs. The low variations in the proportions of vegetation condition classes for the Intact LAL are attributable to the narrow thresholds set for the controlling condition classes (VAST 0 & I) for this derived LAL. The broader thresholds for the Variegated, Fragmented and Relictual, coupled with the spatially heterogenous nature of the Bogan Gate dataset, contribute to the larger variation of weighted average proportions of vegetation condition classes in these LALs.

250 metre moving window radius

![Image of LALs derived using a 250 metre moving window]

Figure 11a: LALs derived using a 250 metre moving window
Figure 11b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 250 metre moving window

500 metre moving window radius

Figure 12: LALs derived using a 500 metre moving window
Figure 12b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 500 m moving window

1000 metre moving window radius

Figure 13a: LALs derived using a 1000 m moving window
Figure 13b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 1000 m moving window

Figure 14 shows the effect of increasing the size of the moving window radius on the percentage of the study area allocated to each derived LAL. The gradients of the curves are a measure of the responsiveness of the derived LALs to changes in the size of the moving window. The trends exhibited in this graph are somewhat similar, although different in magnitude, to the trends observed in the Shoalhaven study area. The derived Fragmented LAL is the most responsive (steepest gradient) and the only one that increases in area or proportion dominance. The derived Fragmented LAL predominates at all three moving window sizes and its dominance rises steeply as the radius of the moving window size is increased.

In contrast, the proportions of the derived Variegated and Relictual LALs decline at approximately similar rates. The derived Intact LAL is the least responsive and comprises minor proportions at all three moving window sizes. The dominance of the Managed (VAST V) vegetation condition class throughout the Bogan Gate study area (Figure 3a), in contrast to the Shoalhaven study area where the Residual (VAST I) and Managed (VAST V) vegetation condition classes are simultaneously dominant in different parts of the study area (Figure 2a), explains the sharp rise in dominance of the derived Fragmented LAL in the Bogan Gate study area.
Figure 14: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the Bogan Gate study area.

LALs – Australia wide dataset

Given the different scales and quality of data used to compile the national vegetation condition dataset (Lesslie et al. 2008), it is not surprising that there are some problems in interpreting the continental level LALs dataset derived using the above GIS enabled LAL method. For example, the patterns of LAL derived for NSW do not appear to fit neatly with the areas adjacent, found in Victoria and Queensland.

The spatial distribution pattern (Figures 15a, 16a and 17a) of the LALs is consistent with and follows the land-use patterns across the continent. The central interior of the continent (largely extensive land-use zone) is dominated by the *Intact* and *Variegated* LALs. *Fragmented* and *Relictual* LALs dominate the major production or agricultural landscapes (intensive land-use zone) such as the Murray-Darling Basin and the Wheat-belt. Heavily populated areas and unreserved areas in close proximity to them, particularly along the coastal zone, also tend to be dominated by *Fragmented* and *Relictual* LALs. And, increasing the moving window size produces more generalised maps consistent with what was observed with the regional datasets.

In comparison to the regional datasets, the continental dataset shows minor variations of the weighted average proportions of vegetation condition classes of the derived LALs with moving window size changes (Figures 15b, 16b and 17b). The comparatively smaller variations may be attributable to the sheer size of the dataset.
2.5 kilometre moving window radius

Figure 15a: LALs derived using a 2.5 kilometre moving window

Figure 15b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 2.5 kilometre moving window
5 kilometre moving window radius

Figure 16a: LALs derived using a 5 kilometre moving window

Figure 16b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 5 kilometre moving window
10 kilometre moving window radius

Figure 17a: LALs derived using a 10 kilometre moving window

Figure 17b: Average proportions of vegetation condition classes (VAST) for LALs derived using a 10 kilometre moving window
Figure 18 shows the variation of area (proportion as a per cent) allocated to the various LALs with changes in size of moving window. At 2.5 kilometre moving window size, the Australia is dominated by the *Intact* LAL (~46 per cent) closely followed by the *Variegated* LAL (~42 per cent). The area proportion of the *Variegated* LAL increases steadily as the moving window size is increased to become the dominant LAL at 10 kilometre moving window size. *Relictual* LAL is lowest (5 per cent or less) at all three window sizes, demonstrating its scarcity and disaggregated occurrence across the continent.

![Figure 18: Effect of increasing the size of the moving window radius on the percent of the study area allocated to derived LAL across the continent](image-url)
Discussion

The GIS enabled LAL method outlined above represents LALs as a function of increasing fragmentation and increasing modification of vegetation condition due to surrounding land use and land management practices. Derivation of LALs using this method requires input condition datasets to be benchmarked on a continuum relative to a fully mature or natural benchmark or reference condition, where each class is measured relative to the benchmark in terms of vegetation structure, floristics and regenerative capacity. The resultant maps show landscapes that have been altered to varying degrees by differing impacts of land management practices on the original vegetation types.

The results presented above show that the LALs proposed by the McIntyre and Hobbs (1999) conceptual model can be successfully derived from appropriate vegetation condition datasets — in this case vegetation condition states datasets compiled using the VAST framework. However, experimentation may be required to determine appropriate thresholds for each dataset and environmental conditions. Thresholds developed with one dataset may be appropriate to use with another dataset as was the case with the datasets used in this report. Important issues that need consideration when considering application of the results of the method described in this report are discussed below.

Scale

Multi-scale LAL analyses were facilitated by using a range of moving window sizes applied to each vegetation condition dataset. The results show that the spatial configuration and extent of the derived LALs are sensitive to the size of the moving window or landscape area. Larger moving window sizes produce generalised LAL boundaries and may be more suited for strategic applications over large geographic areas, e.g. catchment and regional priority setting. Smaller moving window sizes produce detailed spatial patterns and boundaries which may be more suitable for regional and local operational type applications, e.g. sub-catchment and property management planning.

Scale plays an important role in determining the dominant derived LAL. Within the two regional study areas, the derived LALs appear homogenous at small scales (small radius of moving window) and become increasingly heterogonous as the moving window size is increased. The choice of size of moving window may have implications for the intended applications of the results and further testing and sensitivity analysis may be required to determine the most appropriate window size for any area under consideration.

Comparing LALs between different study areas

Caution should be exercised when comparing LALs results between two or more study areas unless sufficient prior information is available to account for natural (i.e. without human interference) processes, patterns and scales (spatial, temporal and functional) of landscape change. Lindenmayer and Fischer (2006) argue that high productivity areas, often associated with highest species diversity, are typically those that are modified first and most extensively and that landscape change is not a random process. In addition, they note that in most modified landscapes the remaining areas are typically not representative of the unmodified landscape. These factors make it necessary to exercise caution when comparing the results between the two regional study areas used in method development discussed in this report.

At both 250 and 500 metre moving window radius, the Shoalhaven study area could be interpreted as being dominated by the Intact LAL. However, at 1000 metre moving window radius the same area becomes dominated by the Fragmented LAL (Figure 6). In contrast, the Bogan Gate study area has no clear dominant LAL at 250 metre moving window radius. However, the Fragmented LAL rapidly becomes dominant as the moving window size is increased (Figure 10).
The derived LALs for the Shoalhaven case study consist of large and contiguous areas in contrast to the relatively smaller and disaggregated derived LALs of the Bogan Gate study area. These differences in extent and spatial configuration of the derived LALs also reflect the underlying differences in extent and spatial configuration of the vegetation condition (VAST) datasets between the two regional study areas. The derived LALs help to express the differences in the native vegetation between the two study areas in terms of:

- amount and configuration
- average patch size
- distance between patch sizes
- connectivity between patches.

In addition, the method used to derive the vegetation condition dataset/s will have a strong influence in determining which of the vegetation condition classes predominate across a landscape and therefore ultimately influence the derived LALs. Where the condition dataset is derived from land use and/or land tenure datasets rather than models of site-based habitat scores, patterns of vegetation condition will map closely to land use and/or land tenure types. For example, the Shoalhaven study area predominantly consists of Residual vegetation condition class across the centre (mainly National Parks tenure) and Removed vegetation condition class on the outer areas (mainly agricultural land use); this pattern is also mirrored in the derived LALs.

**Application of derived LALs**

The above descriptions and maps, statistics and graphs of LALs can be used to inform natural resource management assessments and to address a range of vegetation/landscape management issues including:

- objectively describing, characterising and comparing different areas in terms of degrees of landscape modification
- monitoring long term performance of the effectiveness of rehabilitation/management/program efforts and target setting to determine trends in landscape pattern
- guiding the development of strategies and plans to meet targets
- prioritising investments through ranking of sub-catchments, catchments, and regions
- providing insights into landscape processes by analysing this dataset in combination with other datasets, such as temporal land and forest cover, tenure and land use.

However, it is not envisaged that these maps, statistics and graphs of LALs by themselves would be used to define landscape management principles or investment criteria. Rather, this information may be used to inform the development of management principles and investment criteria. For example, landscape or ecology restoration principles commonly recommend that the highest priority be given to protecting areas that are in the ‘best’ condition (Intact LALs), lower priority to improving vegetation connectivity, and lowest priority to improving and reconstructing degraded landscapes. The derived LALs may help identify areas to focus on for further detailed investigations in order to achieve those outcomes.

**Limitations of LALs**

It is important to note that the vegetation condition datasets used in this study are still under development. They have not yet been subjected to site-based scoring of vegetation structure, composition and functional attributes and modelling the results across the landscape. Inevitably, any errors in these interim vegetation condition datasets, particularly in relation to coding polygons with the appropriate vegetation condition class, will affect the accuracy and reliability of the derived LALs.
The LALs derived in this study reflect structural or physical characteristics rather than functional properties of the study areas. As such, they do not reflect the functional needs of any particular organism.

For LAL maps and statistics derived by the GIS enabled LAL method to be useful in long term landscape monitoring, guidelines would need to be developed for consistently mapping the spatial and temporal inputs that determine the vegetation condition datasets.
Conclusions

This study has demonstrated that a GIS enabled LAL method can be used to derive maps and statistics of LALs envisaged by McIntyre and Hobbs (1999) in their LAL conceptual model. Further, this report has shown that LAL maps and statistics can be derived at the regional level provided appropriate vegetation condition datasets and suitable software are available. While these developments are promising, further analyses are required to fully evaluate how well thresholds developed with one dataset may be appropriate to use with another dataset.

These developments have become feasible due to advances in methods for describing, classifying and mapping and modelling of native condition classes (EMR 2006) and compilation of these models using a nationally consistent approach like VAST (Thackway and Lesslie 2006) and the development of spatial tools in GIS, i.e. FRAGSTATS. This report has integrated these developments making it possible to routinely describe and map the four LALs of McIntyre and Hobbs (1999), i.e. Intact, Fragmented, Variegated and Relictual. However, the merits of the mapped and graphed products presented above have yet to be evaluated in the field.

The GIS enabled LAL method described in this report should enable the McIntyre and Hobbs (1999) LAL conceptual model to be implemented routinely by conservation biologists and natural resource managers to help in assessing the full spectrum of human impacts observed across agricultural and fragmented landscapes.

As with any mapped product, caution should be exercised in applying these LAL maps and statistics. The vegetation condition datasets used in this report have not been evaluated using independent site-based observations to assess the quality and reliability of the final maps. However, with regard to the two regional study areas the primary intent in developing these datasets was to compile maps of vegetation types (McNellie, M [NSW DECC] 2008, pers. comm., 21/01/08); a secondary outcome of collecting the site data was that these data could be used to discover the degree of vegetation modification/condition relative to a fully natural benchmark.

The attributes collected by NSW DECC included observations of modification structure, taxonomic composition and functional attributes, e.g. regeneration and evidence of past land use and land management practices. Site-based observations were scored relative to an implicit or putative reference condition (Thackway et al. 2006). As such, the vegetation condition datasets and the derived LALs datasets are a reflection of the density and heterogeneity of mapped condition classes and are only as good as the sampling intensity of the supporting site-based data.

Where decision makers require information about the status and trend of fragmentation and vegetation condition within agricultural landscapes, the demonstrated method can be used to describe and map increasing levels of modification of vegetation types due to human land use and land management practices. However, the choice of size of moving window radius may have implications for the intended applications of the results. Larger moving window sizes produce generalised alteration level boundaries and may be more suited for strategic applications over large geographic areas, e.g. catchment and regional priority setting, while smaller moving window sizes produce more detailed spatial patterns and boundaries which are more suited to regional and local operational type applications, e.g. property management planning.
References


A method for deriving maps of landscape alteration levels from vegetation condition datasets

Williams, J 2005, *Native Vegetation and Regional Management: A guide to research and resources*, Greening Australia Ltd, Yarralumla.
### Appendix 1

#### RGB* values for VAST condition classes

<table>
<thead>
<tr>
<th>VAST Condition classes</th>
<th>Colour</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAST 0</td>
<td>Red</td>
<td>209</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>115</td>
</tr>
<tr>
<td>VAST I</td>
<td>Red</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
<tr>
<td>VAST II</td>
<td>Red</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
<tr>
<td>VAST III</td>
<td>Red</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>69</td>
</tr>
<tr>
<td>VAST V</td>
<td>Red</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>191</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>191</td>
</tr>
<tr>
<td>VAST VI</td>
<td>Red</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
</tbody>
</table>

* (red, green and blue)

#### RGB* values for derived LAL classes

<table>
<thead>
<tr>
<th>Derived LAL</th>
<th>Colour</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact</td>
<td>Red</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
<tr>
<td>Variegated</td>
<td>Red</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>68</td>
</tr>
<tr>
<td>Fragmented</td>
<td>Red</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
<tr>
<td>Relictual</td>
<td>Red</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>0</td>
</tr>
</tbody>
</table>

* (red, green and blue)
Appendix 2

Rules and steps implemented in compiling the national VAST dataset

1. VAST class 0, *Naturally bare*, was derived from class 16 of the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type 2004.

2. VAST class VI, *Removed*, was derived from the national ‘2000-1 Land Use of Australia’, Version 3 and equates to the values of 5.4 Residential, 5.7 Transport and Communication and 6.2 Reservoir/dam in that dataset. The 2000-1 Catchment scale land use mapping in Tasmania was used to more accurately represent forestry than is the case with the national 2000-1 dataset.

3. VAST class I, *Residual*, was derived from the Wilderness of Potential National Significance areas within the Australian Land Disturbance Database, for all States and Territories except Western Australia. In WA these areas were identified by selecting locations with a Total Wilderness Quality value of greater than or equal to 12 and an area greater than 100 000 ha.

4. The balance of VAST class I (*Residual*), class II (*Modified*), class III (*Transformed*) and class V (*Replaced*), were derived from the Biophysical Naturalness (BN) dataset. BN values of 0 were assigned a VAST class of V (*Replaced*), BN values of 1 a VAST class of III (*Transformed*), BN values of 2 and 3 a VAST class of II (*Modified*) and BN values of 4 and 5 given a VAST class of I (*Residual*).

5. Remaining gaps in the national VAST dataset were then filled with land use data. Catchment scale land use data was used for Tasmania to ensure forestry was accurate. Remaining holes on mainland Australia were filled by the 2000-1 Land Use of Australia, Version 3.

6. The input datasets were then integrated in the order outlined above (with the bare ground having the highest priority and the combined land use datasets having the lowest priority).

7. The interim VAST dataset created up to this point was then compared with the Native Vegetation Extent 2004 dataset (Thackway et al. 2000) to ensure that areas of native vegetation and naturally bare areas had been represented. Areas that had been classed as VAST class V, *Replaced*, were checked against this dataset and re-classified to VAST class III, *Transformed*, if the Native Vegetation Extent dataset included the areas as native. The largest area of re-classified I kilometre cells occurred in NSW.