



Biodiversity Benefits Project – Phase 3

Mapping of Vegetation Enhancement Activities

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**A report to the Australian Government, Department
of the Environment and Heritage**

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Executive Summary

The Biodiversity Benefits Phase 3 project has mapped 216,379 hectares of on-ground vegetation enhancement activities across six case studies at 691 individual sites. Data from the project allows stakeholders to apply the Biodiversity Benefits Framework to assess the effectiveness of their on-ground activities by utilising existing landscape scale data. Mapping has occurred over a variety of landscapes from fragmented agricultural landscapes in the south-east of Australia, rainforest communities in the Wet Tropics and rangelands in Western Australia. In addition to primary data collection, the project has also resulted in the development of mapping and attribute data collection protocols and tools to enable NRM groups to map and inventory their on-ground activities.

Tools developed include the BioAudit relational database management system for managing and analysing on-ground vegetation enhancement data and the FieldAudit handheld computing system linked to a GPS which allows field mappers to rapidly collect data in the BioAudit system. The report evaluates the ease of data capture and notes that the primary challenge in collecting biodiversity benefits information is to obtain historical data regarding vegetation enhancement inputs (e.g. quantity of seed, provenance) and outputs (e.g. survival rates). Via the case studies, the project has identified issues confronting NRM groups who wish to collect biodiversity benefits data to support their planning activities. These include the following:

- Collecting data to Biodiversity Benefits minimum specifications requires a high level of skill and resources and may be best coordinated by regional bodies who routinely maintain this technical capability (approximately \$25,000 for 100 enhancement polygons);
- Although the initial cost to conduct baseline mapping is high, ongoing maintenance and addition of sites to a district database is expected to be cost effective and could be done by regional groups if suitable IT systems are in place;
- Utilising private contractors was the most efficient mechanism for data acquisition for a large project such as this;
- There is a need to develop more rigorous methods and guidelines for the assessment of vegetation enhancement inputs and outputs (e.g. volume of seed, number of plantings, survival rates);
- Ensuring standard mapping protocols are enforced is critical to enable inter and intra site comparison, ongoing monitoring, and with some flexibility built into the system to allow for regional requirements (e.g. new vegetation condition scoring methods);
- To operationalise the BioAudit approach, there is a requirement for improved IT systems based on BioAudit designs which allow stakeholders to collect, manage and analyse their own data using centralised WWW-based tools and databases; and
- The current use of extant vegetation mapping does not adequately address issues of scale and accuracy and this requires urgent attention if this critical data are to be used to support monitoring and evaluation. Map producers must assess map accuracies and communicate outcomes to decision-makers to ensure that scale and accuracy assumptions are made explicit.

It is unrealistic to expect the widespread national mapping of past on-ground vegetation enhancement activities to Biodiversity Benefits specifications. We recommend that mapping tools and protocols be made available to NRM groups to enable them to conduct their own mapping utilising national standards. We also recommend the mapping of a larger number of study sites to act as long-term monitoring sites to assess the biodiversity benefits of vegetation enhancement activities. In addition to collecting data, this would also include conducting a more detailed biodiversity benefits assessment. A scaleable sample of study sites would allow for inter-study site comparisons of the effectiveness of on-ground activities. This may in-turn facilitate the adoption of adaptive management approaches to improve the biodiversity outcomes of future on-ground vegetation enhancement activities.

Introduction

In January 2002, the NRMCC Land Water and Biodiversity Advisory Committee (now the Natural Resource Programs and Policy Committee) agreed to undertake an assessment of the biodiversity benefits of revegetation and vegetation rehabilitation and protection programs, including an analysis of the most effective program interventions to deliver biodiversity outcomes. The Committee established a Task Group to complete the assessment, and CSIRO Sustainable Ecosystems was commissioned to undertake the work. CSIRO developed a four step framework (<http://www.deh.gov.au/land/vegetation/benefits/index.html> Last Accessed September 21, 2006), but were unable to determine the benefits of NHT-funded vegetation enhancement activities as few on-ground projects recorded the necessary information, such as the precise location of their work. Under Phase 2 of the project, CSIRO used the four-step framework to assess the biodiversity benefits of vegetation enhancement activities and applied it to seven case studies of varying size and with various levels of data completeness (<http://www.deh.gov.au/land/vegetation/benefits/index.html> Last accessed September 21 2006). The framework is designed to assist in the design of new projects, or to design and implement monitoring procedures to assess the biodiversity benefits of past on-ground works. An objective of the framework was to determine whether the Commonwealth's investment in vegetation enhancement activities leads to an improvement in indicators of biodiversity, and how the Commonwealth should best invest to achieve the greatest biodiversity benefits.

A component of this framework was the use of spatial information to conduct a Biodiversity Benefits assessment at the landscape scale. The framework observed that 'It is impossible to assess the potential benefits of vegetation enhancement without a well-constructed GIS that includes mapping vegetation enhancement activities'. Step 3 of the framework recommends the use of mapped on-ground works to calculate landscape attributes of biodiversity including: increases in total woody cover, changes in vegetation patch size, changes in isolation of patches, the proportion of remnant vegetation protected by fencing and where possible, the type of vegetation. However, in order to calculate these landscape attributes effectively and to ensure results are comparable across study areas, some fundamental spatial and attribute data requirements emerged. Consequently, the following recommendations emerged from the study:

- Mapping of on-ground works should be incorporated into every natural resource management project that receives substantial (>\$100,000) public investment;
- Mapping should be incorporated into a spatial database that adequately describes the purpose and inputs invested in each mapped polygon;
- Ready access to digital data layers for vegetation extent, composition, conservation status and habitat quality is needed at a finer scale; and
- The potential biodiversity value of mapped on-ground works ought to be assessed against regional targets and against the likely benefits expected from changed landscape configurations and management. Those people most closely associated with a mapped project area should conduct this assessment.

These recommendations have led to the establishment of the Biodiversity Benefits Phase 3 project titled 'Mapping of Vegetation Enhancement Activities'. The project is a collaborative research initiative between CSIRO, DEH and case study stakeholders. The project aims to develop methods and protocols for cost effectively and accurately mapping existing vegetation enhancement activities, and to operationally test the methodology for six national case studies. The protocols focus on both spatial data acquisition, and aspatial (attribute) data acquisition and management. The outcomes from this project are expected to make an important contribution to national NRM monitoring and evaluation frameworks by developing tested processes for capturing information on existing vegetation enhancement activities. This data can be used for assessing the baseline status of enhancement activities, for future planning and for ongoing monitoring of biodiversity outcomes. In this report it is stressed that an essential feature of effective reporting and evaluation systems is the use of well structured databases to enable comparison between case studies, and through time for individual study sites. Consequently one project output is a well structured GIS and attribute database which meets minimum data specifications for six national case studies. The objectives for the Biodiversity Benefits Phase 3 project include the following:

- More efficient assessment of the biodiversity benefits of investment in vegetation works, via the use of appropriate spatial information;
- Improved approaches and tools for monitoring vegetation enhancement activities, through implementation of the Biodiversity Benefits Framework;

Expected project tasks include the following:

- Develop design advice on how to select a nationally representative sample of on-ground works to be mapped. The project should examine a sample of Australian Government funded vegetation enhancement projects under Bushcare 1, Bushcare 2, Save the Bush, One Billion Trees program, and include both past and current projects. Implement the sampling design to select suitable case studies of vegetation enhancement works;
- Develop protocol and recommendations for the most cost-effective mechanisms for collecting as much data on these projects as possible within the allocated funding and timing constraints;
- Consult with States and regional bodies and promote their cooperation and collaboration in the project (possibly through previous members of the Biodiversity Benefits Task Force, ESCAVI or the Monitoring and Evaluation Coordinating Committee);
- At the conclusion of the data collection, compile the spatial data into a database, in consultation with ERIN, to enable further analysis using the Biodiversity Benefits Framework
- Undertake preliminary analysis on the data;
- Testing applicability of Biodiversity Benefits Framework minimum data specifications,
- Building capacity of regions and project managers to map their on-ground works and assess the biodiversity benefits of their projects, and to set and measure progress against vegetation targets; and
- Demonstrate that enhanced dataset on projects which will enable improved analysis of the effectiveness of past projects and provide a more objective basis for making future investment decisions in vegetation enhancement.

Project Justification

Why map on-ground vegetation enhancement activities? As this report will highlight, accurately mapping on-ground vegetation enhancement activities to Biodiversity Benefits Framework minimum specifications is a costly exercise. For example, mapping a case study of approximately 100 vegetation enhancement sites can cost in excess of \$25,000. Justifying an investment in mapping of on-ground activities by either regional or local groups can be justified for a number of reasons including the following:

- **Development of monitoring programs:** Regional natural resource management agencies can use the data to develop monitoring programs to assess the effectiveness of their activities and to report against their targets. The mapped vegetation enhancement activities allows groups to stratify their monitoring program by factors such as age of the activity, size of the activity or according to regional risk factors such as neighbouring land uses or threats (e.g. salinity);
- **Assessing progress towards regional NRM targets.** Many catchment action plans specify spatially explicit targets for the enhancement of native vegetation. A target may be a percent increase in area or representativeness by area for a particular vegetation community;
- **Support vegetation mapping programs:** Given the relatively small size of vegetation enhancement activities, assessing this change from satellite imagery is difficult and hence individually mapping activities is the only way a region can assess whether they are on a trajectory which will meet targets;
- **Support vegetation restoration principles:** In addition to the NRM targets, regional NRM bodies prescribe other targets which are fundamentally spatial in nature. For instance, the establishment of corridors for improving the connectivity between parcels of land preserved for conservation, or corridors which are designed for enhancing the abundance of a specific species (see Bennett, Kimber and Ryan 2000). Indeed many of the fundamental principles for enhancing the value of vegetation at the landscape scale described by Bennett, Kimber and Ryan (2000, p.11) and Williams (2005 p. 103) require mapping of on-ground activities. Without detailed mapping of the current vegetation it is impossible to develop effective biodiversity plans;
- **Assess vegetation representativeness:** A key concern many agencies have is the need to more effectively achieve vegetation enhancement targets which improve the representativeness of threatened ecological communities. Data such as that captured in this project allows managers to assess existing species composition relative to pre-cleared status, and allows them to adaptively assess whether they are achieving an improvement in

representativeness (e.g. use of Birds Australia bird atlas data in the Gascoyne-Murchison or contextual EVC mapping in NE Victoria);

- **Adaptive management:** From an adaptive management perspective, Biodiversity Benefits Framework data allows individual groups (e.g. Landcare groups) to assess the success of their activities relative to neighbouring communities. Cost-benefit assessments which compare fencing and revegetation activities, survival rates of specific species, improvements in understorey composition from different treatments, can all be conducted with such data;
- **Assessing risk:** Having accurate maps of vegetation enhancement activities allows managers to more effectively integrate spatially explicit threat mapping. For instance, salinity outbreak mapping or regional stream condition data can be integrated into the planning process more effectively if represented spatially;
- **Project management and compliance:** There are compelling reasons for having mapped vegetation enhancement information to support project management and compliance requirements; and
- There are also a suite of other emerging reasons for mapping the investment in vegetation enhancement activities including the management of vegetation clearing offsets, for modelling future landscape scenarios (Wilson and Lowe, 2003), for providing information to national carbon accounting systems and for the continual update of existing large scale (1:100,000) vegetation maps to name only a few examples.

Report Structure

This report documents the methods, outcomes and key findings from the Biodiversity Benefits Phase 3 project. The report firstly examines the site selection methodology which led to the choice of the six case study projects. The selection of suitable case studies was a challenging component of the project as it required the identification and engagement of case study projects according to prescriptive project criteria, and within specified time frames. Selecting these case studies to optimise across criteria including the spatial extent of the vegetation enhancement activities, geographical representativeness, stakeholder willingness to participate and ability to meet project timelines proved to be a major project challenge.

The report introduces the methods and protocols used to map on-ground vegetation enhancement activities. A more rigorous treatment of these methods is presented in Appendices A and B owing to their length, detail and to ensure they are self-contained to allow them to be provided to other users. The appendices document the development of methods for the rapid acquisition of spatial and attribute information to support ongoing monitoring and evaluation frameworks. They describe mapping protocols, standards and recommendations for mapping on-ground words using both field based GPS techniques and desktop mapping approaches utilising remotely sensed data. It pays particular attention to the development of the BioAudit relational database management system for managing and analysing vegetation enhancement data. BioAudit formalises the minimum data specifications reported in the Phase 2 report using entity-relationship data models. An associated development is the creation of the *FieldAudit* tool which is handheld computer software linked to a GPS to enable rapid field data acquisition and synchronisation with the main BioAudit database. The *FieldAudit* suite of tools are described in detail given their potential utility to regional bodies interested in mapping their on-ground activities.

The report then introduces each of the six case studies and provides some preliminary results based on data in the BioAudit database and contextual GIS data. As the primary focus of this research was the development and implementation of mapping methods and tools, the analysis phase is not as detailed as the Phase 2 report. However the BioAudit database contains a rich array of data which could be used to conduct a more detailed analysis for any of these case studies. The primary purpose of the analysis phase is to evaluate the utility of the BioAudit data model and mapping protocols.

The concluding discussions in the report examine key issues which have emerged from this study. For example, it examines the ease of data acquisition derived from a survey of stakeholders to assess the feasibility of collecting BioAudit data. Findings from this component of the project are likely to be useful if the methodology is operationalised in the future. The discussion also examines institutional issues which have provided challenges to the project including the need for extensive stakeholder engagement at various administrative levels. The report concludes with a suite of recommendations based on the mapping of six national case studies to the Biodiversity Benefits Framework minimum mapping specifications. It provides an appraisal regarding the feasibility of operationalising the mapping methodology to support national monitoring and evaluation imperatives. The report also examines the broader issues which need to be addressed before regional bodies or local groups can

effectively conduct a Biodiversity Benefits assessment using the Biodiversity Benefits specifications and protocols.

In addition to documenting the methods for spatial and attribute data acquisition, the Appendices also document two other major components of this project. The first (Appendix C) is the need to better understand and appropriately apply landscape metrics to summarise the structural change which has occurred in a landscape from on-ground vegetation enhancement activities. There are a number of commonly used metrics which summarise the structural change in vegetation including total increase in area enhanced, proportional increases in vegetation, nearest neighbour distances and distances to core areas. However, some of these metrics, such as the nearest neighbour distance are scale dependent. We examine the issues associated with the use of landscape metrics have attempted to overcome limitations by developing a method which is more robust to scale and provides a more useful summary of the structural change from on-ground vegetation enhancement activities. This method is described in Appendix C and applied it to the Nullamanna case study to highlight its utility.

Appendix D examines the issue of vegetation mapping accuracy and its impact on a Biodiversity Benefits assessment. Mapping of native vegetation is a core requirement for such analyses and there has been found to be problems with the quality of existing mapping. Using the Border Rivers case study as an example the importance of detailed extant vegetation mapping to support monitoring and evaluation is examined and the discussion highlights how inaccurate mapping can lead to misleading assessments. The discussion provides some recommendations for practitioners to address limitations associated with the use of existing and future vegetation mapping products.

Methods

Data Collection and Analysis

There are two components to developing a database for inventorying, monitoring and assessing on-ground vegetation enhancement activities. They consist of a spatial database (GIS) and an attribute database. The spatial database records the spatial boundary of each activity while the attribute database stores the descriptive information (funding sources, inputs, survival rates, site photographs). Although these databases can be integrated, they represent two distinct phases of data acquisition, and commonly require two distinct databases as GIS tables are generally not efficient at storing complex attribute data. The development of the spatial database requires extensive use of GIS and associated technologies (GPS and remote sensing). The attribute database is normally managed using a relational database management system (RDMS). Owing to the level of detail required to describe the methodology, rules and protocols the mapping and attribute collection methodologies are documented in detail in Appendix A and Appendix B. By including them in the appendices, these methodologies can be self-contained for use by others independent of the primary report.

The attribute data component receives particular attention as the database technologies and protocols provide a useful template for storing and managing on-ground vegetation enhancement data for other study regions in Australia. The description of the protocol has been treated in detail to enable adoption of this approach by other agencies or organisations with an interest in collecting and managing data pertaining to on-ground vegetation enhancement activities. The results section for each case study provides additional methodological descriptions when these differ from the broader protocols. The methods component of this report describes the site selection methodology, it documents the mapping protocol (Appendix A) and discusses the attribute data acquisition and management system (Appendix B).

As this report focuses on the development of methodologies, standards and protocols for collecting Biodiversity Benefits data, the case study analysis component receives only limited attention. However, for each of the case studies preliminary results are provided to highlight what can be reported with such information. For a more detailed treatment of Biodiversity Benefits analyses options readers should refer to Freudenberger and Harvey (2003) and Freudenberger et al. (2004). The analysis techniques adopted in this study can be summarised as follows:

1. **Database Query and Reporting** – the BioAudit database is used to generate summary statistics and graphs reporting on various aspects of the study region's on-ground activities. This can include showing the temporal change in activities graphed by area of activity, enhancement activities shown by area, survival rates plotted as histograms or patch size histograms;
2. **Landscape Metrics** – creation of summary statistics which assess the spatial arrangement or pattern of vegetation enhancement activities in the landscape. These are generally presented pre and post the vegetation enhancement activity and can include measures of clustering,

connectivity and arrangement. Appendix D provides a more detailed treatment of the use of landscape metrics and also documents the development of new methods for summarising the spatial change in a landscape from on-ground vegetation enhancement activities; and

3. **Contextual Analysis** – analyses (primarily spatial) which includes the use of additional GIS data to examine the change which has occurred in a landscape. This may include incorporating additional vegetation mapping (e.g. EVC data in Victoria) to examine the complementarity of vegetation communities; creation of digital elevation models to examine how vegetation enhancement activities are distributed in the landscape; inclusion of land use data to examine the distribution of activities from the perspective of risk to ecological communities; and utilising other landscape-scale indicator data such as Birds Australia Bird Atlas data, or rangelands monitoring sites.

The appropriateness of each approach will vary from study region depending on the availability and quality of the data. Analysis techniques (1) and (2) can always be implemented if Biodiversity Benefits minimum data specifications have been met. The feasibility of conducting a contextual analysis will depend on the availability of supporting data. As the database query and reporting component is conceptually straightforward, Appendix C examines the use of landscape metrics in greater detail. The discussion examines a number of landscape metrics, discusses their limitations and presents a new approach which provides a technique for summarising structural change in landscapes from on-ground vegetation activities. Options for contextual analysis are discussed within the methods section of each case study as they vary depending on the availability of contextual data for each study area.

Site Selection Methodology

The study site selection and stratification was conducted in collaboration with DEH. This phase consisted of two components including an initial 'desktop' stratification which utilised DEH databases, and a 'liaison' phase which involved discussions with possible stakeholders, NHT facilitators and potential contractors. The second phase was the most challenging component of the overall project as it attempted to engage potential study sites on the basis of technical and social criteria. For instance, the stakeholders in the study region needed to have the necessary historical awareness of vegetation enhancement activities to provide useful information, they needed to have the capacity to meet contractual obligations to the project, and an appreciation of the importance of baseline mapped data to support monitoring and evaluation.

Close attention was paid from the start of the project to liaison and collaboration with staff of regional NRM bodies, and State and Australian Government agencies. Brokering of relationships involved a combination of contact and liaison. This was aimed at ensuring 'top-down' support for 'bottom-up' action on case studies. At the 'top' level, contact was made:

- Initially with leaders of NRM joint teams in DEH and DAFF;
- Then (where relevant) the joint team member responsible for a region being considered for a case study; and
- Then the State-based Biodiversity Facilitator.

This degree of contact ensured that joint teams and key members of the Australian Government NRM Facilitator Network were aware of the conduct of the project and associated management arrangements. It also enabled the project to access detailed knowledge and informed views on potential case studies, conditions and key contacts at State and regional levels. Some of the joint team and Facilitator Network contacts were able to assist with promotion of the project to regional and local level staff and volunteers. Ensuing contacts at the regional and local levels varied widely. In some cases, contact was recommended with a Regional Facilitator/Coordinator based with a State Government agency. In other cases, direct and initial contact was appropriate with staff of regional NRM bodies at much the same time as with local project managers. Some regional staff and some local project managers also recommended that contact be made with a chairperson or higher level coordinator to ensure clear lines of communication and accountability as contractors were engaged for mapping of case studies. Some of the relationship brokering benefited from informal contact at events such as the National Conservation Incentives Forum in July 2005, which included a presentation on the project. Such events are part of the NRM knowledge management system and provide valuable opportunities for contact and engagement.

For the desktop phase, DEH developed a list of potential case studies based on information from the DEH Program Administrator database covering NHT1 investments. Regions which received less than \$1 million in investment were excluded from the analysis to ensure that a sufficient number of vegetation enhancement activities had occurred in the region. The initial stratification was based on

the size of the NRM investment and the population density in that region to favour regions which had received substantial investment and had relatively high population densities. The results of this stratification are provided in Table 1.

Table 1. Result of preliminary stratification from DEH databases. Regions were selected on the basis of the population density and the investment in activities (DEH priorities areas are denoted by an asterisk). Candidate regions which have emerged from the stratification and steering committee meeting are shown in bold.

Investment in region -NHT1 biodiversity related programs 1996/97 to 2003/04	Population Density of Region		
	High	Medium	Low
	> 100 persons per sq km (urban, peri-urban)	1-100 persons per sq km. (intensive land use)	<1 person per sq km . (extensive land-use)
\$5 million \$ greater	[none]	*Northern Tas *Goulburn-Broken, Vic Southern Tas South West, WA	*Cape York, Qld Northern Territory Avon, WA
\$1 million to less than \$5 million	*Mount Lofty Ranges and Greater Adelaide, SA Sydney Metro. South East Qld Port Phillip & Westernport, Vic Hawkesbury-Nepean, NSW Swan, WA	*Lachlan, NSW *Murray, NSW *Murrumbidgee, NSW *North Central, Vic Hunter-Central Rivers, NSW Northern Rivers, NSW Burnett-Mary, Qld Wet Tropics, Qld MDB, SA North West Tas Corangamite, Vic Glenelg-Hopkins, Vic West Gippsland, Vic South Coast, WA Central West, NSW Namoi, NSW Southern Rivers, NSW Border Rivers, Qld Mackay Whitsunday, Qld Northern and Yorke Agricultural, SA South East, SA	Northern Agricultural, WA * North East, Vic * Rangelands, WA Wimmera, Vic Border Rivers-Gwydir NSW Burdekin-Wet Tropics, Qld Condamine, Qld Desert Channels, Qld Fitzroy, Qld Maranoa-Balonne, Qld Kangaroo Island, SA Mallee, Vic

The second phase of the site selection process involved a more detailed assessment of potential case studies by evaluating the availability of existing databases, opportunistic site selection where existing mapping capacity presently existed in a region, liaison with NHT facilitators and via input from the project steering committee. The opportunistic site selection coincided with DEH priority regions identified in the phase one stratification. The combination of the phase one coarse stratification, and second phase assessment resulted in the following list of possible study regions:

- Wet Tropics, Qld;
- Avon, WA;
- Border Rivers, Qld/NSW;
- Kangaroo Island, SA;
- North-East, Vic; and
- Rangelands, WA - Gascoyne-Murchison (rangelands case study).

To select a study site within these broad regions operational project criteria were developed and via stakeholder liaison a final selection of case studies was made. The criteria included the following:

- Has the region received significant NHT funding to support vegetation enhancement activities which can be mapped? (i.e. on-ground works);
- Has any prior mapping occurred for these enhancement activities?
- Have polygons been mapped?
- What attributes have been collected?
- Is there a strong community network (i.e. existence of champions) to support mapping activities (i.e. a philosophy which values the importance of monitoring, evaluation and mapping)?
- Is there existing capacity to conduct the mapping? For example, have Landcare officers already conducted some mapping using GIS/GPS? Have they used contractors or consultants to conduct this mapping and if so are these individuals available to conduct additional mapping?
- Would the collaborating region be agreeable to making their data available to DEH at the conclusion of the project or are there IP issues associated with any data capture?
- Balancing the operational imperatives such as IP, technical capacity, time constraints.

Based on these criteria the following case studies were selected: (1) Nullamanna Landcare Group (Border Rivers NSW), (2) Cudgewa and Tintaldra Landcare Groups (NE Victoria), (3) Wallatin Wildlife and Landcare Inc. (Avon WA), (4) Trees for the Evelyn and Atherton Tablelands Inc. (Wet Tropics Qld.), (5) Kangaroo Island Natural Resource Management Board (SA), and (6) Murchison River (Gascoyne-Murchison WA) (see Figure 1). The results section describes each of the case studies in more detail and the following section details the engagement and collaboration process. It is important to note that within any one NHT region, these case studies represents only a small sample of potential case studies which have received funding to conduct on-ground vegetation enhancement activities. They were selected as they satisfied the greatest number of study site selection criteria rather than because their on-ground activities were of a higher quality or a greater extent. The case studies are diverse in terms of their geography and ecology, the type of on-ground activities they have conducted and their spatial extent. As such they have provided the project a useful example of the range of mapping and database issues which are encountered if the protocols were to be expanded to other study sites or regions. Consequently the methods and guidelines will be robust for other national site assessments.

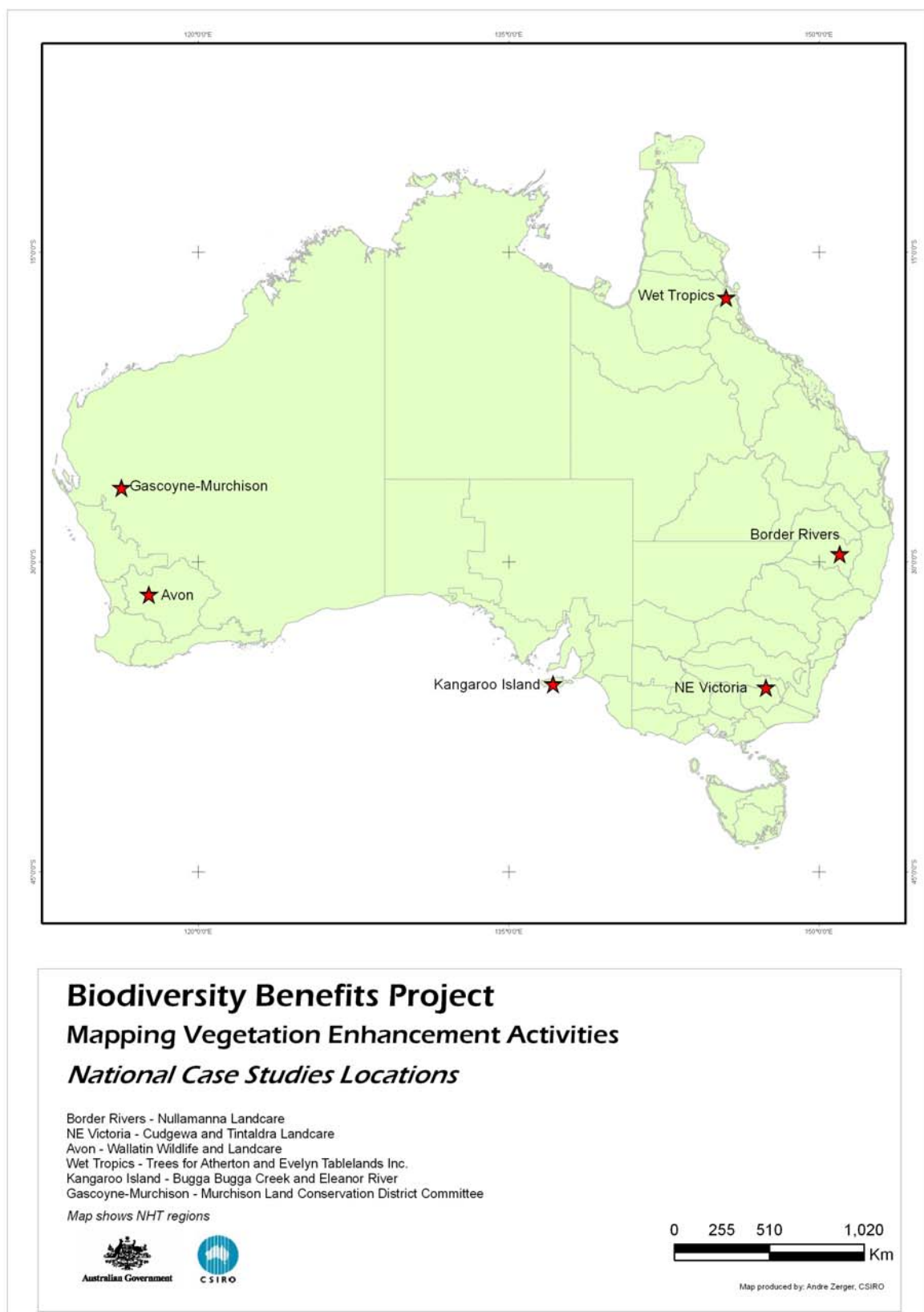


Figure 1. Location of six national Biodiversity Benefits Phase 3 case studies.

Results

Case Study 1 – Nullamanna Landcare Group, Border Rivers NSW

The Nullamanna Landcare Group (21,000 hectares) is located 20 km north east of Inverell and centred on the township of Nullamanna. In its Catchment Action Strategic Plan (June 2000), The Nullamanna Landcare Group has identified a number of major issues affecting the catchment including salinity, soil erosion, better pastures, nightshade, windbreaks, water quality and vegetation. From this list of primary issues and through a community consultation process, the group has identified three priority issues to address in their catchment planning including (a) salinity, (b) water quality and (c) vegetation. Of particular interest to this study is issue (c) which has as its objective the improvement of biodiversity across the catchment via revegetation and remnant protection activities.

Over the past decade the group has attracted substantial funding for a range of vegetation enhancement activities with diverse objectives. This primarily consists of Envirofund funding to mitigate salinity and erosion, and extensive NHT funding to support native vegetation enhancement activities through primarily corridor establishment. The case study was conducted in collaboration with Col Meacham (Chairperson, Nullamanna Landcare Group and with the assistance Mr. Dick Walker (President, Gwydir and Macintyre Resource Management Committee) and Mr. Warwick Browne (General Manager, Gwydir Border Rivers Catchment Management Authority). A total of 13 NHT projects totalling \$296,000 dollars were assessed across the Nullamanna Landcare Group with funding extending from 1994 to 2003. Based on DEH project information from between 1996 and 2005, the entire Border Rivers NHT region received a total of \$1.29 million dollars of NHT funding (J. Tomkins 2005, pers. comm.). Consequently, the Nullamanna Landcare Group accounts for approximately 24 % of all activities in this NHT region (excluding data for 1994 as this was not available). Figure 2 shows the boundary and extent of on-ground activities across the Nullamanna Landcare group.

Mapping of the Nullamanna Landcare Group was conducted in November 2005 by Mr. Damian Wall (Minchem Pty. Ltd) using specifications developed by CSIRO (Appendix A & B). Vegetation enhancement activities were mapped using landholder interviews and a SPOT5 false colour composite image (acquisition date: 15/11/2004) using 'on-screen' digitising with ArcView GIS. In addition to mapping the boundaries of vegetation enhancement activities, site coordinates were also collected including a reference coordinate for each enhancement activity (site) and the location of this reference coordinate relative to the patch. This information was included in the relational database to provide a spatial reference between attribute information and spatial information in the event spatial and attribute data are separated. At present the link between the spatial information and the relational database is via the 'SiteID' identifier which is maintained manually.

In addition to primary data acquisition for this case study, ancillary contextual data was also made available and added to the GIS to enable analysis and mapping. A key dataset for conducting such an analysis is detailed vegetation mapping for the study region. Detailed vegetation mapping, particularly if accompanied by pre-European mapping, enables regions to assess improvements in vegetation cover, representativeness of vegetation communities, and allows one to examine any improvements in landscape connectivity. Existing vegetation mapping was sourced from Border Rivers-Gwydir Catchment Management Authority (Steenbeeke 2001). Extant woody vegetation was mapped from Landsat 5 satellite imagery. However, deficiencies have been identified in the ability of this mapping product to adequately represent extant woody vegetation across the Nullamanna Landcare Group. The primary concern is that smaller remnants are entirely ignored owing to the sensor limitations of Landsat 5. Discriminating paddock trees from such sensors is an even greater challenge. The concern arises when one considers the size of the vegetation enhancement activities across a management zone such as the Nullamanna Landcare Group. Table 2 shows that most vegetation enhancement activities are less than 2.5 hectares in area and few are greater than 10 hectares.

Attribute data collection used the *BioAudit FieldAudit* tool to collect vegetation enhancement activity attribute information directly via landholder interviews. After primary data collection, the *FieldAudit* data files were synchronised by CSIRO using an email transfer from the mapping contractor. The major post processing requirement was to apply site identifiers (SiteID element) from the database to all relevant activities in the GIS file (Shapefile attribute table).

Table 2 and Table 3 provide a summary of key revegetation and remnant fencing activities for the Nullamanna study site. The impact of revegetation in this landscape is small relative to the total amount of existing vegetation in this landscape (0.39 %) although as is discussed in Appendix D, these figures can be misleading as mapping scale and accuracy will impact upon these results. Fencing is more cost effective in terms of its ability to protect larger areas of remnant vegetation

relative to revegetation (452 ha versus 83 hectares). Fencing efficiencies of 39.4 ha/km are commensurate with those described in Freudenberger and Harvey (2004) (32 ha/km) however, this study region has received significantly less funds than comparable study areas hence it may be fair to assume that the in-kind contribution has been larger. Relative to other case studies, the average size of revegetation patches is also quite high (8.9 ha). There has also been a small decrease in the nearest neighbour distance for this region indicated a small improvement in connectivity. The GIS database highlights that activities have included a mix of shelter belt establishment, major areas of riparian protection which also serves to connect habitat, and isolated revegetation activities.

Figure 3 provides a box plot showing the objectives by the total area for that objective for the vegetation enhancement activities in the Nullamanna Landcare Group. The box plot also indicates the range for each objective (stems in the plot) and the median value (solid bar). This data allows for multiple objectives at individual sites hence total areas are greater than the total area of the enhancement activities in this region. The primary objective in this region is the protection of threatened species although the total area for this activity is skewed by one large activity (268 ha). As with the other case studies there is a peak in funding and activity between 1999-2000. Interestingly, funding continues to increase towards 2005 but this is associated with an overall decrease in area enhanced. Without further analysis of the database, it can be assumed that this highlights a shift away from fencing towards revegetation activities. As with most case studies, patch-area histograms for vegetation enhancement activities (Figure 5) highlight the fact that enhancement activities achieve very small increases in total vegetation cover. Figure 7 highlights that most of the revegetation has been located on average, 8 km from other remnants in this landscape.

Table 2. Nullamanna Study Site: Revegetation activities summary

Revegetation Activities	Statistics
Total amount of revegetation (ha)	83.5
Total perimeter of revegetation (km)	41.6
Number of revegetation patches	31
Average revegetation patch size (ha)	8.9
Revegetation as percentage of study site	0.39
Pre (extant & remnant enhancement) vegetation as percentage of the study site	27.3
Total area of study site (ha)	21036

Table 3. Nullamanna Study Site: Fencing of remnant vegetation

Fencing Activities	Statistics
Area of remnants fenced and enhanced (ha)	55.9
Total area of mapped remnants (ha)	5754.4
Area of mapped remnants fenced (ha)	452.5
Remnant area fenced as percentage of all remnants	7.8
Total number of remnants greater or equal to 10ha	29
Total number of remnants less than 10ha	4828
Fenced remnants greater than 10ha	14
Fenced remnants less than 10ha	1
Total perimeter of mapped remnants (km)	1148.5
Total length of funded fencing for remnant protection (km)	56.8
Area of remnant protected per km of funded fence (ha/km)	20.54

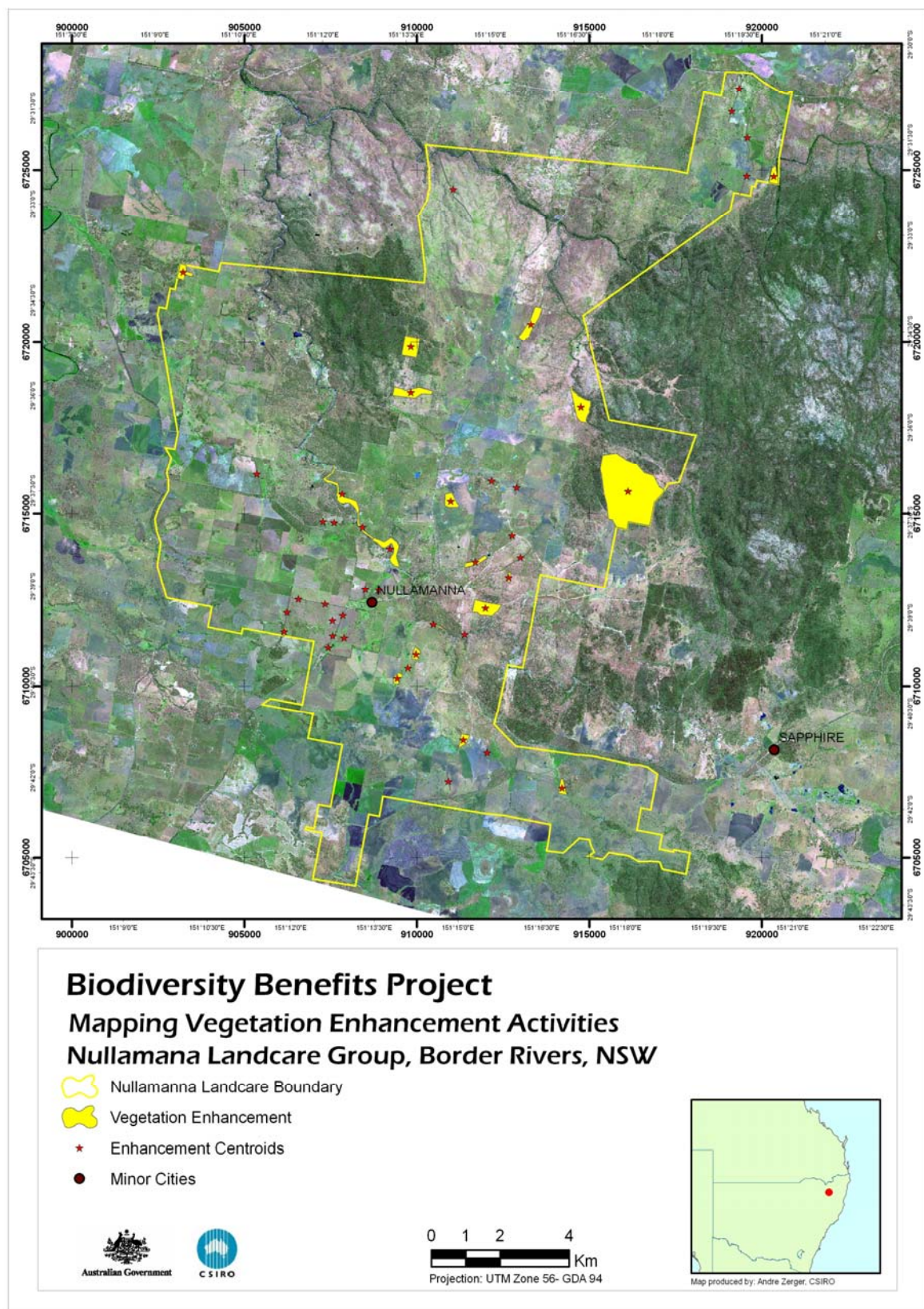


Figure 2. Nullamanna Landcare Group – study area boundary and mapped vegetation enhancement activities.

Table 4. Nullamanna case study: Nearest neighbour indexes for vegetation enhancement activities

Vegetation Enhancement Activity	Mean Nearest Neighbour Distance (metres)	Mean Nearest Neighbour Distance Index
Pre mapped vegetation enhancement activities	68.5	0.46
Post mapped vegetation enhancement activities	67.3	0.45

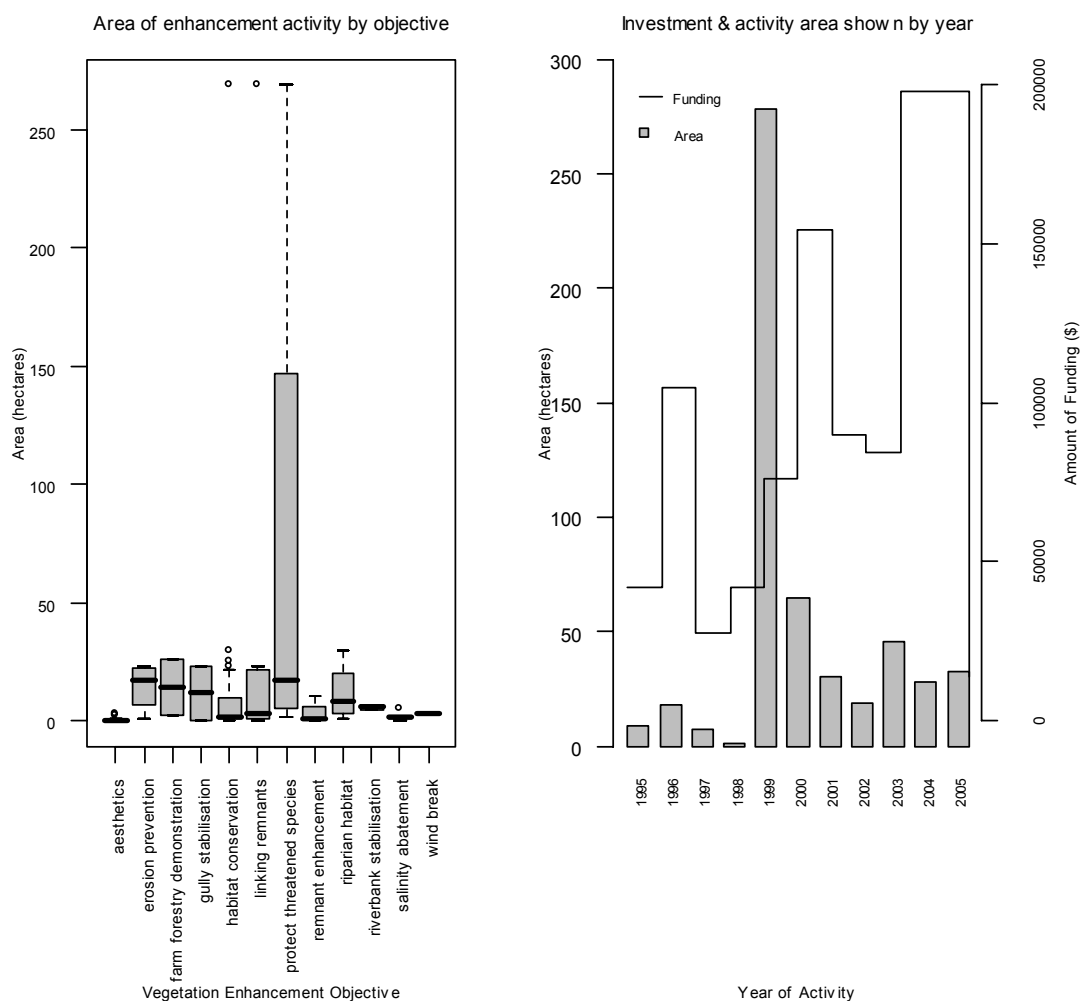


Figure 3. Nullamanna Landcare Group – Area of vegetation enhancement activity shown by enhancement objectives and amount of funding and area of activity shown by funding years. The BioAudit data model allows for multiple objectives at individual sites hence total areas are greater than the total area of activities in this study site (stems in the plot show the data range and the solid bar is the median value).

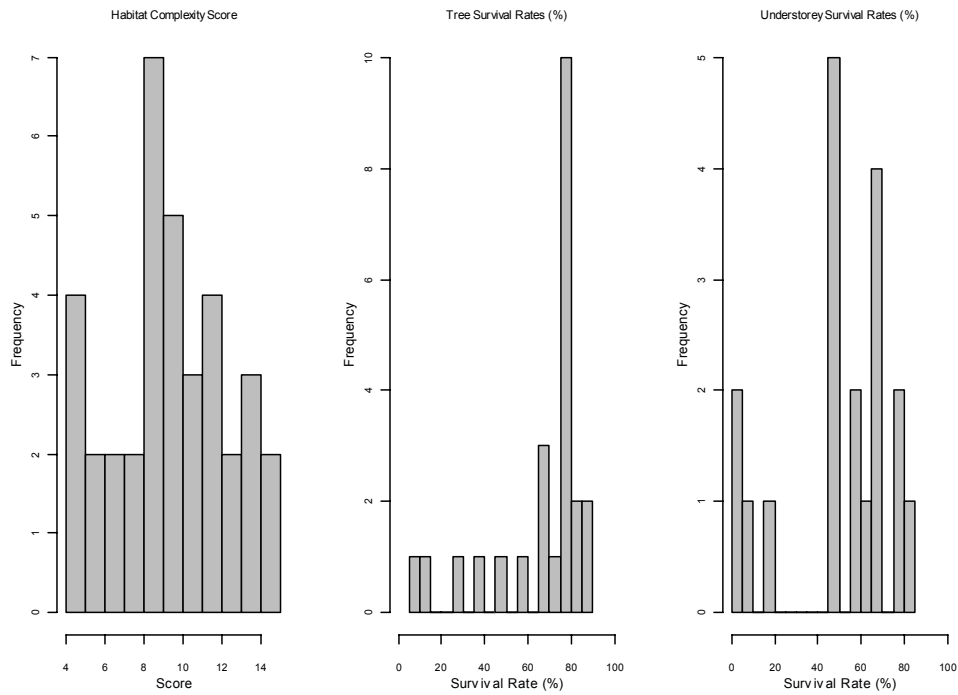


Figure 4. Nullamanna Landcare Group – Vegetation enhancement activity outcomes. Histograms showing range of condition scores and tree and understorey survival rates from mapped vegetation enhancement activities (including remnant protection, enhancement and revegetation)

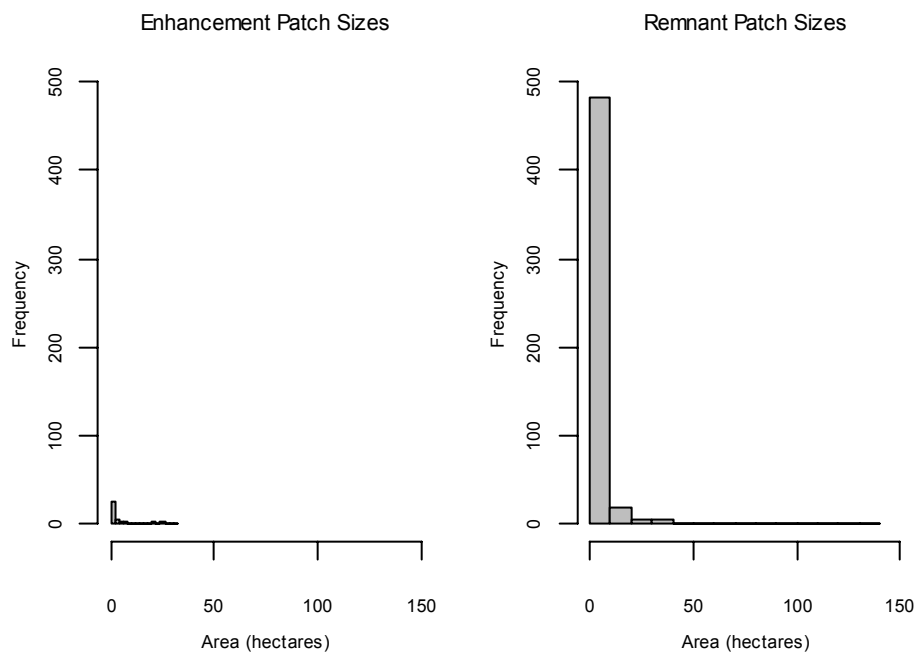


Figure 5. Patch area histograms for new on-ground vegetation enhancement activities including revegetation and fencing (enhancement patch sizes), and existing remnant patch size distribution from Landsat 5 vegetation mapping. Only patches less than 268 hectares are shown as one large revegetation site in Nullamanna skews these graphs.

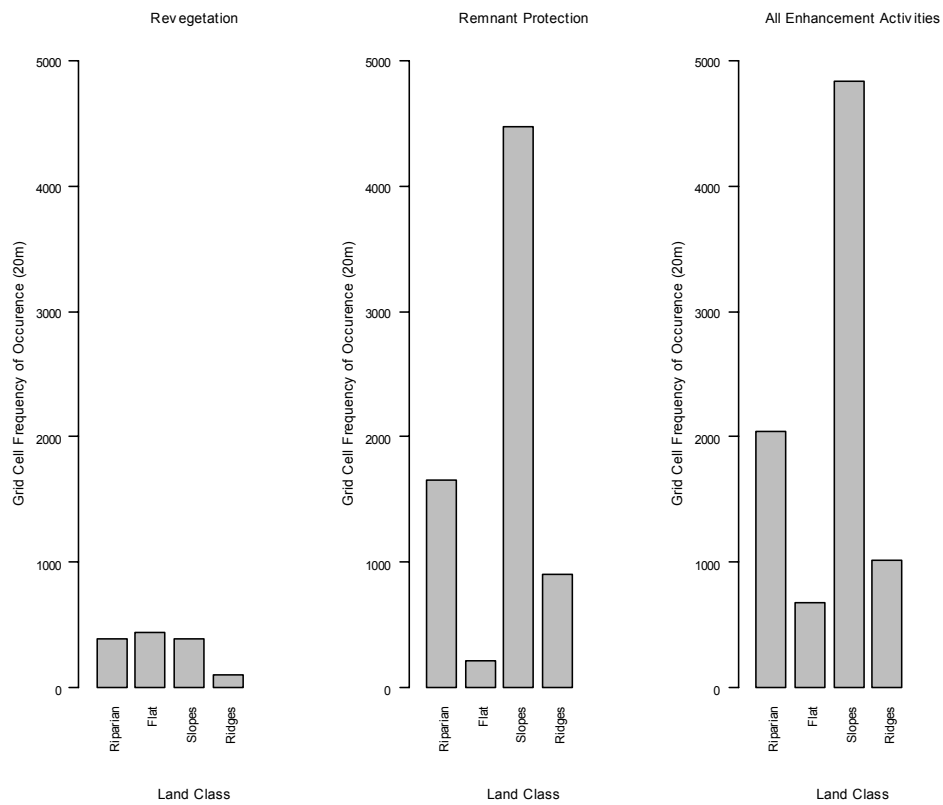


Figure 6. Nullamanna Landcare Group – Area of vegetation enhancement activity shown by land classification for revegetation polygons, remnant protection polygons (fencing) and all activities. The land classification raster utilised a 20 metre cell resolution.

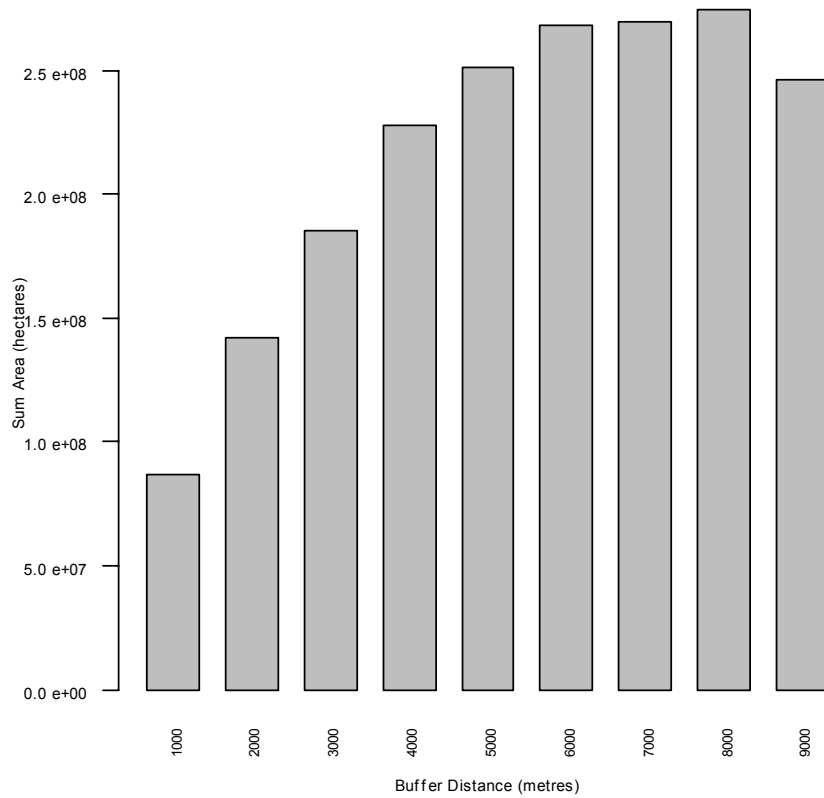


Figure 7. Nullamanna Landcare Group – habitat buffers algorithm results showing relative increases in vegetation area for increasing buffer distances from 1 km to 10 km in 1 km increments. Bar plot shows that most revegetation is on average 8 km from other remnants in the landscape.

Case Study 2 – Cudgewa and Tintaldra, North East Victoria

The Cudgewa study site is located in the western foothills of the Australian Alps, some 40km west of Corryong and 80km east of Wodonga. The case study was conducted in collaboration with the Cudgewa and Tintaldra Landcare Groups and the study is confined to the administrative boundary of the Cudgewa and Tintaldra Landcare Groups. The Landcare groups are responsible for some 42,240ha of land surrounding the Cudgewa Creek in the lower reaches of the catchment. This area extends south west from the Murray River at Tintaldra, along the valley floor and lower slopes to Cudgewa, then west to Lucyvale and Berringama. Much of the upper catchment is forested public land and is managed by government agencies. Generally, clearing has occurred on the valley floor and lower foot slopes while leaving the surrounding ridges and hilltops forested.

The Cudgewa Catchment Landcare Group was formed in 1993. Since then they have been involved in a wide range of programmes including whole farm planning workshops, control of Patterson's curse, bent grass, blackberry, St Johns Wort, and rabbits, enhancement of eucalypt remnants through fencing and understorey plantings, and stock control fencing of riparian sites. The Tintaldra Landcare Group was formed in 1995. They have been involved in the Corridors of Green Program to establish vegetation corridors along the Murray River as well as undertaking other revegetation and weed control projects. Both the Tintaldra and Cudgewa groups have been involved with other groups in the catchment-wide Water Quality Monitoring and Catchment Planning Project.

In 1998, communities in the Cudgewa catchment developed a catchment plan to provide a basis for future actions which addressed the specific needs and concerns of the local community while meeting the aims of the North East Regional Catchment Strategy. Among others, the plan identified erosion, water quality, declining remnant vegetation health, salinity and pest species as issues that needed to be addressed.

The high rainfall and hilly terrain of Cudgewa catchment, in combination with the erodability of the granitic soils of the area, mean that erosion can be a problem. Examples of streambed, bank, sheet and gully erosion, as well as landslips, can all be found within the Cudgewa catchment. Erosion can result in loss of productive land, degradation of water quality and access problems for stock and landholders. The Landcare groups have begun to address these issues by raising awareness of erosion issues, processes and control methods and by promoting stream erosion prevention processes including controlling or excluding stock access, revegetation of riparian areas and control of willows through the establishment of demonstration sites.

Water quality, and in particular high turbidity levels and algal blooms, have been a concern to the community of the Cudgewa catchment for some time. The Cudgewa catchment is a net exporter of water to the Murray so a large number of downstream users will be affected by water quality issues. Water quality monitoring is undertaken monthly to identify changes in water quality and problem areas. This has enabled promotion of water quality issues and has raised the community's awareness of best management practices. Two Natural Heritage Trust projects have provided assistance in riparian fencing, revegetation and bank stabilisation programmes.

Concern about ongoing tree decline and its relationships with salinity, water quality, agricultural productivity and biodiversity has been identified by the Cudgewa and Tintaldra Landcare Groups. Tree declines are an increasing problem throughout the catchment on farmland, roadside reserves and public land. In particular, areas of Blakely's red gum woodland and river red gum in the lower catchment are suffering serious dieback. As well as providing shade and shelter for stock and habitat for wildlife, trees control the recharge of groundwater, minimising problems associated with water logging and salinity. The 'Remnant protection' and 'Reversing Red Gum Decline' NHT projects have been implemented to help maintain and improve remnants in the region. These projects have been complimented by the establishment of revegetation sites by landholders and activities aimed at improving the awareness of the community to the causes of tree decline and best management practices to prevent and address decline.

Mapping of the Cudgewa and Tintaldra Landcare Groups was conducted in February 2006 by Mr. Damian Wall (Minchem Pty. Ltd) using specifications provided by CSIRO (Appendix A & B). Vegetation enhancement activities were mapped using landholder interviews and a SPOT5 false colour composite image using on-screen digitising with ArcView GIS. In addition to mapping the boundaries of vegetation enhancement activities, site coordinates were also collected including a reference coordinate for each enhancement activity (site) and the location of this reference coordinate relative to the patch. Existing vegetation mapping was provided by the Victorian Department of Sustainability and Environment in the form of a 1:100,000 scale EVC map tile for Corryong. Figure 8 shows the boundary of the study region and maps the on-ground vegetation enhancement activities.

Table 5 and Table 6 summarise the key statistics for the on-ground vegetation enhancement activities in the Cudgewa and Tintaldra case study. The region has revegetated 73.7 ha and fenced 86.3 ha. The average size of revegetation activities is relatively small (0.76 ha) and the GIS highlights that this is owing to the large number of linear shelterbelts and riparian protection zones created in this landscape. This is also highlighted by the relatively low perimeter to area ratio of 1.2. Relative to other study sites, few of the activities were fencing only with the majority consisting of revegetation, combined with fencing. The nearest neighbour distance has decreased from 362 metres to 318 metres indicating that some improvements in connectivity have been achieved, probably owing to the extensive establishment of linear corridors and riparian protection which will lead to such results (Table 7).

The major vegetation enhancement activity in this study site is revegetation for riparian protection followed by the protection of threatened species. As with the Nullamanna case study, Figure 10 shows a steady increase in funding leading up to about 2004, however this also corresponds to a net increase in area enhanced which reflects the fact that this region has focussed on revegetation rather than fencing of existing remnants. Figure 12 shows that revegetation activities have been successful with relatively high survival rates of tree species, although understorey survival rates have been significantly less.

Table 5. Cudgewa and Tintaldra case study: Revegetation activities summary

Revegetation Activities	Statistics
Total amount of revegetation (ha)	73.7
Total perimeter of revegetation (Km)	59.9
Number of revegetation patches	97.0
Average revegetation patch size (ha)	0.76
Length of fencing for revegetation (km)	60.4
Average perimeter to area ratio of funded fences	1.2
Revegetation as percentage of study site	0.17
Pre (extant & remnant enhancement) vegetation as percentage of the study site	39.3
Total area of study site (ha)	42240

Table 6. Cudgewa and Tintaldra case study: Fencing of remnant vegetation

Fencing Activities	Statistics
Area of remnants fenced and enhanced (ha)	70.1
Total area of mapped remnants (ha)	16510.5
Area of mapped remnants fenced (ha)	86.3
Remnant area fenced as percentage of all remnants	0.5
Total number of remnants greater or equal to 10ha	190
Total number of remnants less than 10ha	427
Fenced remnants greater than 10ha	2
Fenced remnants less than 10ha	31
Total perimeter of mapped remnants (km)	1741.2
Total length of funded fencing for remnant protection (km)	17.2
Area of remnant protected per km of funded fence (ha/km)	0.9

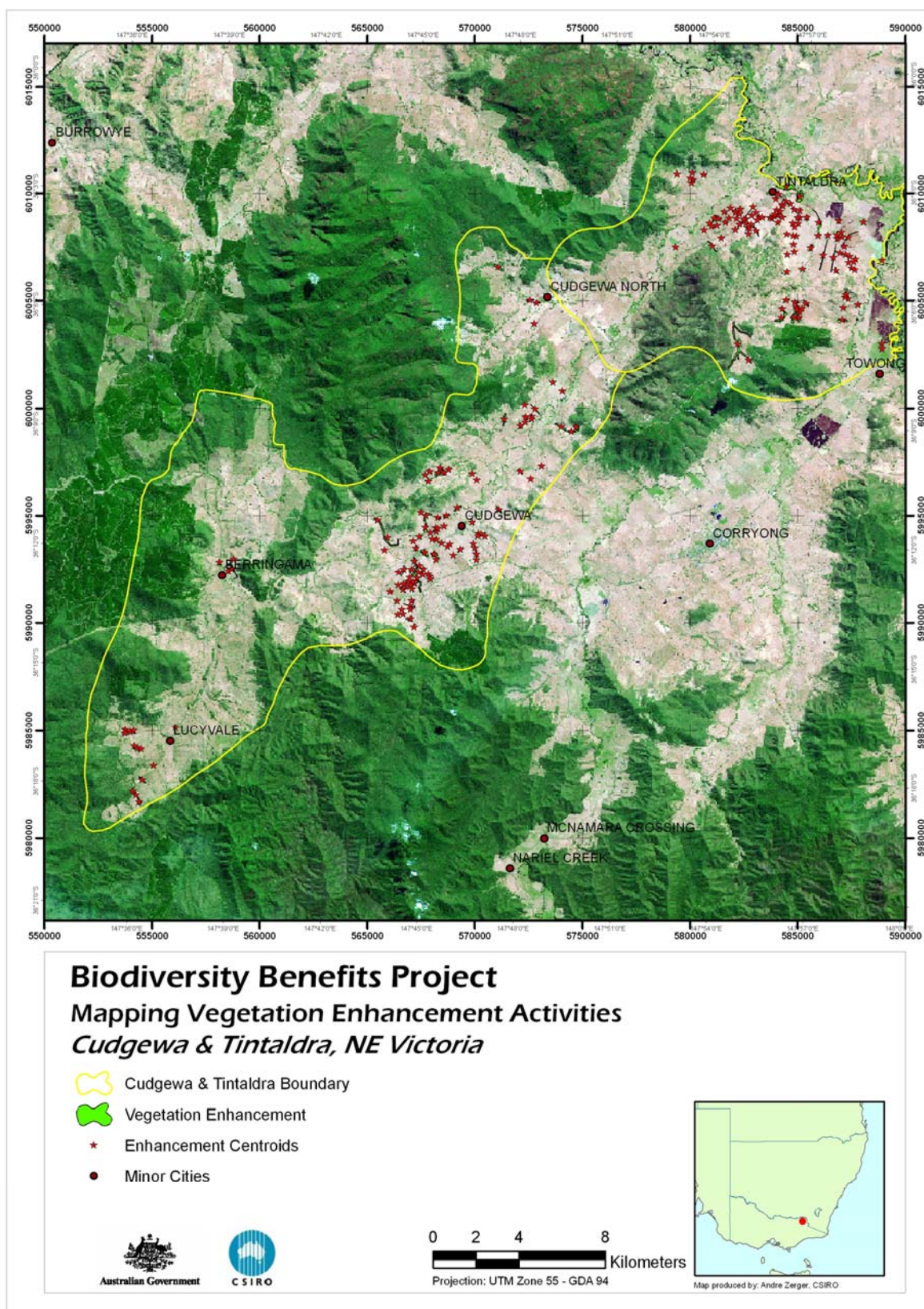


Figure 8. Cudgewa and Tintaldra Landcare Group – study area boundary and mapped vegetation enhancement activities.

Table 7. Cudgewa & Tintaldra case study: Nearest neighbour indexes for vegetation enhancement activities

Vegetation Enhancement Activity	Mean Nearest Neighbour Distance (metres)	Mean Nearest Neighbour Index
Pre mapped vegetation enhancement activities	362	0.49
Post mapped vegetation enhancement activities	318	0.51

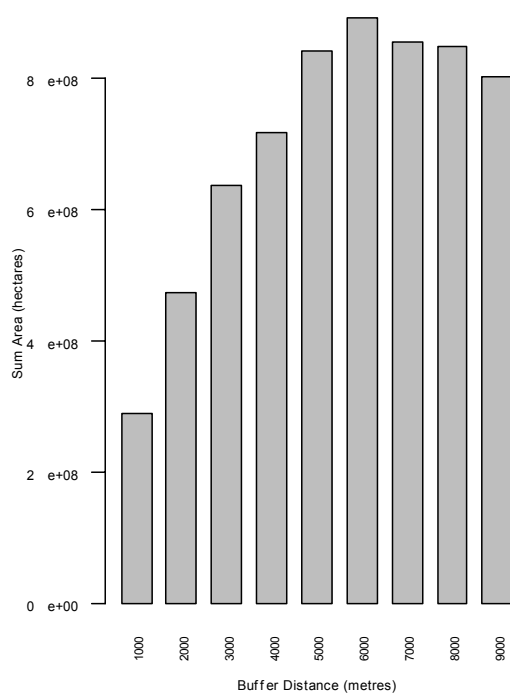


Figure 9. Cudgewa and Tintaldra Landcare Group – habitat buffers algorithm results showing relative increases in vegetation area for increasing buffer distances from 1 km to 10 km in 1 km increments. This shows that most revegetation, on average was 5-6km from other remnants in the landscape.

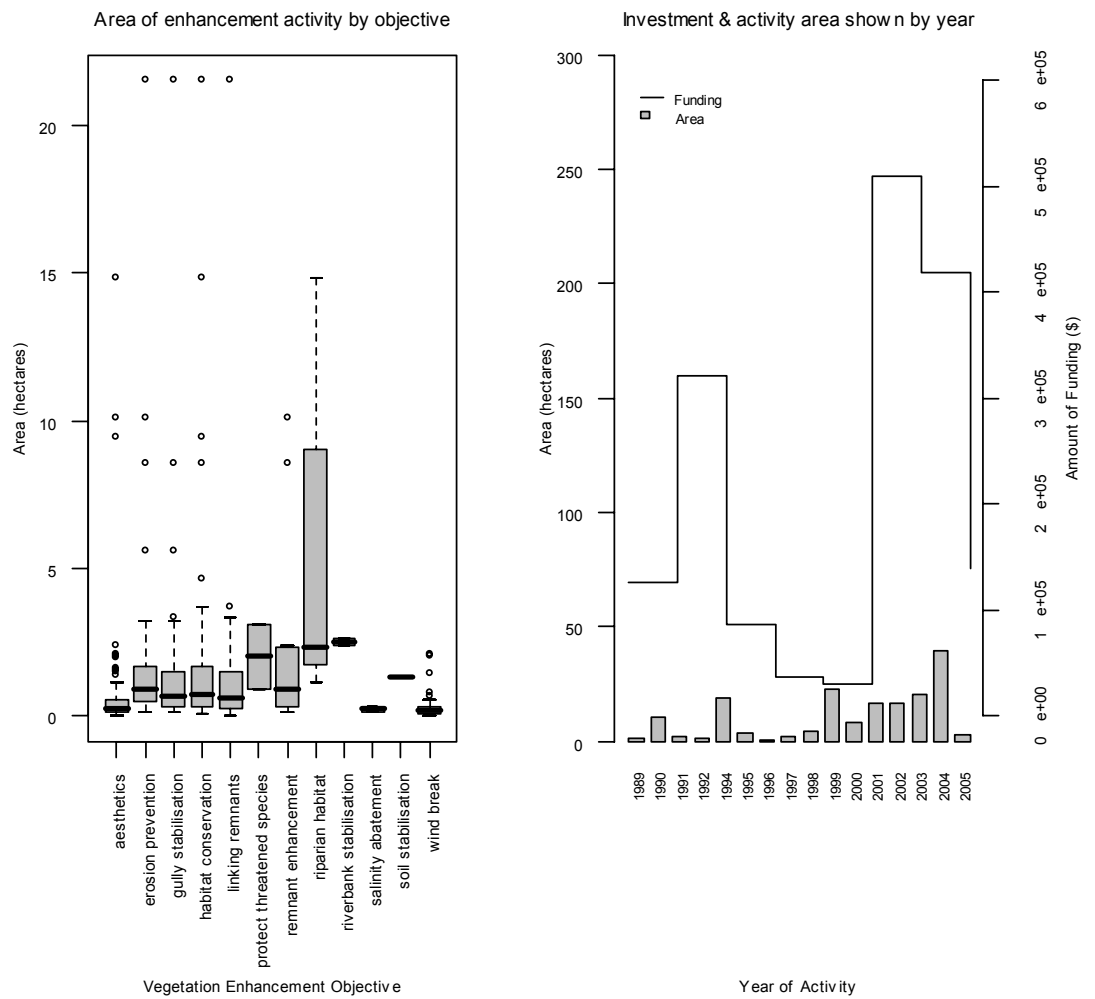


Figure 10. Cudgewa and Tintaldra Landcare Group – Area of vegetation enhancement activity shown by enhancement objectives and amount of funding and area of activity shown by funding years. The BioAudit data model allows for multiple objectives at individual sites hence total areas are greater than the total area of activities in this study site (stems in the plot show the data range and the solid bar is the median value).

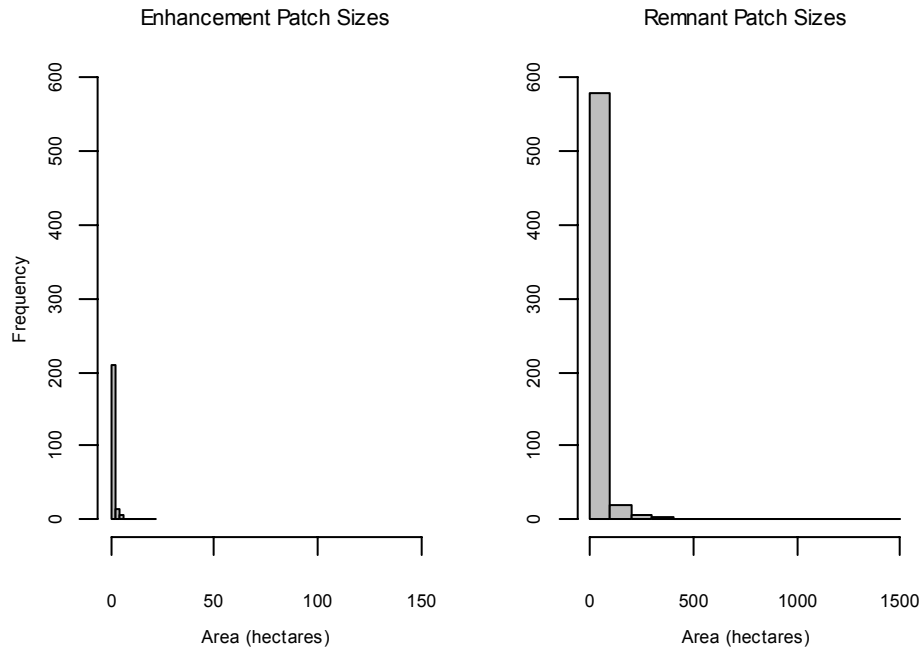


Figure 11. Patch area histograms for new on-ground vegetation enhancement activities including revegetation and fencing (enhancement patch sizes), and existing remnant patch size distribution from EVC vegetation mapping.

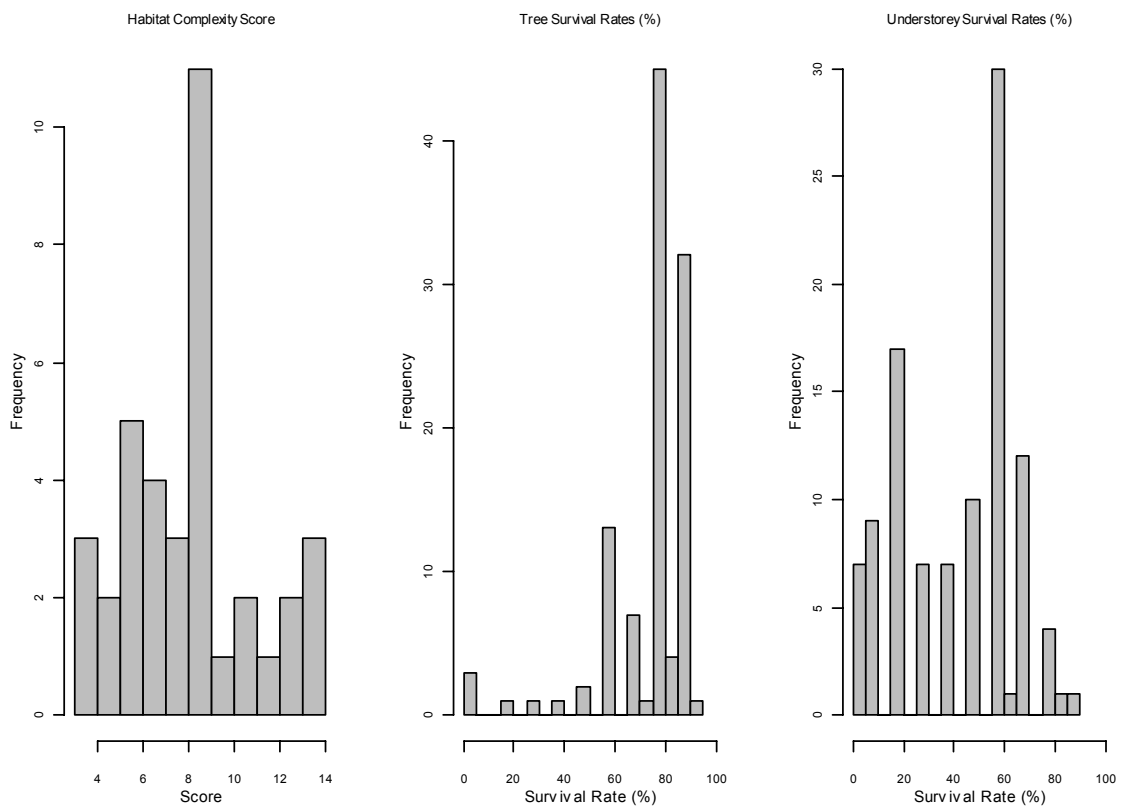


Figure 12. Cudgewa and Tintalra Landcare Group – Vegetation enhancement activity outcomes – histograms showing range of condition scores and tree and understorey survival rates from vegetation enhancement activities (including remnant protection, enhancement and revegetation).

Case Study 3 – Avon WA – Wallatin Wildlife and Landcare Inc.

The Upper Wallatin Creek Catchment Group was the first group formed in the Kellerberrin Land Conservation District in the Yilgarn Catchment. Landholders in the upper catchment responded to a request by the newly formed Kellerberrin Land Conservation District in 1984 to inspect problems arising in the catchments. As a result of this initial investigation the Upper Wallatin Creek Catchment became involved in a number of studies. A significant amount of on-ground works have been done in the catchment since 1984 with external funding and individual landholder funding assisting the group in addressing land degradation problems on a catchment scale. Works implemented included revegetating recharge and saline discharge areas, establishing trees along drainage lines and establishing wildlife corridors. The landholders of the upper catchment area recognized the advantages of working with the lower Wallatin Creek catchment and in July 1996 formed Wallatin Wildlife and Landcare Inc. encompassing the upper and lower catchment. The catchment consisted of 19 landholders and covered 26,066 hectares. The catchment runs in a north west direction from Doodlakine to the north of Kellerberrin. The catchment was expanded on 30th June 1998 to encompass O'Brien Creek catchment which is situated west of the Wallatin catchment. Many of the landholders in Wallatin catchment are also in the O'Brien catchment. The number of landholders making up Wallatin Wildlife and Landcare Inc. now totals 25 and the catchment covers over 40,000 hectares. The study site is located within the Avon NHT region and represents approximately 0.32 % of this region. Relative to the other case studies, this is a significantly low representation; however the Avon is a large NHT region.

This study site was mapped by Dr. Patrick Smith at CSIRO Sustainable Ecosystems Floreat (WA) in Perth using air photo interpretation and extensive landholder interviews. It formed the basis of a larger research project titled 'Best practice management for salinity and biodiversity in the Wallatin and O'Brien Creek Sub-catchments' which is determining the biodiversity value of past vegetation enhancement work. The broader project is utilising detailed field work to evaluate the biodiversity benefits of these activities including plant, fungi, bird, mammal, reptile and invertebrate surveys. This case study mapped a total of 414 activity polygons which is a large number when compared to the other case studies. However, because a major effort was made to capture all the activities, less attention was devoted to the collection of attribute information and hence only primary data has been incorporated into BioAudit. Figure 13 shows the study area boundary and the location of on-ground vegetation enhancement activities mapped for this case study.

Table 8 and Table 9 provide summary statistics for the Avon case study which mapped 414 vegetation enhancement activities. Owing to the limited list of descriptive attributes which could be collected for this case study, the results focus on the spatial component of the database. This region has achieved high rates of revegetation (1750 ha) and high fencing rates (2241 ha) for a study area of 37,667 ha. This has led to high revegetation ratios of 4.64 % of the study area being revegetated. This is significantly greater than the seven case studies examined in Freudenberger and Harvey (2004) which documented increases between 0.17 % to 2.61%. Consequently this case study stands out as one which has achieved significant landscape change from on-ground vegetation enhancement activities. Fencing ratios (9.5 ha/km) are comparable to the Nullamanna case study although this study region has fenced some five times as much remnant vegetation. As with the other case studies, the mean patch size of revegetation activities is about 5 ha which is at the higher end of what is commonly seen, although as explained earlier this value can be skewed by large individual activities. Owing to the relatively rich time series available for this case study, nearest neighbour distances were examined with greater temporal detail and are shown in Table 10. Nearest neighbour distances have steadily decreased from 303 m to 221 m over this 14 year period. This is the largest improvement in connectivity of all the case studies. Figure 16 highlights the pattern seen with other case studies showing a steady increase in on-ground vegetation activities leading up to 2000 followed by a general decrease in activity after this period which returns to pre 1990 levels of activity.

Table 8. Avon case study: Revegetation activities summary

Revegetation Activities	Statistics
Total amount of revegetation (ha)	1750
Total perimeter of revegetation (Km)	698
Number of revegetation patches	414
Average revegetation patch size (ha)	5.6
Length of fencing for revegetation (km)	305
Average perimeter to area ratio of funded fences	0.06636
Revegetation as percentage of study site	4.64622
Pre (extant & remnant enhancement) vegetation as percentage of the study site	23.02462
Total area of study site (ha)	37667

Table 9. Avon case study: Fencing of remnant vegetation

Fencing Activities	Statistics
Area of remnants fenced and enhanced (ha)	127.6
Total area of mapped remnants (ha)	8672.9
Area of mapped remnants fenced (ha)	2241
Remnant area fenced as percentage of all remnants	25.8
Total number of remnants greater or equal to 10ha	99
Total number of remnants less than 10ha	283
Fenced remnants greater than 10ha	32
Fenced remnants less than 10ha	39
Total perimeter of mapped remnants (km)	996.7
Total length of funded fencing for remnant protection (km)	233.8
Area of remnant protected per km of funded fence (ha/km)	9.5

Table 10. Avon case study: Nearest neighbour indexes for vegetation enhancement activities shown by year of activity

Vegetation Enhancement Activity	Mean Nearest Neighbour Index (metres)	Mean Nearest Neighbour Index
1990	303	0.61
1992	299	0.60
1993	304	0.60
1994	293	0.61
1995	293	0.61
1996	273	0.60
1997	264	0.60
1998	246	0.58
1999	236	0.57
2000	226	0.56
2002	223	0.56
2004	221	0.57

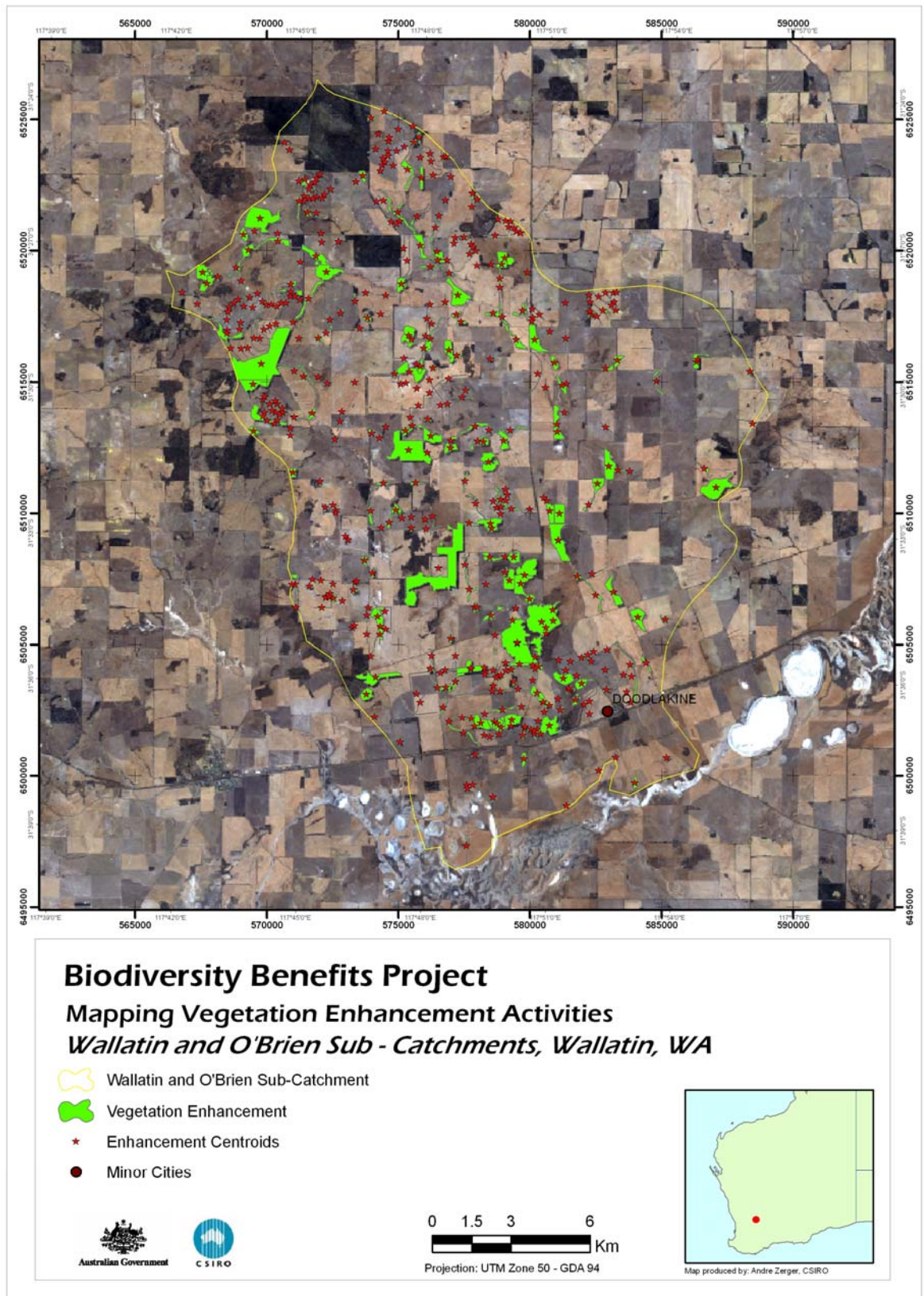


Figure 13. Wallatin and O'Brien Sub-catchments, WA – study area boundary and mapped vegetation enhancement activities.

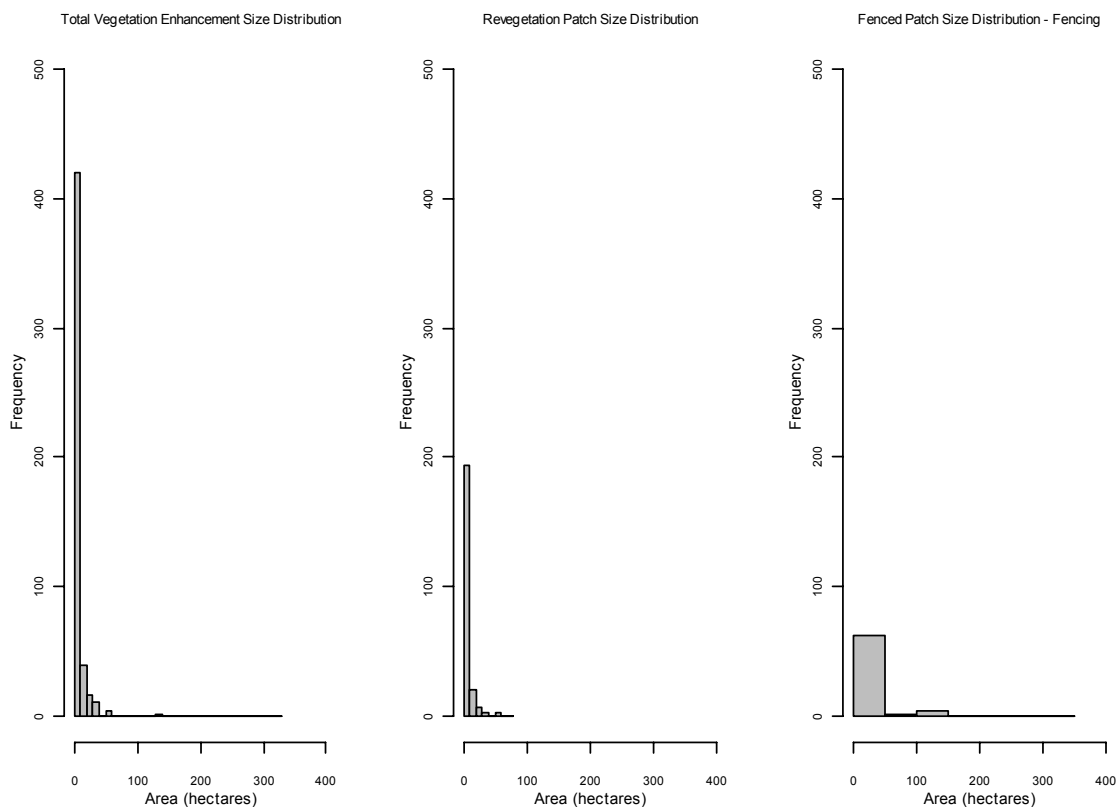


Figure 14. Wallatin and O'Brien Sub-catchments, WA – patch area histograms for all vegetation, revegetation only and fenced remnants (Histograms do not account for remnants which were enhanced, enhanced and protected, or revegetated and protected).

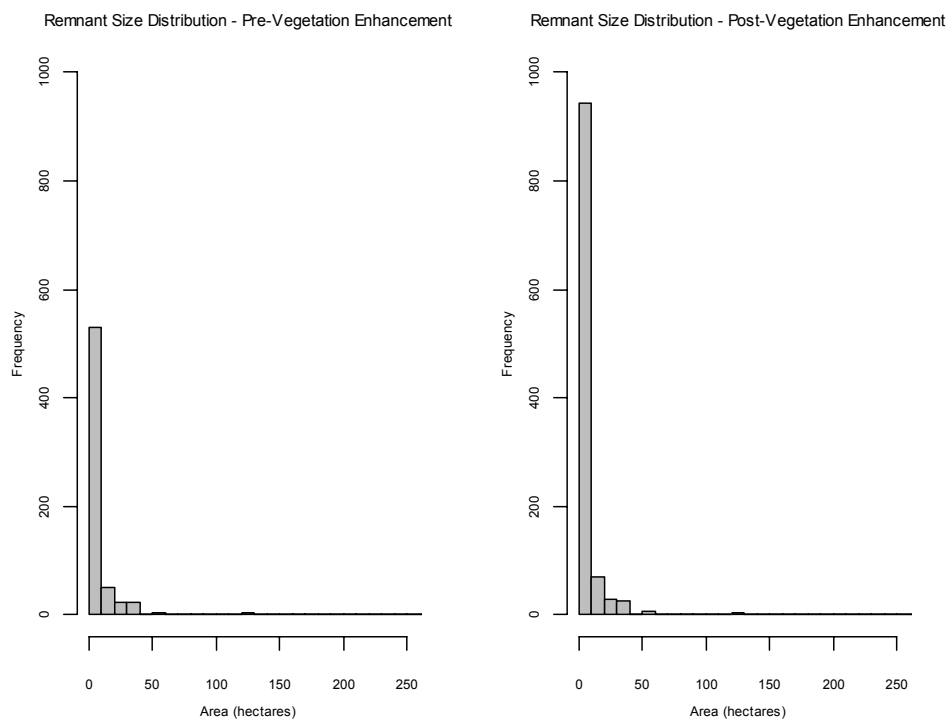


Figure 15. Wallatin and O'Brien Sub-catchments, WA – patch area histograms for period preceding major revegetation activities (1990) and current (2004).

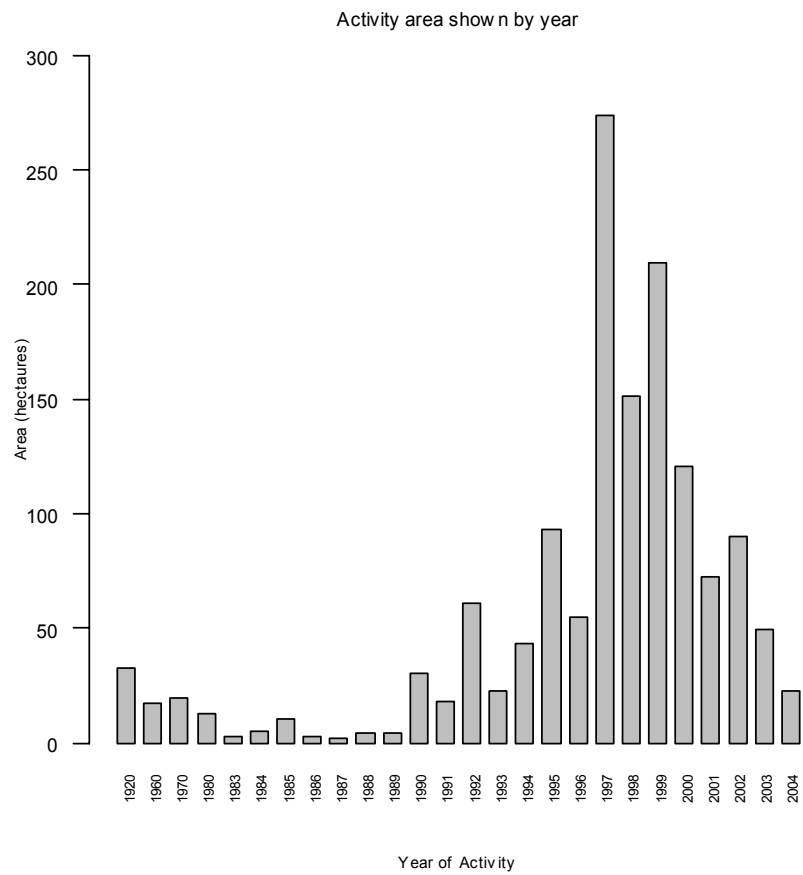


Figure 16. Wallatin and O'Brien Sub-catchments, WA – Area of vegetation enhancement activity shown by years.

Case Study 4 – Wet Tropics, Qld

The Queensland Wet Tropics case study was conducted in collaboration with the Trees for the Evelyn and Atherton Tablelands Inc. (TREAT) and focussed on the Peterson Creek Wildlife Corridor Project. The Queensland Wet Tropics abuts the Queensland coastline for over 400 km, between south latitudes 15°40' and 19°15'. The width varies from 20 to 80 km. The Queensland Wet Tropics conforms to the Wet Tropics Bioregion (Goosem *et al.*, 1999) and is part of a larger area identified by WWF as the Queensland Tropical Forests Ecoregion. Occupying less than 0.2% of the land area of the continent and about 1% of Queensland, the Queensland Wet Tropics contain a vastly disproportionate share of the biodiversity of Australia, including 3,181 vascular plant species in 224 families representing approximately 18% of Australia's vascular flora, 107 mammal species, 368 bird species, 113 reptiles species, 51 native species of freshwater fish and 51 amphibians. These include many endemics (Stanton *et al.*, 2006).

Since European settlement, 23% of all the vegetation of the area has been totally cleared for sugarcane and pastures. This clearing has been mostly in the lowlands and on the Tablelands to the west of the main coastal range. Of the 14,242 km² remaining uncleared, an estimated 3,000 km² has been subject to selective logging activity, and some areas of woodland have also been subject to light grazing activity. For the region as a whole, it is estimated that 58% of the Queensland Wet Tropics remains in pristine condition (Stanton *et al.*, 2006).

Much of the region is officially protected as part of a World Heritage Site, but clearing of forest for agriculture, pastoral activities, and urban infrastructure development continue outside the World Heritage Area. This clearing, however, is increasingly being regulated by legislation. The greatest threats to the area now arise from altered fire regimes, introduced weeds, feral animals, water extraction from streams and aquifers, and drainage of lowland areas (Stanton *et al.*, 2006). Global warming also poses serious threats to the region, which have yet to be clearly defined (Williams *et al.*, 2003).

TREAT is a community-based tree planting group of over 500 members, operating mainly on the Atherton Tableland in the Wet Tropics Region of far North Queensland. It was formed in 1982 with the principal objective of encouraging people to plant native rainforest trees. Native trees have been planted on a number of farms or urban gardens for a variety of reasons, including the rehabilitation of degraded lands, improvement of water quality, provision of windbreaks, the restoration of forest remnants, rebuilding of vegetated wildlife corridors and to enhance landscape aesthetics (TREAT, 2006). The organisation's members work voluntarily throughout the year with the Queensland Parks and Wildlife Service - Restoration Services - Lake Eacham Nursery, rearing trees to rebuild the framework of the tropical rainforests of the Atherton and Evelyn Tablelands. Over the past 20 years, almost a half a million native plants have been propagated and planted. Production involves seed collection and preparation, the rearing of seedlings and the care of the young trees until they are ready to be planted out (TREAT, 2006).

TREAT volunteers are involved in a number of activities beyond tree-planting. These activities include monitoring of wildlife populations, studying vegetation changes and running school awareness programmes. Operating within priority frameworks set by Integrated Catchment Management Committees and government bodies, TREAT works with government and non-government agencies, landowners and other community groups (TREAT, 2006). TREAT projects have ranged from the revegetation of 7 hectares on the shores of Lake Tinaroo, to the planting of 70 trees in a Kindergarten school yard and helping to build a 3 km wildlife corridor to facilitate wildlife movement between two isolated forest remnants. Refer to <http://www.treat.net.au/PROJECTS.html> for a listing of projects that TREAT has been involved in. The six key projects currently being managed by TREAT are estimated to cost a total of \$900,000. Each project is of several years duration. Part of this cost is being met with grants of \$400,000 provided by the Natural Heritage Trust. The balance is met by TREAT in the form of voluntary in-kind labour. A number of smaller projects are supported with grants from various sources (TREAT, 2006). Figure 17 shows the study area boundary and the location of all on-ground vegetation enhancement activities for the Peterson Creek study area.

Mabi Forest is a type of rainforest that occurs in North Queensland. Its pre-clearing extent on the Atherton Tablelands covered the area north and west of Malanda, occurring on highly fertile basalt-derived soils in areas where rainfall is between 1300 and 1600mm (TREAT, 2006). It is now found only in small patches on the Atherton Tablelands, between the towns of Atherton, Kairi, Yungaburra and Malanda, with a remnant patch also located at Shiptons Flat, near Cooktown. Mabi Forest is otherwise known as Complex Notophyll Vine Forest 5b and includes the Queensland Regional Ecosystem 7.8.3. Mabi Forest is characterised by an uneven canopy (25–45m) with many tree layers,

scattered deciduous and semi-evergreen trees, and a dense shrub and vine layer. The dense shrub layer distinguishes Mabi Forest from similar rainforests, and provides important habitat for up to 114 bird species.

A variety of plants and animals make their homes in Mabi Forest, including the nationally threatened Large-eared Horseshoe Bat and Spectacled Flying-fox. Other species, such as the Musky Ratkangaroo and the nationally endangered Southern Cassowary, used to occur in Mabi Forest. However, the remaining patches of Mabi Forest are too small for these animals to survive in, and so the Musky Rat-kangaroo and Southern Cassowary have become locally extinct. Three plant species occurring in Mabi Forest are listed as 'vulnerable to extinction'. These are the Pink Silky Oak, Atherton Sauropus (*Sauropus macranthus*) and Atherton Turkey Bush (*Hodgkinsonia frutescens*). Four plants are listed as 'rare': the pink leaf Haplostichanthus, Coorangooloo Quandong (*Elaeocarpus coorangooloo*), Red Penda and Gray's Cryptolepis (*Cryptolepis grayi*) (TREAT, 2006).

Mabi Forest is listed as a critically endangered ecological community under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (DEH, 2006). Mabi Forest was listed due to its restricted distribution and vulnerability to ongoing threats. There are only 1 050 ha of Mabi Forest left, and this occurs as a series of small, isolated patches. Many of the remnant patches of Mabi Forest are being invaded by exotic smothering vines and feral and domestic animals. The use of remnant patches of Mabi Forest by stock can impact on this ecological community through trampling, grazing and soil compaction (DEH, 2006). National listing of Mabi Forest recognises that its long-term survival is under threat. The purpose of the listing is to prevent its further decline, and assist community efforts toward its recovery. State protection under Queensland's Vegetation Management Act 1999 only applies to those parts of the Mabi Forest ecological community classified as an 'endangered regional ecosystem' (DEH, 2006).

The Wet Tropics case study was delivered in collaboration with research staff based at CSIRO Sustainable Ecosystems, Atherton (Caroline Bruce and Andrew Ford) and TREAT (Simon Burchill). The case study utilised pre-existing vegetation mapping, but commenced a BioAudit assessment from first principles for each vegetation enhancement site. Initial vegetation enhancement mapping was carried out in 2001 by Brian Grant (University of Queensland) with assistance from Simon Burchill. The vegetation enhancement polygons were derived mainly using GPS-derived points. These were subsequently corrected by Simon Burchill using GPS points opportunistically collected during field planting days – these points mapped some fence posts and boundaries. The polygons were then checked using aerial photography current to 1997 (geo-rectified by the Wet Tropics Management Authority (WTMA)) and to 2004 (geo-rectified by Kay Dorricott, Atherton Queensland Parks and Wildlife Service (QPWS)).

Owing to the small number of study sites, discussion of Table 11 and Table 12 is not warranted and hence the major emphasis of this case study became the collection of detailed vegetation condition information to act as a baseline to monitor outcomes in the future. Although this discussion focuses on the development of condition assessment methods for these landscapes, it highlights the importance of adopting documented or published condition assessment methods, and allowing flexibility for regions to utilise methods best suited to their conditions. Similarly, this case study has highlighted the fact that at local scale, it is difficult to generate one condition metric which can be monitored over time and rather, the individual components of a condition score must be retained to allow for future analysis.

Considerable effort was devoted to assessing the condition of vegetation enhancement activities along the Peterson Creek corridor. This was necessary as methods used in the southern Australia (i.e. Habitat Hectares, Biometric) are not ideally suited to the rainforest communities targeted in this case study. Vegetation condition is a relatively new field of science that provides important quantitative and qualitative data, in the form of attributes, for real time scale comparisons to be made of a permanently marked, or positioned, monitoring site. Much debate has occurred in recent years as to the most appropriate vegetation assessment technique and methodology. However, to date each state in Australia appears to be presiding over its own assessment protocols.

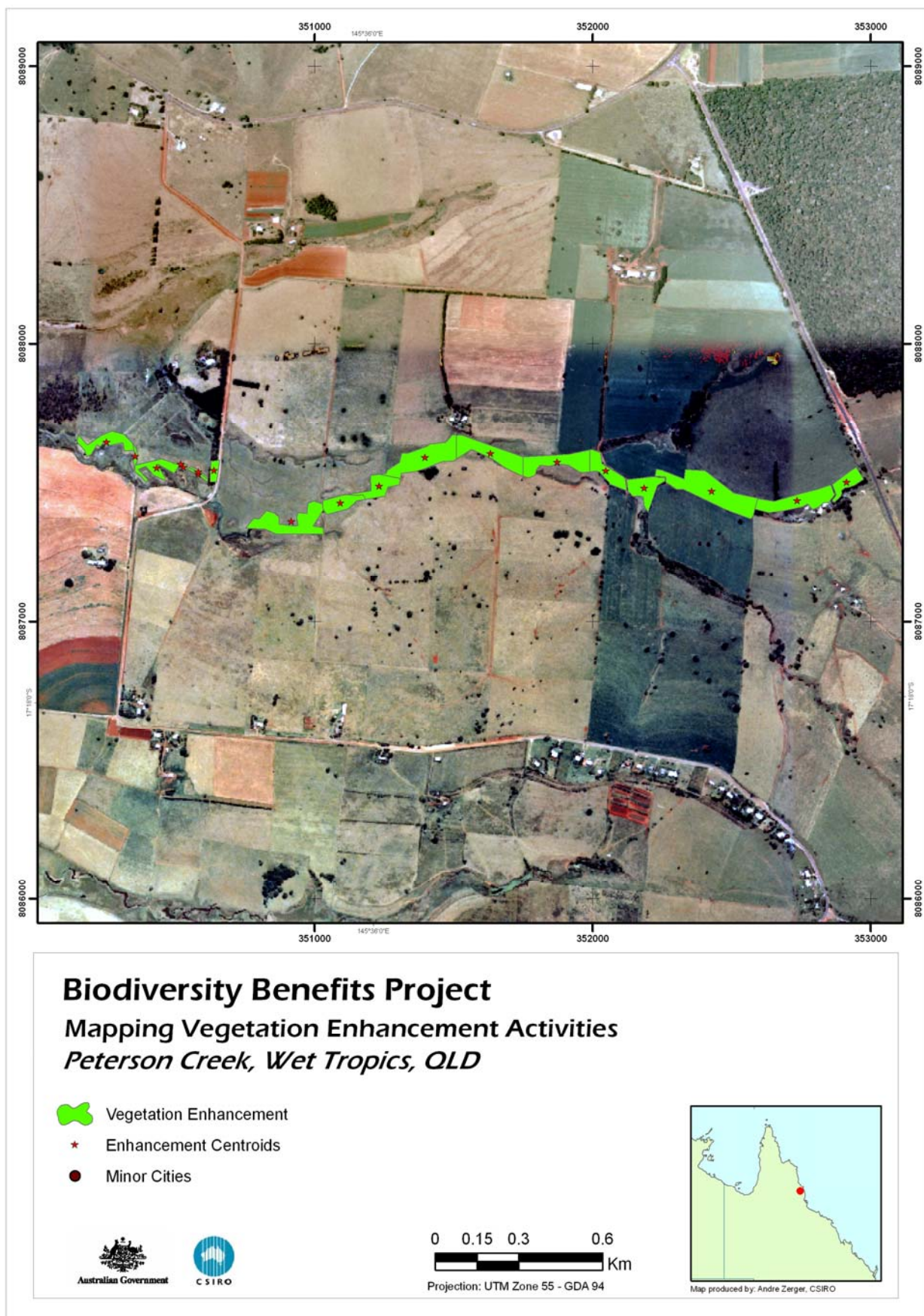


Figure 17. Peterson Creek Wildlife Corridor Project – study area boundary and mapped vegetation enhancement activities.

Parkes *et al.* (2003) developed the 'Habitat Hectares' assessment framework for Victoria in order to, 'assess native vegetation quality'. A similar technique, based upon 'Habitat Hectares', called 'BioCondition' is currently being trialled and developed for Queensland (Environmental Protection Agency, unpublished data) to "provide a framework that provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values". Other state-based manuals include Greening Australia (2002) for the greater ACT area and Gibbons *et al.* (2005) ('BioMetric') for NSW. Greening Australia (2002) is unique in that its technique is designed to monitor and document revegetation projects that involve the conservation, protection and maintenance of grassy ecosystems. Similarly, Kanowski and Catterall (2006) have developed the 'monitoring toolkit' specifically to monitor and assess revegetation projects in rainforest landscapes.

The choice as to which method to follow for the Peterson Creek Biodiversity Benefits Project was ultimately relatively straightforward. Having said that, it needs to be noted that there was an expectation that community groups will follow-up the baseline monitoring that CSIRO performed in mid 2006. With this in mind, a simple and non-ambiguous assessment model was required. For this project the 'BioMetric' method was too complex and has too many quantitative protocols to follow. The 'Habitat Hectares' and 'BioCondition' methods are similar and warranted consideration. However, both methods are intended to assess native (or natural) vegetation. As Peterson Creek is a revegetation site these methods were deemed to lack some important rainforest revegetation attributes and characteristics. This is not to say that the above methods won't work in revegetation projects, but they don't consider aspects of rainforest revegetation which the 'monitoring toolkit' places high emphasis upon. For example, vectored recruitment shows how "attractive" a revegetation site is to frugivorous birds. Such recruitment occurs naturally in natural ecosystems, but is not a given in revegetation activities. Adopting a method that records such recruitment has the potential to highlight the ecosystem functioning in revegetation sites, which will be seen as an improvement upon the original enhancement activity.

Further, the 'Habitat Hectares' and 'BioCondition' methods have the potential to dramatically increase the number of assessments, as both require distinct 'patches' of vegetation for their respective assessment methodologies. It is therefore conceivable that for one even-aged revegetation site/enhancement activity that 2 or 3 assessments need to be undertaken as the structure and compositional attributes of the site may vary considerably in relation to the floristic assemblage planted, or even local edaphic effects. With increasing size of each enhancement activity, there is the expectation to undertake more than one assessment to account for such variability. Kanowski and Catterall (2006) suggest that one assessment in an "average" area would be sufficient. At Peterson Creek there are 9 enhancement activities, and if other methods were chosen some 15-20 assessments would need to be made to conform to respective acceptable protocols and attributes.

In addition, the time to complete an assessment was taken into account. The 'BioCondition' and 'Habitat Hectares' methods are estimated to take about 2 hours per assessment, whereas Kanowski and Catterall (2006) suggest 45-60 minutes per assessment. This is true as most monitoring sites at Peterson Creek took 40-50 minutes, depending upon the age of the revegetation site. With the above considerations taken into account, it was decided to adopt the 'monitoring toolkit' assessment technique. And in particular the proforma for their 'building phase' of revegetation sites has been used, irrespective of the age of the revegetation (Appendix F). This is to ensure a consistent method and recording scheme across the revegetation sites. Normally the proforma for the 'establishment phase' would be utilised for sites in which canopy closure hasn't occurred and usually refers to the actual original planting time or shortly afterwards. Finally, the attributes collected in the 'monitoring toolkit' have shown to be correlated with the use of revegetated sites by rainforest wildlife (Kanowski and Catterall, 2006). This wildlife includes not only vertebrates such as birds, but also invertebrates such as beetles and mites. Thus, by using this toolkit the community groups will be gathering data which are known to be good surrogates for faunal assemblages without actually sampling for them. Appendix F provides a completed example template for such as assessment for one of the study sites in Peterson Creek. The complete vegetation condition assessment results for all sites in Peterson Creek can be obtained from the authors.

Table 11. Wet Tropics case study: Revegetation activities summary

Revegetation Activities	Statistics
Total amount of revegetation (ha)	15.1
Total perimeter of revegetation (Km)	8.8
Number of revegetation patches	19
Average revegetation patch size (ha)	2.1
Length of fencing for revegetation (km)	10.2
Average perimeter to area ratio of funded fences	0.002
Revegetation as percentage of study site	0.41
Pre (extant & remnant enhancement) vegetation as percentage of the study site	42.8
Total area of study site (ha)	3659

Table 12. Wet Tropics case study: Fencing of remnant vegetation

Fencing Activities	
Area of remnants fenced and enhanced (ha)	NA
Total area of mapped remnants (ha)	1567
Area of mapped remnants fenced (ha)	NA
Remnant area fenced as percentage of all remnants	NA
Total number of remnants greater or equal to 10ha	47
Total number of remnants less than 10ha	41
Fenced remnants greater than 10ha	NA
Fenced remnants less than 10ha	NA
Total perimeter of mapped remnants (km)	178.7
Total length of funded fencing for remnant protection (km)	NA
Area of remnant protected per km of funded fence (ha/km)	NA

Case Study 5 – Kangaroo Island, SA

The Kangaroo Island project was conducted in collaboration with the Kangaroo Island Natural Resource Management Board (KINRMB) and centred on the Eleanor River sub catchment in the Seddon Plateau Fragmented Habitat Area and the Bugga Bugga Creek sub catchment in the Dudley/Haines Plateau Threatened Habitat Area (Figure 18 & Figure 19). Kangaroo Island is located off the southern coastline of South Australia, some 14km south west of the Fleurieu Peninsula at the closet point and roughly 130km south west of Adelaide. Kangaroo Island is approximately 150km long from east to west and about 55km wide from north to south. The island has been described as roughly wedge shaped, with high sea cliffs on the north western shoreline and a central lateritic plateau which slopes downwards to limestone plains and sand dunes along the southern shore.

Much of the following background information is derived from Willoughby et al. (2001). In 1991, 47% of the island's 440,188 ha area was covered by native vegetation while 51% had been cleared for cropland and pasture. The remaining 2% comprised sand dunes or cliffs, lakes and swamps, agro forestry and urban areas. Of the remaining native vegetation, 55% is protected in national parks and Wildlife reserves, 9% are subject to heritage agreements on private land, with 36% occurring on unprotected private land. The most common native vegetation type on Kangaroo Island is mallee, accounting for 64% of all mapped native vegetation. The mallee is dominated by communities of *Eucalyptus diversifolia* or *E. remota* with smaller areas of *E. cosmophylla*, *E. cneorifolia*, and *E. rugosa*. Woodland dominated by *E. cladocalyx* and *E. baxteri* communities are the next most common accounting for a further 29% of mapped native vegetation while the remaining native vegetation comprises shrubland (6%), forest (1%) and fernland. Three mallee, two woodland and two shrubland communities are considered regionally threatened.

Soils and geology play a large part in determining the distribution of vegetation communities on Kangaroo Island. Mallee occurs mainly on sandy or stony soils over limestone or laterite whereas forests and woodlands generally occur on deeper or more fertile soils. Estimates of pre-European vegetation cover indicate that woodland occurred over 56% of the island while mallee occurred over roughly 43%. This highlights the preferential clearing of woodland for agriculture, in part due to the more fertile soils on which woodlands occur.

Native vegetation on Kangaroo Island is highly fragmented, with nearly 90% of blocks being less than 20 hectares in size and 97.3% of blocks being less than 100 hectares. These blocks however, account for only 8.2% of native vegetation. Indeed, 76.8% of native vegetation occurs in just two blocks, the Flinders Chase National Park and Cape Gantheaume CP and contiguous areas. While these and other large remnants have sufficient native vegetation to sustain populations in the long term, the viability of smaller fragments is limited, as their isolation limits movement and increases the risk posed by catastrophic events such as disease, fire and genetic isolation. The Biodiversity Plan for Kangaroo Island states that many species and plant communities, including some which are endemic to the island, face extinction due to the immediate effects arising from fragmentation, isolation and degradation of remnant vegetation. Strategies for the management of threatened habitat areas on Kangaroo Island include; retaining all areas of native vegetation, fencing and destocking native vegetation, increasing the size of remnants by buffering with native species, and linking isolated remnants.

The Kangaroo Island case study was coordinated in collaboration with the Kangaroo Island Natural Resources Management Board (KINRMB) through staff including Grant Flanagan and Mark Morris. Mapping commenced in March 2006 and concluded in June 2006 with some 106 on-ground vegetation activities being mapped and assessed for two distinct study regions (Bugga Bugga Creek and Eleanor River). On ground mapping and landholder assessments were conducted by KINRMB staff according to mapping and attribute collection protocols developed by CSIRO (Appendix A & B). For this case study, data was entered into an Excel spreadsheet and then normalised into the BioAudit database once delivered to CSIRO.

Table 13 and Table 14 provide summary statistics for revegetation and fencing activities aggregated over the two Kangaroo Island case studies (Eleanor River and Bugga Bugga Creek). The total impact of revegetation relative to the study area bounds is relatively small at 0.56 % and as with the other case studies (Nullamanna and Cudgewa), fencing efficiencies are significantly greater than for revegetation (1202 ha compared to 65 hectares). Revegetation ratios need to be treated with caution as arbitrary square study bounds were developed for the two Kangaroo Island case studies which will impact upon the ratios observed. For other case studies administrative units such as Landcare boundaries were used. Fencing efficiencies across the two Kangaroo Island case studies are relatively low (7.3 ha/km) although factors such as site accessibility will be a primary influence over these rates.

The average size of revegetated patches is also relatively low at 2.05 ha and this is also highlighted in Figure 22 which provides patch-area histograms for remnants and enhancement activities. In regard to connectivity, the Kangaroo Island case studies provide one of the greatest decreases in nearest neighbour distances for enhancement activities. This indicates that although the magnitude of the activities is not necessarily as large as other regions, on-ground activities have been established proximal to other revegetation sites and to existing remnant vegetation. In both instances, nearest neighbour distances decreased by half (from 475 to 209 metres, and 604 to 254 metres for Bugga Bugga Creek and Eleanor River respectively).

Figure 20a highlights the fact that most on-ground activities have focussed on activities which enhance existing remnants. In regard to the investment and activities shown through time (Figure 20b), the trends identified for Kangaroo Island are commensurate with those seen for almost all other case studies. Namely, there is a steady increase in activity shown by area from the early 1990's and culminating in a major peak in 1999 followed by a steady decline towards 2005. These results mirror those identified in Nullamanna, Cudgewa and Wallatin. Indeed for all these case studies, the period from 1998 to 2000 makes up the majority of on-ground activities observed through the entire period of NHT-type funding. An interesting analysis could utilise these temporal trends and develop future revegetation scenarios for specific targets.

Table 13. Kangaroo Island case studies: Revegetation activities summary

Revegetation Activities	Statistics
Total amount of revegetation (ha)	65.63
Total perimeter of revegetation (Km)	29.13
Number of revegetation patches	32.00
Average revegetation patch size (ha)	2.05
Length of fencing for revegetation (km)	0.00
Average perimeter to area ratio of funded fences	0.00
Revegetation as percentage of study site	0.56
Pre (extant & remnant enhancement) vegetation as percentage of the study site	22.63
Total area of study site (ha)	11620.00

Table 14. Kangaroo Island case studies: Fencing of remnant vegetation

Fencing Activities	
Area of remnants fenced and enhanced (ha)	2564.67
Total area of mapped remnants (ha)	763.84
Area of mapped remnants fenced (ha)	1202.91
Remnant area fenced as percentage of all remnants	29.78
Total number of remnants greater or equal to 10ha	52.00
Total number of remnants less than 10ha	124.00
Fenced remnants greater than 10ha	24.00
Fenced remnants less than 10ha	46.00
Total perimeter of mapped remnants (km)	402.56
Total length of funded fencing for remnant protection (km)	164.5
Area of remnant protected per km of funded fence (ha/km)	7.3

Table 15. Bugga Bugga Creek case study: Nearest neighbour indexes for vegetation enhancement activities

Vegetation Enhancement Activity	Mean Nearest Neighbour Index (metres)	Mean Nearest Neighbour Index
Pre mapped vegetation enhancement activities	475	1.00
Post mapped vegetation enhancement activities	209	0.71

Table 16. Eleanor River case study: Nearest neighbour indexes for vegetation enhancement activities

Vegetation Enhancement Activity	Mean Nearest Neighbour Index (metres)	Mean Nearest Neighbour Index
Pre mapped vegetation enhancement activities	604	1.25
Post mapped vegetation enhancement activities	254	0.86

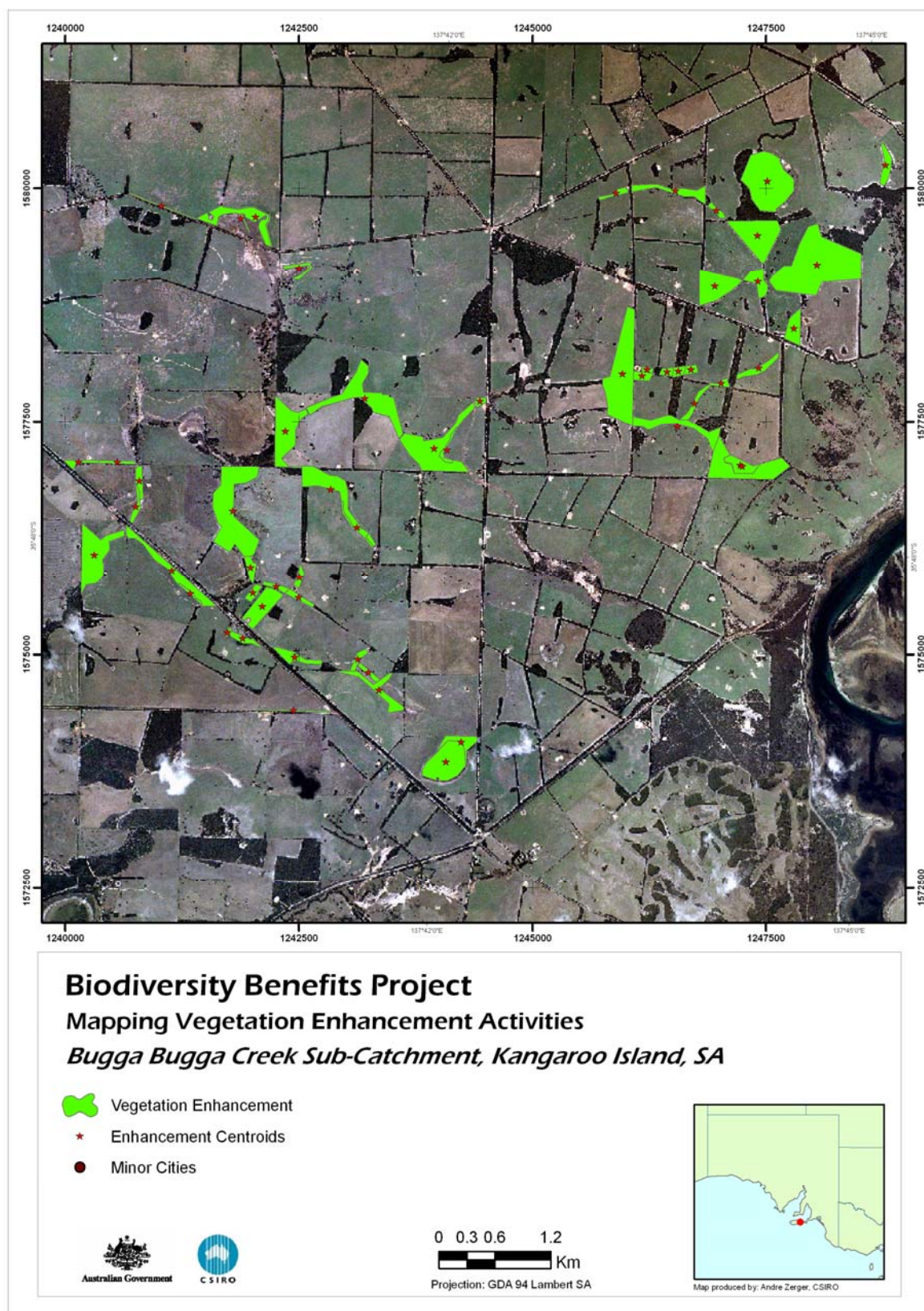


Figure 18. Bugga Bugga Creek, Kangaroo Island – study area boundary and mapped vegetation enhancement activities.

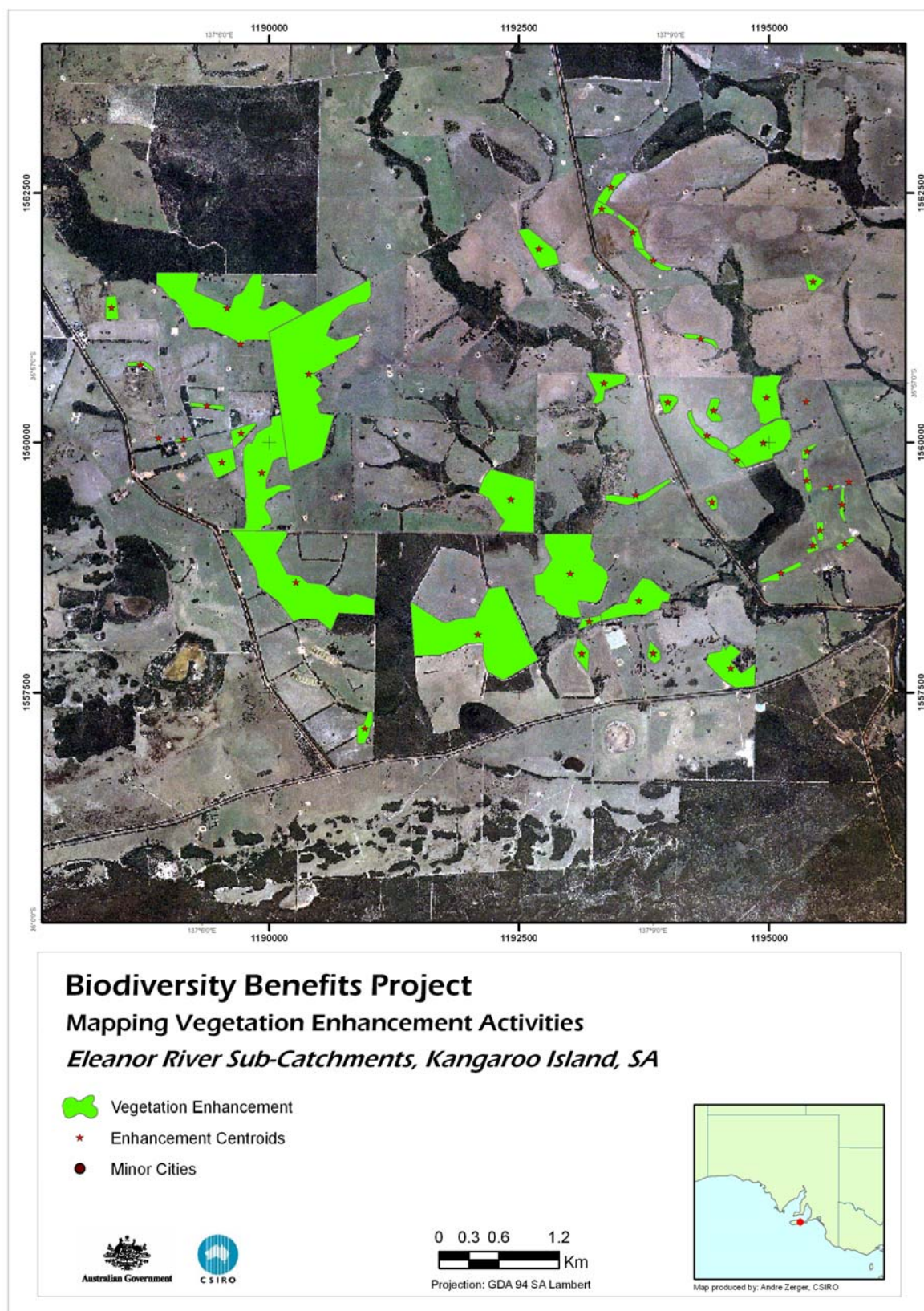


Figure 19. Eleanor River, Kangaroo Island – study area boundary and mapped vegetation enhancement activities.

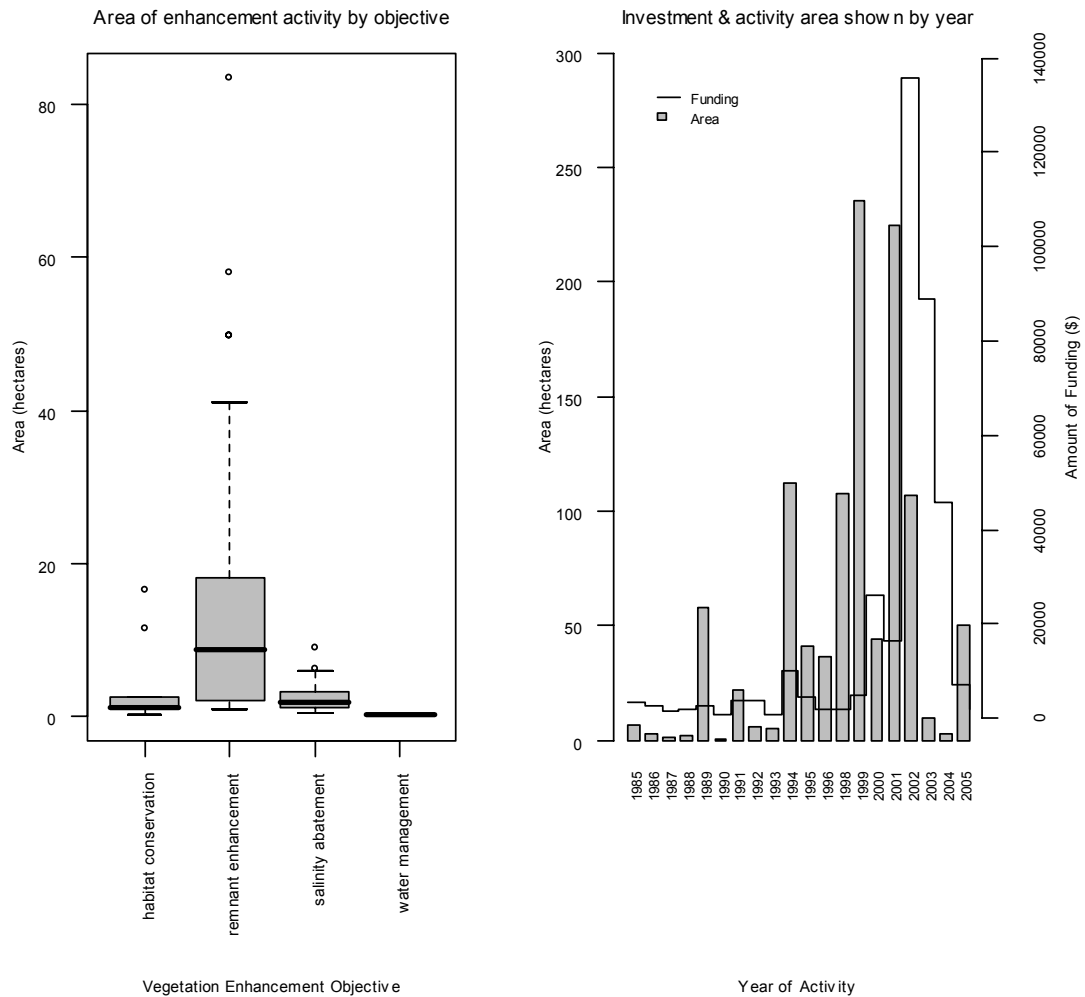


Figure 20. Eleanor River and Bugga Bugga Creek, Kangaroo Island – Area of vegetation enhancement activity shown by enhancement objectives and amount of funding and area of activity shown by funding years. The BioAudit data model allows for multiple objectives at individual sites hence total areas are greater than the total area of activities in this study site (stems in the plot show the data range and the solid bar is the median value).

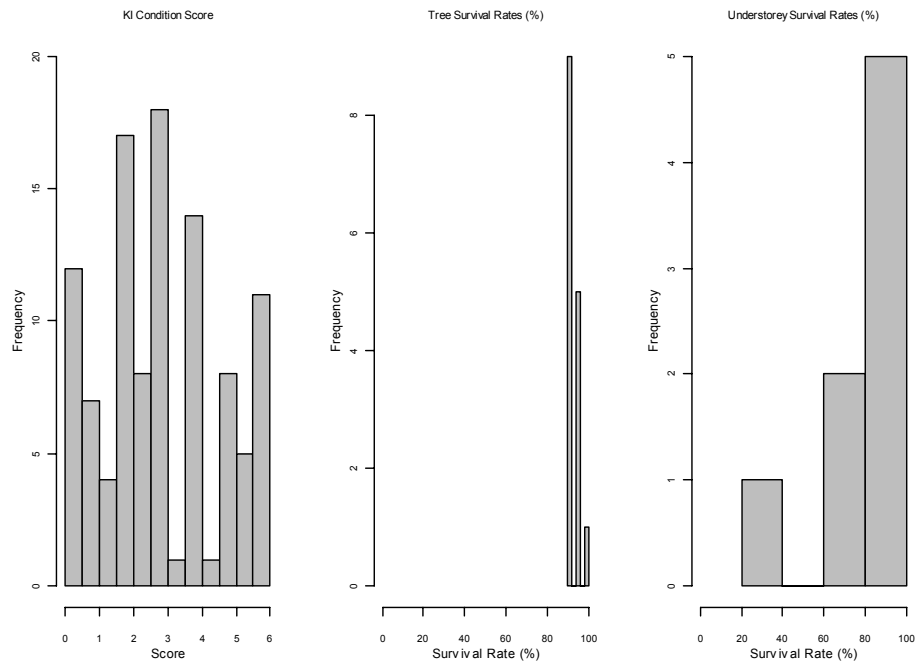


Figure 21. Eleanor River and Bugga Bugga Creek, Kangaroo Island – Vegetation enhancement activity outcomes – histograms showing range of condition scores and tree and understorey survival rates from vegetation enhancement activities (including remnant protection, enhancement and revegetation).

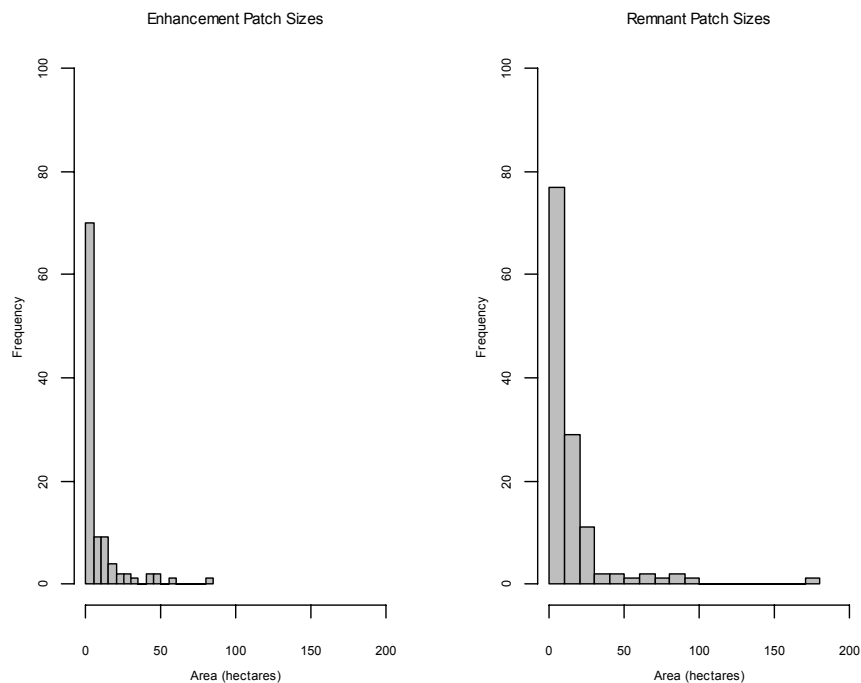


Figure 22. Patch area histograms for new on-ground vegetation enhancement activities including revegetation and fencing (enhancement patch sizes), and existing remnant patch size distribution from state NVIS vegetation mapping.

Case Study 6 – Gascoyne Murchison, WA

The only rangelands case study in the Biodiversity Benefits Project Phase 3 was conducted in collaboration with the Murchison Land Conservation District Committee (MCDC) which is based in the Murchison Shire, Western Australia. The primary collaborator was Mark Halleen. This case study was a challenging case study to deliver owing to two unexpected major cyclonic events (cyclone Claire and Floyd) which delayed the field component of this project a number of months. These events resulted in extended flooding along the Murchison River making field work in early 2006 impossible. The study site was finally mapped at the end of May 2006. The study area covers approximately 44,000 square kilometres (Figure 23) and primarily focuses on wool production although many landholders are diversifying into other agricultural practices. The committee was formed in 1986 and is concerned with all aspects of Landcare with a primary focus on controlling grazing pressures by ensuring conservative stocking rates and removal of feral animals. Other MCDC Landcare priorities include the following:

- Relocating watering points from degraded areas;
- Fencing to land types to achieve better control of preferred grazing areas;
- Slowing down water flow by brushing up gullies and neck points in creeks;
- Fenced enclosures to allow natural regeneration;
- Revegetation work on degraded areas;
- Monitoring vegetation and soil condition;
- Control of introduced animals such as foxes and cats with baiting program; and
- Control and eradication of weeds.

The primary Landcare activity in this region is the Murchison River Restoration Project which seeks to fence the floodplain of the Murchison River to primarily control grazing (up to 334 km of fencing). Consequently, this is the primary on-ground vegetation enhancement activity which has been mapped and evaluated in this case study. Interestingly, a large proportion of the cost of fencing in this case study is provided by landholders. According to the original NHT proposal, the project description is as follows:

‘This project involves nine neighbouring pastoral stations (totalling 1,880,317 hectares) who, with community support, aim to create a corridor to improve the biodiversity of flora and fauna through the restoration and protection of the riparian zone and flood plain of the Murchison River. The centre-piece of this project is the fencing of 206,200 hectares of river land systems. This will have substantial positive environmental outcomes by reducing the damaging effects of overgrazing, implementing total grazing management and thus reducing domestic and feral grazing pressure in these fragile landscapes. Ultimately, this project aims to demonstrate the benefits of a commitment to ecologically sustainable pastoral management. The project has the potential to demonstrate the relevance of integrated catchment management in Western Australian Rangelands’

According to the LCDC (<http://landcare.murchison.wa.gov.au/projects> last accessed July 25, 2006) the fencing of the Murchison River is expected to achieve the following broad outcomes:

- Reduction in native plant degradation;
- Reduction in soil erosion;
- Less sediment load in the river;
- Improved litter accumulation and nutrient cycling;
- Improved water retention;
- Improved water quality;
- Improved biodiversity conservation through improved habitats;
- Improved riparian drought refuges for native animals; and
- Recreation of landscape linkages and conservation corridor.

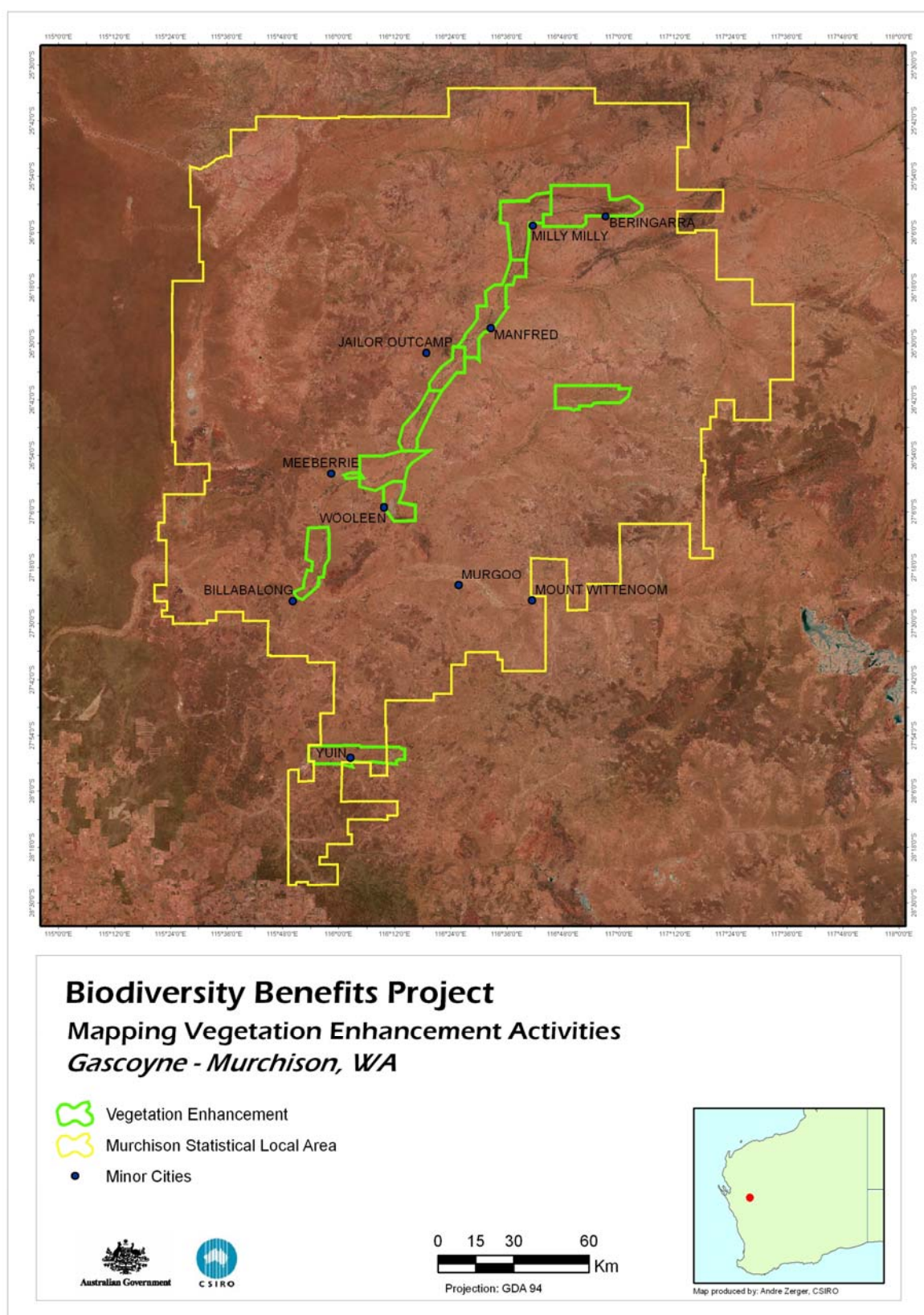


Figure 23. Gascoyne-Murchison Case Study, WA – study area boundary and mapped vegetation enhancement activities.

Mapping of the Murchison case study was conducted in May 2006 by Mr. Damian Wall (Minchem Pty. Ltd) using specifications provided by CSIRO. Vegetation enhancement activities were mapped using landholder interviews and a Landsat 5 false colour composite image sourced from the Australian Greenhouse Office (1994 imagery) using on-screen digitising with ArcView GIS. Owing to the extent of this study area, SPOT5 imagery provided too much detail to effectively map the on-ground activities and it was found that Landsat 7 imagery addresses this. In addition to mapping the boundaries of vegetation enhancement activities, site photographs and site coordinates were also collected including a reference coordinate for each enhancement activity (site) and the location of this reference coordinate relative to the area mapped.

Table 17. Gascoyne Murchison case study: Fencing of remnant vegetation

Fencing Activities	Statistics
Total area of mapped remnants (ha)	217123
Area of mapped remnants fenced (ha)	210736
Remnant area fenced as percentage of all remnants	97
Total number of remnants greater or equal to 10ha	98
Total number of remnants less than 10ha	235
Fenced remnants greater than 10ha	11
Fenced remnants less than 10ha	0
Total perimeter of mapped remnants (km)	1532
Total length of funded fencing for remnant protection (km)	425
Area of remnant protected per km of funded fence (ha/km)	5.27

As this is a rangelands case study, the use of analyses such as those adopted in Nullamanna or north east Victoria are not warranted. For instance, inter-patch distance metrics or measures of change in mean patch sizes are not appropriate in these landscapes. The Gascoyne-Murchison case study is one which best utilises contextual GIS data to support an analysis. The West Australian rangelands have a number of excellent monitoring systems available which compliment the mapping of on-ground vegetation enhancement activities. The primary example of this is the West Australian Rangelands Monitoring System (WARMS, Watson et al. 2006, Holm et al. 1987)). Although it was not possible to obtain the primary data from WARMS in time for inclusion in this report, there are 16 WARMS sites which occur in the mapped BioAudit regions along the Murchison River and these could be used to conduct an analysis of rangeland condition. An alternative source of regional scale vegetation condition information which did not provide coverage across over this particular case study is West Australia's LandMonitor project (<http://www.landmonitor.wa.gov.au/index.html> last accessed September 7, 2006)

To highlight the potential utility of contextual GIS data, ancillary vegetation condition data was sourced from the Department of Agriculture's inventory and condition survey of the Murchison River catchment and surrounds (Curry et al. 1994). By intersecting the land systems mapping with BioAudit mapping it is possible to generate vegetation condition and erosion status summaries based on data from the survey (Curry et al. 1994). Figure 24 shows frequency histograms of vegetation condition for mapped BioAudit regions in the Gascoyne-Murchison case study. It is important to note that this is shown only for illustrative purposes as the Curry et. al. (1994) study was conducted before the establishment of most of the on-ground activities more current rangelands survey data would need to be included to asses the current status.

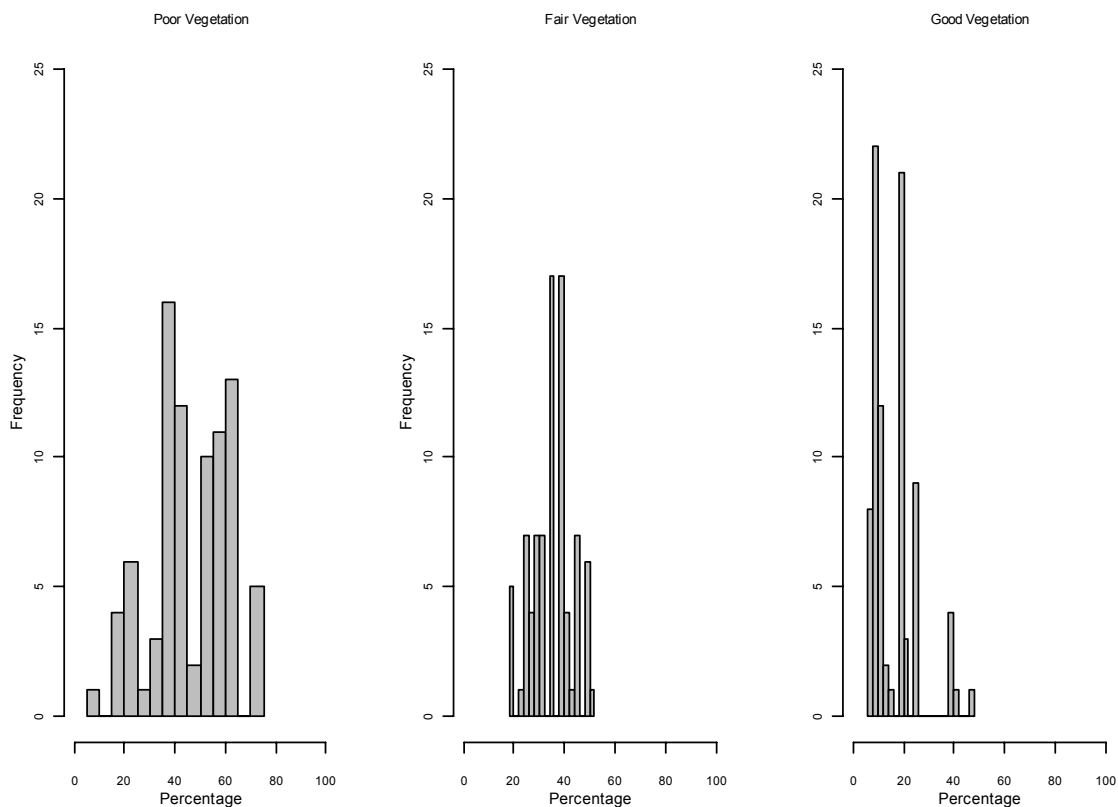


Figure 24. Gascoyne-Murchison Case Study, WA – distribution of vegetation condition scores for enhancement polygons based on Murchison River rangelands survey data.

An additional assessment of biodiversity benefits was conducted for the Gascoyne-Murchison case study by utilising landscape-scale Birds Australia bird atlas data. The analysis compares bird abundance data at treatment sites (vegetation enhancement sites) against a randomly selected control region. The analysis highlights the potential value of contextual, spatially explicit data to monitor the effect of vegetation enhancement activities and although the analysis is preliminary, the results are very promising. The occurrence of bird species was compared between the first Atlas of Australian Birds (Atlas 1) which continued for five years between 1 January 1977 and 31 December 1981, and the New Atlas of Australian Birds (Atlas 2), which ran for three years and five months, from 1 August 1998 to 30 December 2001. During Atlas 1, volunteer observers searched a 10-minute grid (approximately 15 km × 17 km) recording all bird species seen or heard, producing a bird list for each grid. were compared with two types of survey from Atlas 2; Area Searches within 500 m and Area Searches within 5 km, both focused around a central point and lasting at least 20 minutes (no longer than a day). For a full description of the data collection, as well as the vetting and processing methods used in Atlas 1, see Blakers et al. (1984) and for Atlas 2, see Barrett et al. (2003).

In order to quantify the effect of survey method on the comparison of atlases, observers who took part in *Atlas 1* were encouraged to repeat some surveys using the same method they had used during that first atlas. As a result, 1,771 × 10-minute grid surveys (*Atlas 1* method) were completed during *Atlas 2* (1998-2001), mostly in NSW. For a description of the analysis of *survey method effect* between the two atlases, see Garnett et al. (2002) or Barrett et al. (2003). The total number of bird species, number of woodland-dependent ground-foraging species, and number of understorey-dependent species per survey was estimated within a 1000m buffer of the revegetation site. Note that *Atlas 1* surveys were collected at the 10-minute scale, so a portion of *Atlas 1* surveys will extend beyond this buffer.

To assess the potential impact of vegetation enhancement activities on bird species, a control region was delineated for this study area. The control region was delineated in the GIS and was chosen to contain the same amount of river length as existed along the enhanced section of the Murchison River and in a similar landscape. Figure 25 shows the treatment and control study regions and the distribution of Atlas 1 and Atlas 2 Birds Australia data. The number of species per survey was compared for *Atlas 1* control sites (n = 5 surveys), *Atlas 1* revegetation sites (n = 25 surveys), *Atlas 2* control sites (n = 29 surveys) and *Atlas 2* revegetation sites (n = 17 surveys). Woodland-dependent

ground-foraging species and understorey-dependent bird species were defined as per Ford *et al.* (1986).

The overall number of bird species recorded per survey was greater during *Atlas 2* compared with *Atlas 1* (Figure 26), partly due to there being more rainfall during this second atlas period (Barrett *et al.* 2003). Nevertheless, the increase in bird species reported per survey tended to increase more steeply in the fenced sites compared with the control sites (Figure 26), suggesting that the biodiversity value in these sites have been enhanced by the on-ground activities. A stronger response was shown by understorey-dependent bird species and ground-foraging woodland bird species, with the number of species recorded per survey increasing in the revegetation sites during *Atlas 2* compared with *Atlas 1*, while decreasing in the control sites over this same period (Figure 27 and Figure 28 respectively).

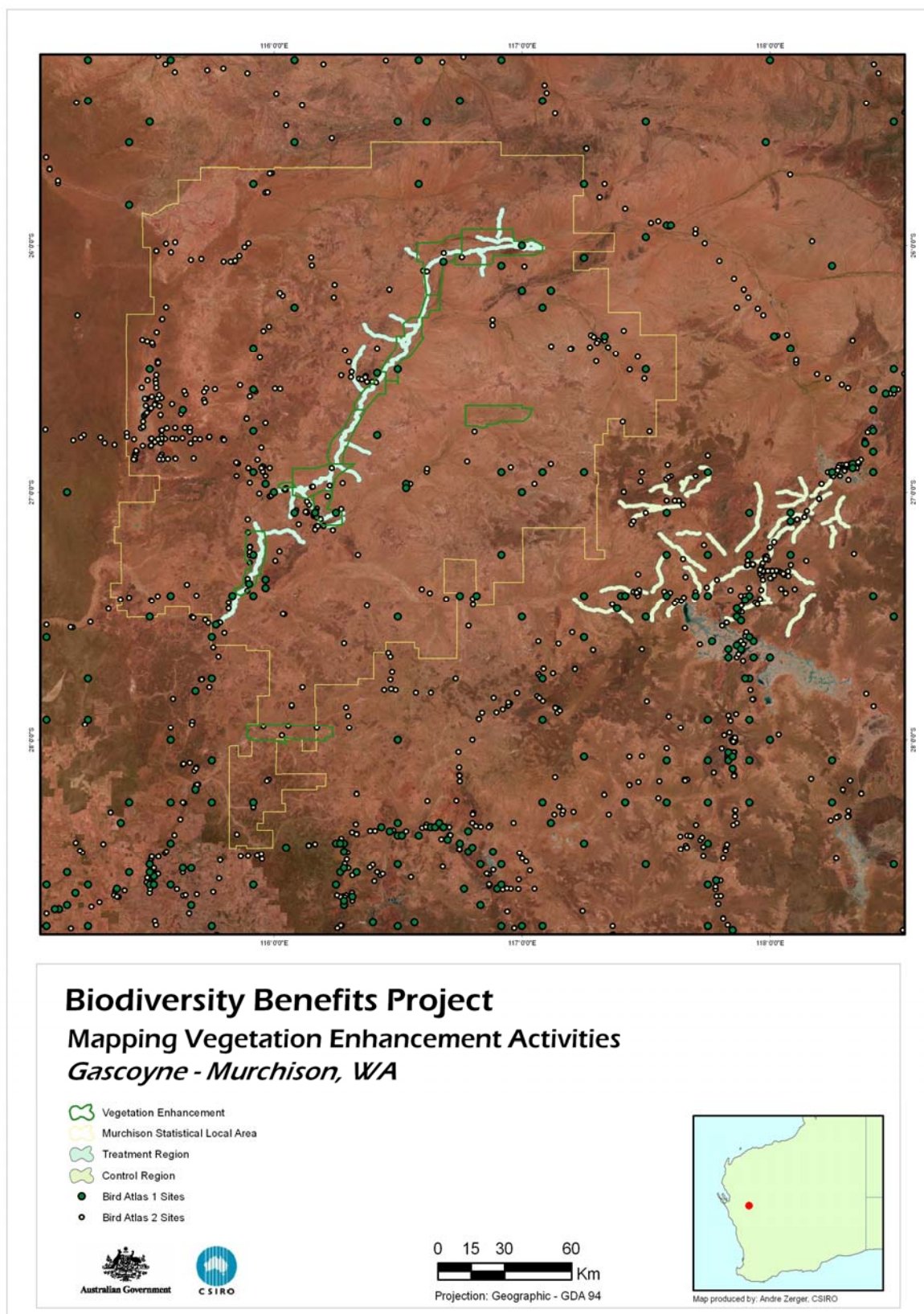


Figure 25 Gascoyne-Murchison case study showing the treatment (vegetation enhancement activities) and control region

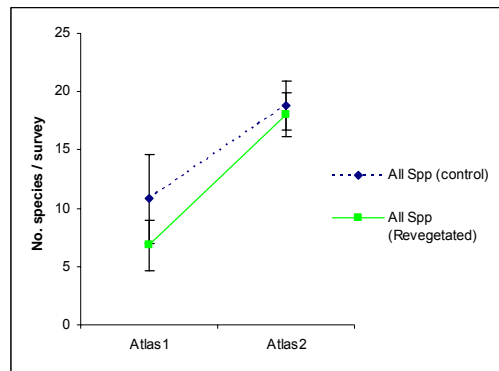


Figure 26. Total number of bird species recorded per survey during *Atlas 1* and *Atlas 2* in revegetated sites vs. control sites.

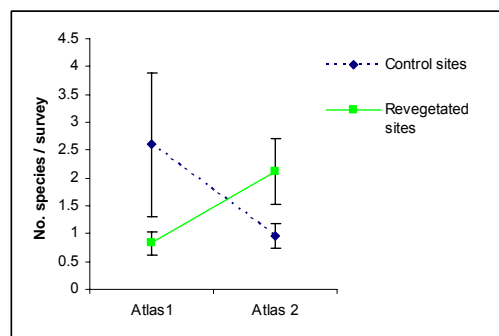


Figure 27. Number of understorey-dependent bird species recorded per survey during *Atlas 1* and *Atlas 2* in revegetated sites vs. control sites.

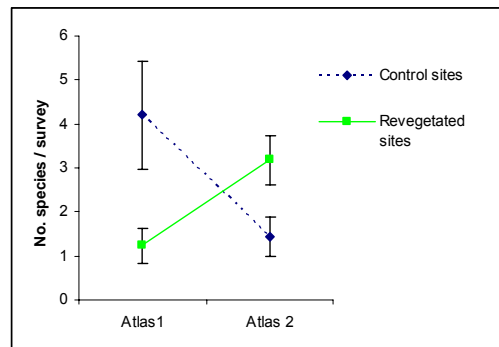


Figure 28. Number of ground-foraging, woodland bird species recorded per survey during *Atlas 1* and *Atlas 2* in revegetated sites vs. control sites.

Discussion

The introductory sections of this report provide a background to this study, a justification for collecting spatially explicit on-ground vegetation enhancement data and present the general methodology and tools used to capture and analyse information about on-ground vegetation enhancement activities to support a Biodiversity Benefits assessment. Detailed methodological descriptions have been provided in the appendices paying particular attention to establishing robust mapping rules and relational database technologies. The methods and tools were then applied to six national case studies in an effort to capture as much on-ground information as possible within the funding and timing constraints. Through the six case studies, details for approximately 700 activities nationally have been mapped and attributes collected. By applying the methodology to actual case studies it is possible to evaluate the feasibility of mapping vegetation enhancement activities and to provide protocols (mapping and attribute collection) to NRM agencies who are interested in collecting similar data to support their planning and monitoring activities.

The case study analysis is kept intentionally brief as this study has focussed on the development of methods and techniques. For a more thorough treatment of analysis approaches which utilise mapped data readers should refer to Freudenberger and Harvey (2004) (<http://www.deh.gov.au/land/publications/application/index.html> Last accessed September 29 2006) which provides a detailed treatment of the use of such data. The data capture and analysis component will guide the ensuing discussion which examines outcomes and limitations. The objective of the discussion is to assess the technical feasibility and utility of collecting Biodiversity Benefits data, and to examine some of the institutional and conceptual issues regarding the application of the Biodiversity Benefits Framework. A key question emerging from this project is 'how feasible is it to expect NRM groups to collect data to the specifications documented in this study?' Although the focus is on the Biodiversity Benefits Framework, the findings are likely to be useful for other analyses of vegetation enhancement activities as the fundamental data requirements will be similar. For example, the ongoing efforts by Australian government agencies to develop a continental forest monitoring framework and a national system for monitoring and reporting revegetation activities could benefit from these findings. The ensuing discussion focuses on the following key issues:

- An assessment of the ease of attribute collection
- Institutional needs associated with the mapping of case studies
- Operationalising the use of the methodology
- General limitations encountered in the study

BioAudit Elements – Ease of Acquisition

A key component of this project was to test the practicality of the Biodiversity Benefits minimum data specifications. Sections of this report documented the development of the BioAudit database which formalises the relationships between elements using entity-relationship diagrams and a relational database management system in order to ensure minimisation of data duplication and allow for temporal update. In addition to collecting data using BioAudit, the research has also evaluated the practicality of collecting the elements for the six case studies. The outcomes from this stage of the project are important as it provides NRM agencies a better sense of which elements are problematic, which require more time during an assessment, and what administrative systems need to be put in place to ensure that all the elements can be populated in a database.

For example, much of the project information and objective information could be garnered from ongoing grant proposals as they are developed, submitted and awarded. To assess the ease of attribute data acquisition, an evaluation document was provided to the mappers to assess the ease of data acquisition for each of the BioAudit elements. Mappers were asked to rank each attribute with regard to the ease of acquisition and to add any additional comments. Table 18 summarises the results for each of the case studies and provides a mean response. The mean response should be treated with caution as the sample size is low and the data are ordinal and hence the precision provided in this value may not be warranted. It has been included to rapidly summarise the overall result for each attribute. The results from this evaluation can be summarised as follows:

- **Administrative Domain:** This information was straightforward to collect;
- **Project Information Domain:** Obtaining accurate project information including project codes, project names, amount of funding was particularly problematic. Landholders rarely maintained this information and it was necessary to consult historical documents to obtain this data. In

some districts corporate knowledge was lacking to provide rapid responses to these questions although for each case study this information was eventually attained (generally after mapping was completed). Acquisition was particularly an issue for historical activities (> 5 years old). This information was primarily the domain of the local coordinator (e.g. Landcare officer). In some instances funding sources were confused between amount requested and amount received. The BioAudit data model allows for in-kind contributions to also be recorded. However, it was found that this information is generally unreliable and certainly not comparable between landholders or case studies;

- **Objectives Domain:** Data in this domain was easy to collect as the broad categories of objectives provided in BioAudit accommodated all the necessary options. One important issue raised in this study is the utility of the quoted objective. Project proposals commonly contain multiple objectives to ensure grant success, irrespective of the primary vegetation enhancement objective. For instance, across all case studies, aesthetics ranks low, however anecdotal evidence suggests it can be a primary driver for many vegetation enhancement activities. Consequently, the inclusion of such qualitative information in an assessment should be treated with caution;
- **Sites Domain:** Data contained in this domain was relatively simple to acquire as it relied on either basic landholder information or information that the mapper was already collecting (e.g. site number, site size, site type). The primary concern in this domain was the collection of information about the remnant vegetation type and an ability to do this consistently given the range of vegetation classifications possible. There is merit in restricting the description of remnant vegetation types to NVIS classifications to ensure consistency between case studies. In some case studies this can be obtained from existing vegetation mapping although as discussed earlier, many smaller remnants such as those recently fenced do not appear in available vegetation type mapping (e.g. EVC mapping);
- **Enhancement Activity Domain:** Obtaining accurate quantitative information regarding inputs was problematic and analogous to the issues discussed in the project information domain. This was primarily the case for counts of tube stock or amount of seed applied. In many case studies there was no historical information available regarding the quantity and provenance of the plantings. This was particularly problematic in cases where direct seeding had occurred. For most of these case studies an estimate provided by the landholder was used while in the case of tube stock, volumes could be inferred from the size of the activity using commonly accepted ratios. As such, the data pertaining to inputs should be treated with caution;
- **Outputs Domain:** Survivorship data was the most problematic domain with universal difficulty in attaining this information. This is particularly problematic for older activities as little or no information regarding these outputs was ever collected and obtaining it after many years had passed was challenging;
- **Condition Assessment Domain:** As this information did not require researching historical information, it was relatively easy but time consuming to collect. A variety of methods were used for assessing the current condition of vegetation enhancement activities including published methods (Newsome and Catling, 1979) and methods developed for specific landscapes (Wet Tropics and Kangaroo Island methods). One should not be too prescriptive in regard to the method which is used for any particular case study as some of the known methods are landscape specific. However, ideally the method which is adopted should be well documented to enable repeatability and to enable temporal monitoring. It is also important that there is some system for archiving the primary data used to generate the final score. It is challenging to build a relational database model which accommodates all the condition scoring methods and hence stakeholders need to ensure this information is preserved locally. Gibbons and Freudenberger (2006) provide a thorough treatment of typical vegetation condition assessment methods and examine the conceptual issues associated with using specific methods;
- **Coordinates Domain:** This information was straightforward to collect. The only caution is to ensure that correct projection and datum information is logged into the database to ensure that sites can be revisited accurately in the future; and

Table 18. Summary table showing results of an evaluation with mappers in each case showing the ease of data acquisition for each element in BioAudit (0=not applicable, 1=very easy, 2 = easy, 3 = moderate, 4 – difficult, 5 = very difficult).

Domain	Element Name	Nullamanna	Avon	Cudgewa	Kangaroo Is.	Gascoyne-M.	Wet Tropics	Mean
Administrative	LandHolderName	1	1	1	1	1	1	1.0
	DistrictName	1	1	1	1	1	4	1.5
	PropertyName	1	3	1	1	1	3	1.6
	ObserverName	1	1	1	1	1	1	1.0
Project Information	ProjectName	5	4	5	5	5	3	4.5
	ProjectCode	4	4	4	6	4	3	4.2
	FundingSourceName	4	4	4	4	4	4	4.0
	Investment	4	4	4	3	4	3	4.0
Objectives	ObjectiveName	1	3	1	3	1	4	2.2
	ObjectiveTypeName	0	3	0	1	0	4	1.3
Sites	AuditDate	1	3	1	1	1	3	1.6
	SiteNumber	1	3	1	1	1	3	1.6
	SitePrepName	1	4	1	3	1	3	2.2
	SiteSizeName	3	3	3	3	3	3	3.0
	SiteTypeName	1	3	1	1	1	3	1.6
	SiteExperienceName	1	4	1	3	1	3	2.2
	RemVegTypeName	4	3	4	4	4	3	3.7
Enhancement Activity (inputs)	FenceLength	3	4	3	3	3	3	3.2
	CommonName	4	3	4	4	4	0	3.8
	CountTubeStockTrees	4	4	4	5	4	3	3.7
	CountUnderstorey	4	4	4	5	4	4	4.2
	KgSeeds	4	4	4	3	4	0	3.8
	KmDirectSeeding	4	4	4	3	4	0	3.8
	YearEstablished	3	3	3	3	3	3	3.0
	SiteConditionName	1	3	1	3	1	3	2.0
	GrassProvenanceName	1	5	1	0	1	0	1.6
	TreeProvenanceName	1	5	1	3	1	3	2.3
	USprovenanceName	1	5	1	0	1	3	1.8
	RevegTypeName	1	3	1	3	1	3	2.0
Outputs	Gsurvivorship	4	6	4	5	4	3	4.3
	USsurvivorship	4	6	4	6	4	4	4.7
	DSsurvivorship	4	6	4	6	4	0	4.8
	Regeneration	5	6	5	3	5	0	4.8
	Tsurvivorship	0	5	0	6	0	4	5.0
Condition Assessment	ScoreMethodName	3	1	3	3	3	1	2.3
	SiteNum	1	1	1	1	1	3	1.3
	ScoreValue	1	3	1	4	1	0	2.0
Coordinates	WaypointTypeName	1	3	1	3	1	3	2.0
	Easting	1	3	1	3	1	1	1.6
	Easting	1	3	1	0	1	1	1.2
	Northing	1	3	1	3	1	1	1.6
	Northing	1	3	1	0	1	1	1.2
	ProjectionName	1	3	1	3	1	1	1.2
Photopoints	PositionNames	1	3	1	3	1	4	2.2
	PhotoFile	1	3	1	3	1	1	1.2
	PhotoTime	1	3	1	3	1	1	1.2
	OrientationName	1	4	1	3	1	1	1.8

- **Photopoints Domain:** This information was straightforward to collect. The only caution is to ensure that the photo naming convention allow users to spatially locate the photopoint site if it is ever separated from the BioAudit database. This is achieved by using the following file naming convention *coordinatesystem_latitude_longitude_orientation_orientation_date* (where latitude and longitude are eight digit numbers adopting a spherical coordinate system expressed in decimal degrees to five decimal places; the orientation is one of 16 directions [n, nne, ne, ene, e, etc.] and the date is in the format ddmmyyyy). For example, an example photopoint file would be called: 'wgs84_03606567_14789985_NW_25012006.jpg'.

In summary, the major challenge is associated with collecting information about old vegetation enhancement activities whether the information relates to funding sources, project codes, enhancement inputs (seed, tube stock) or survival rates. However, when discussing the relative importance of various attributes it is important to remind ourselves that the primary objective is to develop a system which enables one to assess the biodiversity benefits of vegetation enhancement activities and some basic information will allow one to answer this question effectively. At the most basic level a GIS delineating the boundary of the activity, the date of the activity and some general indication of the inputs will allow us to examine the effectiveness of the activity by conducting a condition assessment at a later stage. Capturing the baseline mapping information and dates of the activity is critical to enable effective monitoring of these activities. The additional attributes pertaining to survival rates, site preparations, site experiences, species provenance could be considered as second level requirements which allow for more effective adaptive management. However the costs of collecting these can be prohibitive if methods are not sufficiently robust to allow inter and intra site comparison.

Project Institutional Needs

Data for this project were delivered by a variety of means including use of private contractors (Nullamanna, Cudgewa/Tintaladra, Gascoyne-Murchison), integration with existing research projects (Avon case study via an existing CRC/CSIRO project), CSIRO staff in other sites (Wet Tropics) and contracted data delivery via NRM agencies (Kangaroo Island Natural Resource Management Board, TREAT). In terms of an ability to meet data quality requirements and project timelines, the use of private contractors proved the most efficient mechanisms for collecting data. This was particularly true when the one consultant was used to map multiple case studies. The major limitation of using consultants is that capacity is not built into the regions and the focus remains on data capture. Other institutional issues encountered in the project include the following:

- There is a long-lead time when formalising the establishment of a case study. Groups charged with managing vegetation enhancement activities such as Landcare groups are responsible for a large number of competing priorities. We found that in general, capacity to deliver (time) was a greater limitation than participant willingness, hence the use of private contractors as the most efficient data delivery mechanism;
- When establishing a case study, 'face-to-face' meetings are essential in building good will and attaining project support. The project initially attempted to engage collaborators via email and telephone meetings and this was met with limited success. A meeting allows project managers to assess participant time commitments, enthusiasm and provides more effective means of 'marketing' the benefits of the project;
- It is critical to establish partnerships, both formal and informal, with other agencies. For example CMA's, natural resource management boards and state government agencies. This minimised possible threats to the project and ensures that data access issues are minimised if not removed entirely;
- It is important to communicate the project objectives to stakeholders. In other words, what is 'in' and what is 'out' in the project with a view of ensuring that false expectations are not created; and
- It is important to provide feedback at the end of the project to ensure transparency and to communicate project outcomes and limitations. In addition to providing data to stakeholders, this project is also providing analogue maps to each case study as tangible project outputs.

The brokering of relationships to locate and engage with suitable case studies involved a complex web of contact and liaison. This reflected directly the complex and highly variable nature of arrangements for regional NRM delivery, which in some places were still in their establishment phase at the start of the project. At that time, it was vital to ensure that joint team and Facilitator Network contacts, and also regional and local facilitator/coordinator networks, were informed about the project, understood the approach being used, and had the opportunity to provide advice and active support. Existing

networks were effective in advancing the project, by providing greater confidence in selection of case studies and key contacts who were able to 'open doors' for technical follow-up. Limitations arose from staff vacancies, absences, or lack of experience in the relevant position, and these had the effect of slowing initial engagement. These lines of communication may become simpler as delivery mechanisms mature, greater mutual awareness develops, and greater continuity is achieved in staffing and personnel at various levels. However, it is unlikely that these will obviate the need for any broadly based project of this sort to:

- Decipher the variability of NRM delivery arrangements and lines of communication between jurisdictions and regions
- Work carefully through those arrangements and lines to ensure that appropriate information flows to all of the people who consider that they need to know about the project and its activities; and
- Ensure that sufficient lead time is built in to the project for this relationship brokering and liaison phase.

A broadly based project will also benefit from events such as national forums and conferences (as part of the NRM knowledge management system) to promote the project and have initial face-to-face interaction with facilitator networks and potential case study personnel. Limitations at the local level generally involved capacity to engage with the project. This had two main aspects:

- Availability of personnel connected with the project; and
- Variable technical literacy and access to data and systems.

Availability of personnel connected with the case study project varied from case to case, and included factors such as:

- Availability of staff of regional bodies and/or state agencies at times of peak load for NHT reporting, and preparation of NRM investment plans and major submissions, noting also that staff need to arrange their leave around such peak loads; and
- Availability of volunteers or part-time personnel at project and governance levels for dialogue or face-to-face meetings, noting the demands of factors such as harvest, fires or floods, and the like.

Technical literacy and access to data and data management and/or mapping systems varied among project managers and personnel. In some cases this capacity depended on third parties such as State agencies. There is a risk that the relaxed data agreements between those agencies and local projects may not extend to data sharing with others, requiring further negotiation. This project had very limited potential to build capacity of regions and project managers, due to its 'experimental'/case study nature and constrained timelines and budget. There is potential for targeted data mapping of this sort to build capacity, although having this as an explicit objective is likely to alter the selection criteria for local projects and favour a quite different set of locations, perhaps based on ready availability of an existing base of skills and systems on which to build. For capacity building to be a realistic objective of such a project, timelines and funding would need to be extended.

All of these factors:

- May delay project commencement and/or slow project progress and completion
- Reflect the realities of NRM delivery at regional and local levels
- Are unlikely to change; and
- Need to be built into the planning of projects, with allowance for likely time lags.

To the extent that these factors are predictable, accessing existing networks through a combined 'top down'/'bottom-up' approach may be the only effective means to gain information that will enable contact and engagement at appropriate levels and at appropriate times, an informed approach to data access and sharing, reasonable expectations of regional and local capacity, and anticipation of likely time lags.

Operationalising the Use of the Methodology

The introduction of this report noted that this project will provide an appraisal of the feasibility of operationalising the methodology more broadly to support national monitoring and evaluation imperatives. We therefore assume that a logical extension of this project is to operationalise the methodology and make it available to stakeholders to conduct an analysis of their on-ground vegetation enhancement activities, and to provide information into regional and national reporting

systems. This research has raised some important issues regarding the feasibility of more broadly distributing the methodology. This section of the report examines some of the major issues associated with the broader use of the methodology in Australia. These issues include (a) coordination of data collection and mapping; (b) the need to develop more effective information systems to collect, archive, manage and analyse data emerging from such studies; (d) the role of existing vegetation mapping to support Biodiversity Benefits analyses.

Coordination and Delivery of Mapping and Attribute Data

The case studies in this project were delivered using a variety of methods including using contractors, regional natural resource management agencies (natural resource management boards), and integrating with existing efforts by local groups and researchers. Based on project experience, it is recommended that mapping be coordinated centrally by regional groups such as CMAs/CMB's or natural resource management boards owing to the technical skills required to map using GIS/GPS and remote sensing technologies, and existing familiarity with relational database management systems. In addition, there will be an ongoing requirement for access to contextual GIS data such as existing vegetation mapping, satellite imagery, aerial photography and this can often be best achieved by such agencies which usually are custodians for such data. In addition, regional bodies often operated existing monitoring systems which could compliment such data.

Regional entities may also be in a better position to act as custodians of this information as it can directly inform their strategic NRM planning. There will be exceptions and a number of local groups (e.g. Landcare groups) have high level technical capacity (e.g. TREAT in this study) but in general, regional bodies are best positioned to coordinate mapping activities, to ensure standards are met to enable comparison between study sites, and can best utilise the databases which are developed. It was found that utilising contractors to conduct the primary baseline mapping is highly effective as they bring high-level technical skills to the challenge and can more effectively meet project timelines. The major downside to utilising contractors is that it fails to develop local or regional capacity. However it is a more effective means to rapidly map the baseline status of on-ground activities before local groups take over maintenance of databases. An effective delivery model may be one whereby regional NRM bodies specify standards, manage contractors, develop timelines and broker agreements with local groups, and mapping is conducted by private contractors.

Information Systems for Data Collection and Management

The Biodiversity Benefits Project Phase 3 paid particular attention to developing information systems for the rapid and effective collection, management and analysis of field data. This included the development of the BioAudit database, the FieldAudit field data acquisition tools and mapping protocols. These tools were primarily developed to serve the needs of the project rather than developing applications for stakeholders. Consequently they are not as robust and user-friendly as applications developed for broader user distribution. Based on learning's from this project, an essential requirement to operationalise the methodology is to develop and provide information system infrastructures to enable stakeholders to collect, manage and analyse Biodiversity Benefits data. This includes the development of WWW-based relational database management systems with a spatial capability analogous to the Victorian Department of Environment and Sustainability's Catchment Activity Management System (CAMS). The system would be interoperable with other databases, for example linking to national NVIS databases to ensure compatibility of vegetation descriptions.

In this project, CSIRO took responsibility for collating and integrating data into BioAudit from stakeholders. The development of interoperable WWW-based database management systems would allow stakeholders to conduct this integration independently of a central database manager. This is particularly important if there is an expectation for stakeholders to periodically update databases with new condition assessments, additional site photographs and new activities. The development of such a system is not trivial and the challenge is to achieve high levels of uptake. For instance, the BioAudit database could be migrated to a WWW-based system allowing stakeholders to interact and add data, however to ensure ongoing uptake the following requirements would need to exist:

- The system would need to provide analysis and reporting capability beyond simple data management to provide a useful tool for users. This would involve extensive stakeholder consultation and stakeholder input to the design phase;
- The interface needs to be simple enough to encourage the addition of new data by stakeholders without encumbering them with new responsibilities;
- It should allow users to see input, output, outcome and monitoring data from other regions so that they can benchmark progress;

- The system needs to integrate with other databases to compliment Biodiversity Benefits data such as data emerging from rangelands monitoring systems, NVIS databases, or state property databases; and
- Improved integration of the FieldAudit tool with any WWW-based database management systems to enable rapid migration of field data to the database.

Use of Existing Vegetation Mapping to Support Analysis

It is increasingly common to report on biodiversity outcomes in terms of the percentage increases in native vegetation as a result of on-ground vegetation enhancement activities. To support such analysis, there is a general reliance on binary maps showing the presence or absence of vegetation. In some instances vegetation type maps (species/communities) are available, however owing to the overwhelming use of binary vegetation extent maps, this discussion focuses on extent mapping only. In this project we have found that vegetation map scale and accuracy can significantly impact upon the results which are generated from any analysis. For example, many of the on-ground activities listed as fencing of existing remnants do not correspond with mapped vegetation polygons provided to the project from various NRM agencies in their available vegetation maps. Therefore, how valid are the statistical summaries if the accuracy of the vegetation mapping is of an unknown quality, or the scale is inappropriate for the type of analysis we are conducting? Inaccurate or too large a scale (e.g. > 1:100,000) extant vegetation mapping raises the following concerns:

- Is the existing extant vegetation mapping comparable with the scale of *BioAudit* mapping which often maps on-ground activities to less than a hectare?
- If the Biodiversity Benefits assessment has mapped fenced remnants which do not appear in the available extant vegetation mapping (e.g. EVC mapping in Victoria) can one add this to the extant mapping to conduct an analysis?
- Is it valid to compare improvements in vegetation cover between case studies where scales and accuracies of extant vegetation mapping differ?
- Is it valid to make assumptions about improvements in structural components of vegetation extent if we have no understanding of the accuracy of the existing mapping?
- And in broader terms, NRM agencies such as catchment management authorities commonly articulate vegetation restoration goals in terms of a specific 'percentage cover' of native vegetation across their management area. How robust are these goals relative to the scale and accuracy of the input vegetation mapping used to conduct the initial assessment, or the mapping used to monitor progress towards these targets? The analysis below shows that setting such spatially explicit targets without articulating issues of scale and accuracy is a concern which can negate the value of setting spatially explicit targets. For example, Table 19 shows typical spatially explicit regional NRM targets which could be affected by issues of scale and accuracy.

To examine these issues and to provide some recommendations for future analysis of biodiversity benefits at the scale of a landscape, a case study accuracy assessment was conducted for the Nullamanna region. The purpose of this evaluation was to assess the accuracy of available vegetation mapping and to frame this in regard to the impact of errors on typical statistics. The first component required the development of an improved woody vegetation classification from higher resolution imagery than was already available. This allows the project to compare statistics between different scales of vegetation mapping. A detailed accuracy assessment was then conducted using a third validation dataset which was created by manually digitising four validation regions in greater detail. This dataset was treated as the truth in the analysis. Appendix D presents the methodology, examines the results in detail and discusses the implications of not assessing or communicating scale and accuracy in vegetation mapping products. The conclusion from this component of the study is that error and scale limitations are inherent in all vegetation mapping products. The problem lies not in the error or scale, but in the fact that it is essential that these are assessed, communicated to users and maintained constant through an analysis to ensure comparability of results. Owing to the importance of vegetation mapping from satellite imagery to most landscape scale vegetation management requirements, it is critical that such analyses are conducted.

Table 19 Example spatially explicit vegetation management targets

Region	Current vegetation cover	Biodiversity Target
Border Rivers-Gwydir CMA, NSW	54 %	By 2015 establish at least 150,000 ha (3 %) of the catchment with new area of native vegetation
Murray CMA, NSW	30 %	By 2016, additional 25,000 ha of remnant vegetation will be actively managed for biodiversity values...by 2016 the area of established new plantings with a biodiversity focus will exceed 10,000 ha.
Central West, NSW	-	By 2015, 1,200,000ha (13%) of the catchment area is managed primarily to maintain or achieve optimal native vegetation condition, and all vegetation types are represented in the catchment...By 2015, restore and enhance the area of high conservation value vegetation by 10,000 hectares.
Goulburn-Broken CMA, Victoria	30 % (715,000 ha)	Increase the cover of all endangered and applicable vulnerable Ecological Vegetation Classes to at least 15% of their pre-European vegetation cover by 2030.
North Central CMA,	-	Improve the quality and coverage of all vulnerable or endangered EVCs and any others with less than 15% of pre-1750 distribution by 10% (as measured by habitat ha)... Increase native vegetation coverage to 20% of the region.

Conclusion & Recommendations

The Biodiversity Benefits Project Phase 3 has mapped 216,379 hectares of vegetation enhancement activities across six cases and at 691 individual sites. The size of these sites ranges from small revegetation sites less than two hectares, to rangeland fencing in excess of 10,000 hectares. Mapping has occurred over a variety of landscapes from fragmented agricultural landscapes in south Eastern Australia, rainforest communities in the Atherton Tablelands and rangelands in the Gascoyne-Murchison. The project has also resulted in the development of prototype data entry tools (FieldAudit), relational database management systems for Biodiversity Benefits data (BioAudit) and detailed mapping protocols to enable groups and individuals to map their on-ground activities to specific standards. Through a variety of case studies the project has iteratively refined the mapping protocols and tested the robustness of the database design to a stage where it is a reliable and flexible system. Clearly, there will be on-ground vegetation enhancements scenarios not yet encountered that may require some re-design of the methodology. However, in general the fundamental design principles should not change.

In addition to the development of protocols and tools, the project has also examined important ancillary issues for conducting a Biodiversity Benefits assessment including the ease of acquisition of specific BioAudit elements which can inform future mapping efforts; the use of landscape metrics to summarise landscape change; and the role of scale and accuracy in vegetation mapping and its impact on analysis results. Based on the experiences from this study some final recommendations and conclusions emerge. These include the following:

- Collecting Biodiversity Benefits data requires a high level of skill and may be best coordinated by regional natural resource management agencies which routinely maintain this technical capability and are in the best position to utilise the data for their landscape scale strategic NRM. Using private contractors was the most efficient mechanism for data acquisition for a large project such as this;
- Following standard protocols is essential to enable inter and intra-site comparison and ongoing monitoring, with additional flexibility built-into the system which allows for customisation (e.g. new condition scoring methods for different regions). By ensuring standard protocols are enforced the methodology encourages the use of adaptive management principles;
- There is a need for improved information technology systems based on BioAudit designs which allow custodians to collect, manage and analyse their own data using centralised WWW-based tools for data entry, management, reporting and analysis which should be developed in collaboration with stakeholders;
- There is a need for the development of more rigorous methods and guidelines for the collection of vegetation enhancement input and output information (e.g. volume of seed and

number of plantings, survival rates). Owing to the difficulty encountered in collecting this data, It may be useful to differentiate Level 1 BioAudit data from less important BioAudit data. Input and output information could be regarded as Level 2 data as it is challenging to collect accurately for older activities. Level 1 data would be the primary site descriptors, coordinates, year of the activity and other baseline information required to conduct an analysis. Appendix Table 3 differentiates elements on the basis of these priorities;

- There is a requirement to establish accuracy and scale standards for vegetation mapping. This important tool is critical for assessing the structural change which has occurred as a result of on-ground vegetation enhancement activities, for assessing progress towards targets, and for monitoring loss of native vegetation at regional scales. At present, the approach to mapping is non-systematic leading to problems when comparing study regions or monitoring individual regions over extended time periods (when vegetation maps change); and
- An assumption inherent in this study is that there is much to be gained from collecting spatially explicit Biodiversity Benefits data to inform future on-ground vegetation enhancement strategies and to monitor progress towards targets. The project justification in this report does this in detail. However, there is merit in extending the preliminary analysis of the case study projects presented herein to better highlight how this information can support local and regional decision making.

It is unrealistic to foresee the widespread mapping of historical on-ground vegetation enhancement activities in Australia given the large past investment in on-ground vegetation enhancement activities since the inception of NHT in the early 1990's. However, it is practical to develop and publish standard mapping, attribute collection and data management protocols, to develop information system technologies which could be adopted by regional and local groups, and to provide case study exemplars which highlight the importance of such data for strategic natural resource management. Nationally, a useful strategy may be to map a sample of representative study sites to act as long term monitoring sites to evaluate the ongoing success of activities utilising Biodiversity Benefits specifications. This scaleable sample of study sites would facilitate inter-study comparisons of the effectiveness of enhancement activities; they would provide an opportunity for communication between stakeholders based on common learning's; and they would support the application of systematic adaptive management strategies to improve biodiversity outcomes of on-ground vegetation enhancement activities.

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Appendix A: Mapping and Spatial Data Acquisition

The primary objective of this component of the project was to efficiently map the boundaries of vegetation enhancement activities to develop 'activity polygons' in a GIS. Although Global Positioning Satellite systems could be used to map these boundaries by walking the boundary of an activity, the use of remote sensing combined with on-screen digitising is recommended for a number of practical reasons. These include the following:

1. For many enhancement activities it is difficult and time consuming to walk the boundary of a patch of vegetation. For instance, some of the case studies contain fenced remnants in excess of 250 hectares. Even for small remnants, boundaries such as creeks, fences and topographically diverse terrain make field mapping challenging, if not impossible. Further, mapping does not warrant the spatial accuracies which are available from GPS.
2. For some remnants, such as scattered woodland communities, it is difficult to differentiate the remnant boundary in the field. It is more efficient to specify a minimum mapping unit (e.g. tree density) and mapping scale in a GIS and to digitise boundaries according to these specifications to ensure development of a comparable database (Appendix D).
3. Providing landscape context in a GIS via the inclusion of property boundaries, fences, other vegetation, and anthropogenic features allows landholders to provide a more accurate spatial representation of the activity boundary.

For these reasons a remote sensing approach has been adopted which uses a variety of imaging platforms combined with on-screen digitising conducted in collaboration with landholders at their properties. Imaging platforms ranged from high resolution mosaiced air photography, to SPOT5 multispectral imagery or Landsat 5 satellite imagery for the larger case studies (e.g. Gascoyne Murchison). The protocol is intentionally not prescriptive regarding the type of remote sensing imagery which should be employed as the choice will be study site specific. However, for typical non-rangelands case studies SPOT5 multispectral satellite imagery has proved highly effective. A field visit of each activity site was conducted and included the capture of a reference waypoint by GPS which would help identify the polygon in the attribute database. In addition to the waypoint, the positioning of this waypoint was recorded relative to the activity polygon (i.e. lower left, centre, and upper east). This was collected in the event the site identifiers were corrupted in the GIS or in the event of a loss of projection and datum information in the GIS layer which could make linking the GIS to the relational database management system difficult.

The resulting GIS layer should contain only a minimum amount of data in its attribute table and most of the activity data should be contained in the BioAudit, or similar, relational database management system. Through the case study assessments the list of minimum GIS attributes are listed in Appendix Table 1 and aggregated by data domains. The SiteID contains the primary link to the relational database management system. The remaining elements have been selected to ensure that if separated from the relational database management system, the GIS layer can still provide a useful summary of the activities in this landscape. The external site identifier (SiteID_Ext) is an identifier which can link to other stakeholder databases and is generally empty. Appendix Table 2 provides a more detailed description of the enhancement types recorded in the GIS attribute table. An outcome from this project is the development of a detailed mapping protocol or rules for mapping on-ground activities. These protocols include the following:

General Protocols

1. **Define primary entity as a 'site' to allow for multiple actions at a site.** The BioAudit database described below contains a primary entity called a 'site'. The site is analogous to a vegetation patch, but the definition has intentionally been kept generic as the term patch can be ambiguous. A property can have many sites and a site can have multiple actions over time. For instance, initial funding may provide for fencing of a remnant (site) and direct seeding. Future funding may pay for additional seed application or planting of grasses, but no additional fencing. In such a scenario the spatial extent of the site has not changed and handling the temporal component is relatively straightforward as the BioAudit database allows for temporal updates or additions. However, in some situations, an enhanced remnant may be expanded in future years via additional funding provided by a funding scheme. In such scenarios, this should be mapped as a new spatial entity, even if it adjoins an existing entity. Hence the primary criteria for the creation of new entities is when new funding is received which results in a change in extent of an existing entity. Consequently a high level of initial mapping

disaggregation is recommended to enable future aggregation, or more importantly, to preserve the temporal history of activities at a site;

2. **Relationship between GIS data file and study area:** Each study area (DistrictName in BioAudit) links to one GIS data file (e.g. Shapefile).
3. **Linking GIS data to the BioAudit relational database management system:** The unique feature identifier linking spatial entities in the GIS (polygons) and the BioAudit database is the SiteID (table tblSites). Where possible a one-to-one relationship has been implemented between the polygons and the BioAudit SiteID attribute. In some instances there is a one-to-many relationship. This occurs in situations where for example a shelter belt is broken by a farm gate and results in the mapping of two separate polygons with the same SiteID. In such situations, it is recommended that the same SiteID be applied but with different Site Numbers as this allows for aggregation in the database at a later stage. It is advised that a mapping threshold should be defined and used consistently to determine whether a spatial entity should form a number of separate entities. This threshold will be landscape specific so it is difficult to be prescriptive about 'break' distances, however these should be defined prior to the commencement of mapping. A criteria may be thematic rather than metric and could include for example permanent roads or water bodies;
4. **Defining project information for GIS data:** Output GIS data must have projection and datum information defined either directly into the file format (e.g. Shapefile) or into the accompanying metadata statement;
5. **Existence of 'Orphaned' GIS records:** Data may exist in the spatial database and not exist in the BioAudit database. For instance, a mapper may map the boundary of a vegetation enhancement activity and wait to conduct a full BioAudit assessment at a later stage. In such instances, the site identifier (SiteID) is tagged as -9999; and
6. **Recording points rather than polygons:** To record a point rather than a polygon it is only necessary to maintain this coordinate information as a reference waypoint in BioAudit rather than the GIS. For example, some infill plantings are difficult to identify spatially. In such situations the action can be recorded in BioAudit by including reference waypoint information.

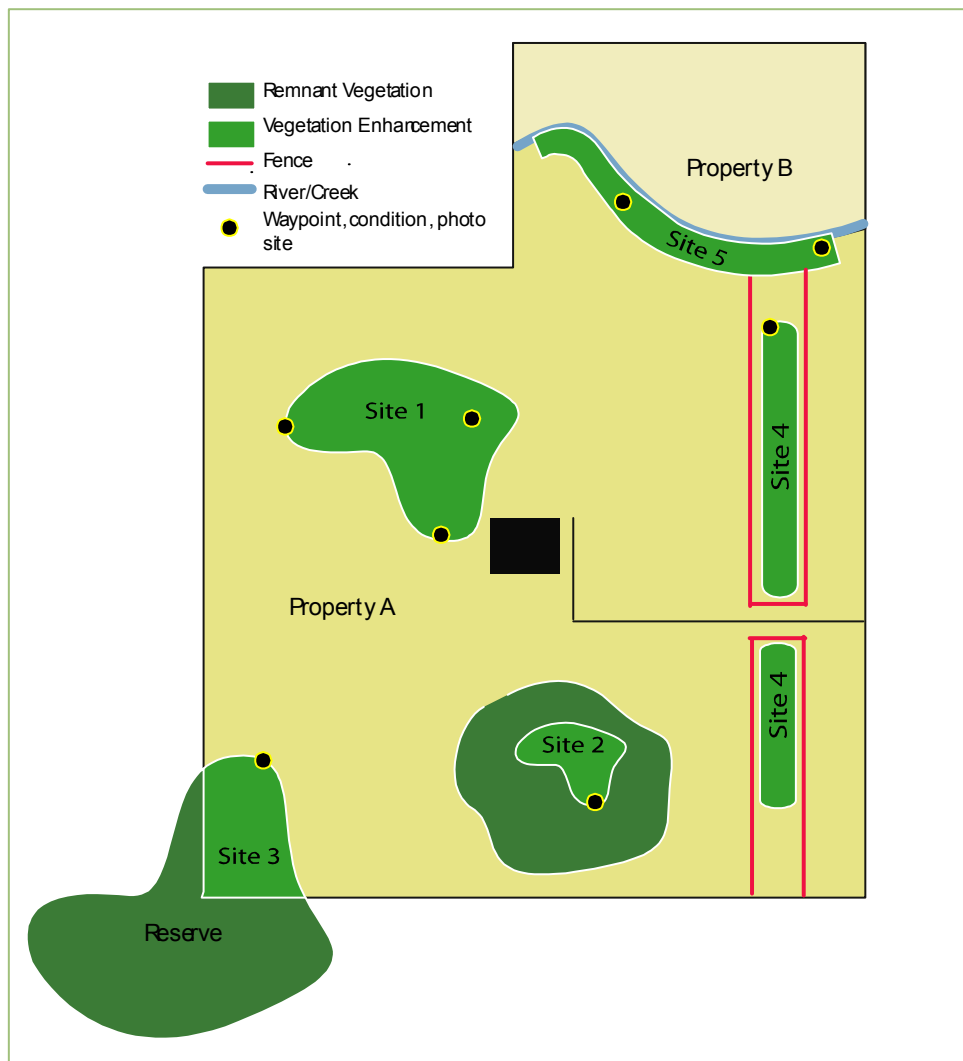
Specific protocols based on different enhancement scenarios:

7. **Mapping fencing:** A polygon has been fenced in whole or in part if the dollar amount attributed to fencing in the relational database management system (BioAudit) is greater than zero;
8. **Mapping fencing adjacent to existing fences:** It is common for landholders to acquire funding to fence a remnant by linking existing fencing on their properties. In such situations, a small amount of fencing protects a large remnant, or site for revegetation activities. In such scenarios, the GIS should define the entire boundary protected on that landholders' property as BioAudit contains a element for 'funded fence length' which allows one to differentiate the funded fence length from the protected fence length. This level of disaggregation allows for later aggregation;
9. **Handling corridor breaks** (Appendix Figure 1 - Site 4): 'Broken corridors' should be mapped as separate spatial entities but with the same site identifier linked to BioAudit. In some landscapes the establishment of shelter-belts and other corridors is a common output enabled by the provision of vegetation enhancement funding. However, corridors are commonly 'broken' by gates and roads. By following this protocol it allows for aggregation at a later stage and acknowledges that in practice, the activity received the same funding which was applied at the same time. If these two conditions do not apply, they should be treated as separate activities;
10. **Defining corridor widths:** It is recommended that in the case of linear corridors, a field inspection calculates the planting width rather than the canopy width and the on-screen digitising reflects the planting width. Using remote sensing alone in the case of vegetation corridors can be particularly problematic as remote sensing will only allow the mapping of canopy width rather than planting width. This can generate misleading area estimates. This may also occur with small remnants or revegetation sites but is a primary concern for corridor establishment;
11. **'Island plantings'** (Appendix Figure 1 - Site 2): Where an 'island' of vegetation may be enhanced and nested within a larger remnant map the location of this 'island' of activity using

GPS. Distinguishing this island visually from remote sensing alone may be impossible. In such situations the only option is to use GPS. If a GPS signal cannot be obtained owing to forest canopy issues this should be recorded as a point and noted in the comments section of the database. This scenario was rare in the in this study;

12. **Mapping juvenile plantings:** Juvenile plantings which do not appear in remotely sensed data should be mapped using GPS by either mapping the boundary or recording a point observation for smaller plantings;
13. **Remnants connected to reserves** (Appendix Figure 1 Site 3): Only map the boundary of the fenced remnant on the landholder's property rather than the entire remnant. In some landscapes, remnant vegetation is already connected to a large reserve located on public land. In such scenarios, a landholder will typically request funding for the portion of the remnant which lies on their property and this is the component that is fenced. Hence, although only a small amount of fencing is applied, a large patch of vegetation is protected from grazing and other impacts. Consequently, should this be mapped? The protocol states that only the boundary on the landholder's property should be mapped as a polygon. The justification for this is that conservation easements are generally already mapped in other agency databases and hence it would be relatively easy to assess the occurrence of such activities by combining spatial databases; and
14. **Mapping riparian protection** (Appendix Figure 1 Site 5): The mapping protocol states that riparian protection areas are mapped to the boundary of an accompanying contextual hydrology (rivers/creeks) GIS layer of a specified scale and documented source. The mapping of sites of riparian protection can cause significant ambiguity and is analogous to the issue of remnants connected to reserves. Namely, when a landholder protects a riparian strip this activity may occur only on their property where the river or creek forms the boundary between two adjacent properties. Consequently, should one map to the landholder's side of the creek; to the creek centre line; to the distal bank, or across the river and to the adjacent property in cases where the neighbouring side is also fenced? This scenario raises important questions in regard to the value of riparian protection where adjacent properties are not fenced and stock can traverse perennial streams to impact into seemingly protected riparian corridors. This later issue cannot be addressed in a mapping protocol, however understanding its existence means one can develop a protocol which enables the assessment of the effectiveness of riparian protection activities in a landscape. For instance, one could use 1:25,000 river networks and mapping would create a polygon feature by mapping the respective fence lines, in addition to the GIS-based river or creek line. It is assumed that the GIS defined creek line will be the midpoint of the water body. Mapping should not occur into neighbouring properties when funding is allocated to individual properties.

It is important to note that this protocol is evolving and may require refinement if different scenarios are encountered in ensuing case studies.



Appendix Figure 1. Schematic showing typical and complex vegetation enhancement mapping scenarios across two neighbouring properties and with a neighbouring conservation easement.

Appendix Table 1. Attribute table definitions for GIS polygons delineating vegetation enhancement activities.

Domain	Element Name	Element Type	Description	Example	Notes
System Generated Elements	FID	numeric	system generated	1,2,3	ArcGIS generated element
	OID	numeric	system generated	1,2,3	ArcGIS generated element. Not always present
	Shape	text		Polygon	ArcGIS generated element
Unique Identifier	SiteID	numeric short integer	primary site identifier used to link polygons to BioAudit database	1,2,3,	Some sites will have a - 9999 SiteID. This indicates that they do not exist in the database. Some sites have more than one polygon, for example if a planting is interrupted by a farm gate. SiteID + SiteNumber provides a unique link to the polygon.
	PolygonNum	numeric short integer	secondary site identifier. Commonly has a value of '1' if the SiteID is unique.	1,2,3,4, 5, such that 1-1 is unique from 1-2	
Administrative Information	PropertyNa	string	name of property	Belview	Name of property corresponding to PropertyName in BioAudit database.
	LandHolder	string	name of landholder	Smith, B.	Name of property corresponding to LandHolderName in BioAudit database.
Enhancement Activity	Veg_Enh_Ty	string	vegetation enhancement type	remnant protection, remnant enhancement, remnant enhancement and protection, revegetation, revegetation and fencing, null	See Appendix Table 2 for a full description.
Coordinates	CentroidX	numeric double	X centroid of the polygon		Used for landscape metric analysis and map production. The datum and projection is the same as that for the parent Shapefile Used for landscape metric analysis and map production. The datum and projection is the same as that for the parent Shapefile
	CentroidY	numeric double	Y centroid of the polygon		
Polygon Size	Perimeter	numeric double	perimeter length of the polygon in metres		Data are derived using GPS and on-screen digitising.
	Area	numeric double	area of the polygon in square metres		
	Acres	numeric double	area of the polygon in acres		
	Hectares	numeric double	area of the polygon in hectares		
External Identifiers	SiteID_Ext	string	Second unique identifier to link to external databases	bel101	Can provide a link to data held by other agencies. - 9999 if no external link present. Link documented in metadata statement.

Appendix Table 2. Vegetation enhancement types and definitions for describing polygons in GIS data.

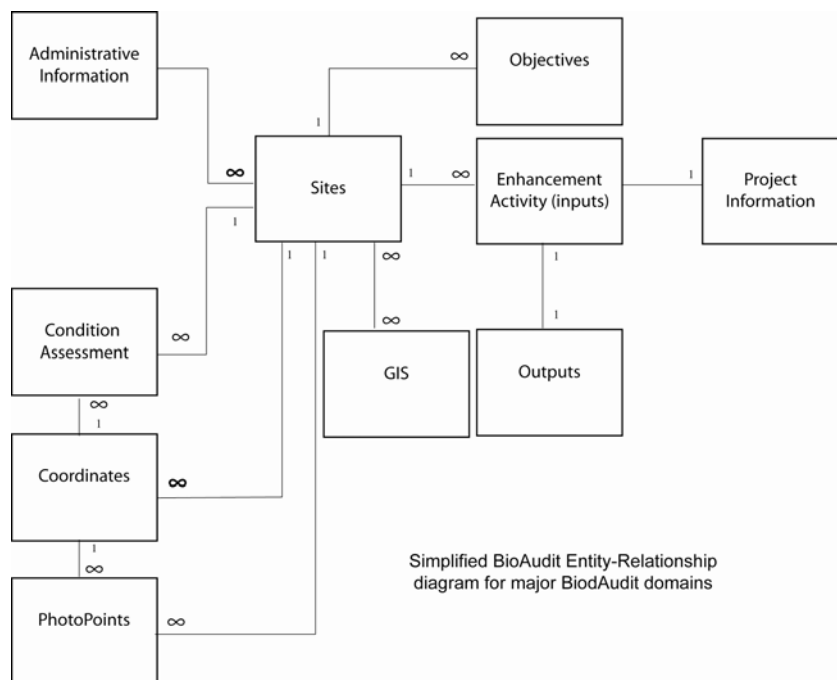
Enhancement Type	Definition
remnant protection	a remnant polygon which has been fenced in whole or in part
remnant enhancement	a remnant polygon where additional planting has been undertaken and which has not been fenced
remnant enhancement and protection	a remnant polygon where additional planting has been undertaken and which has been fenced in whole or in part.
revegetation	a non remnant polygon where revegetation has taken place and which has not been fenced
revegetation and fencing	a non remnant polygon where revegetation has taken place and which has been fenced in whole or in part
null	this polygon has been mapped however no data has been collected that allows us to infer what type of enhancement has been undertaken.

Appendix B: Attribute Data Collection & Management

BioAudit Relational Database Management System

A key output to emerge from the Biodiversity Benefits Project Phase 2 was a list of minimum attributes required to effectively assess the biodiversity benefits of vegetation enhancement activities (Freudenberger and Harvey 2004 Appendix 7. (<http://www.biodiversity.ea.gov.au/land/publications/data/pubs/data.pdf> Last accessed September 21, 2006). This list of attributes was a theoretical list based on the outcomes from the case study assessments. It was never formalised into an appropriate relational data model, nor was it tested operationally in terms of its logic and utility of use. An outcome from the Biodiversity Benefits Phase 3 project is the development of the BioAudit relational database management system for managing and analysing vegetation enhancement activity data. BioAudit formalises and tests these attributes in a new relational data model. Considerable time was devoted to the development of this system to enable the project to effectively manage and analyse its vegetation enhancement data. In addition to supporting internal data management requirements, an important project outcome is that the BioAudit data model could be used by other NRM agencies to manage their vegetation enhancement information. As the database has been tested in an operational environment, the design is now robust. A compliment to BioAudit is the development of the FieldAudit data entry system which will be described in detail in the following section.

BioAudit was designed to overcome some of the limitations of existing methods for recording vegetation enhancement information which are primarily based on non-relational data models and utilise software such as Microsoft Excel. Such approaches have inherent limitations for effectively storing and managing information as they cannot accommodate time series information which is central to an effective Biodiversity Benefits assessment. For example, a site may have received a particular on-ground treatment (e.g. fencing) in one year, followed by additional treatments in following years (e.g. new plantings, weed control). In such a scenario the site location remains constant, but treatments vary in time. More importantly, and in the context of effective monitoring and evaluation, a site may be assessed in ensuing years in regard to its condition. This may include assessing seedling survival rates, conducting a habitat condition assessment or collecting site photographs. Documenting such information in a non-relational database model is difficult. BioAudit overcomes many of these limitations, and introduces efficiencies to ensure minimal data duplication occurs for recurrent element values (e.g. common species names) while ensuring consistency of data entry where appropriate.



Appendix Figure 2. Simplified entity-relationship diagram for the BioAudit database for the nine main data domains.

Appendix Figure 2 provides a simplified entity-relationship diagram for BioAudit. A key design requirement in developing the entity-relationship diagram for the project was to differentiate the dynamic from the static components of the management of vegetation enhancement activity information. It has been assumed that in most cases that once funded and applied, the Administrative Information and enhancement Sites will remain static while the Enhancement Activities (inputs) and the Condition Assessments are likely to change over time. For example, once a revegetation activity occurs, it may be fenced again in future years, or a Landcare officer may revisit the site to capture a new site photograph or to conduct a new vegetation condition assessment. Through the case study assessments, this assumption has been valid, although a number of years need to pass before one can fully evaluate the robustness of this design. As for the mapping component of this project, a protocol has been developed for the aspatial data. The rules do not need to be as explicit as they are formalised in the BioAudit Microsoft Access 2003 database. However some general rules and issues require explanation. These include the following:

1. **District:** A district is an administrative unit such as a Landcare group or an NHT region. A district can contain many Sites (location of a vegetation enhancement activity) and each district is linked to one GIS datafile showing the location of sites.
2. **Sites Domain:** The primary domain in BioAudit is the sites domain. A *Site* is the location of a vegetation enhancement activity. This could be an existing remnant which has been fenced or a revegetated patch of ground. In operational terms it is analogous to a 'patch'. Generally, a *Site* will be mapped in the GIS as a polygon, however it can also be a point feature if sufficient spatial information is not available;
3. **Objectives:** A *Site* will contain *Objectives* which refer to the primary purpose of the activity. Objectives can include salinity abatement, habitat conservation, windbreaks, aesthetics and riparian habitat to name only a few. BioAudit makes a distinction between primary, secondary, tertiary and additional objectives. If a primary objective were to change over time, then it is recommended that a new site is defined. However, from the case study assessments it has been found that objectives are static in time and there is unlikely to be a need for this;
4. **Relationship between Sites and Districts:** A *District* can contain multiple sites with the same *SiteID*. This is rare as it is preferable to have unique *SiteID*'s for any one district. This issue is fundamentally one of mapping scale. An example where this occurs is in the establishment of a linear shelterbelt or windbreak. These spatial features are commonly interrupted by anthropogenic elements such as roads and gates. Therefore, in a spatial sense, and at a particular scale, they are treated as disparate entities but in a management sense they are treated as one. In such cases the funding sources are identical, the activity was established in the same year and received an identical input (e.g. kilograms of seed) but is stored as two disparate polygons. *BioAudit* addresses this by allowing for duplicate *SiteID*'s to be present in a database (*tblSites* table). The frequency of this occurring will be a feature of mapping scale, and spatial resolution of underlying satellite imagery. For instance many more 'breaks' in shelterbelts will be visible in a SPOT5 image at 1:10,000 compared to a Landsat 5 image at a scale of 1:25,000. Where there is doubt, data should be spatially disaggregated where possible. If sites receive different inputs (e.g. seed application rates) then these should be identified as unique sites in BioAudit;
5. **Relationship between Sites and Activities:** One *Site* can have many enhancement activities. Enhancement activities are known as *actions* in BioAudit and this refers to the inputs applied to the site. An enhancement activity may include a specific fence length (in metres), planting of understorey and overstorey species and planting of grasses. This is a one-to-many relationship to accommodate the fact that a site commonly receives different treatments over time. For instance, a site may be initially fenced, and additional funding may be provided in ensuing years for enhancement through understorey planting;
6. **Output Domain:** The output domain contains information about survival rates of planted seedlings, amount of regeneration, and general information about survival rates for understorey and grasses. This is not an indicator of the condition of the site but rather an indicator of the immediate outputs from the activity;
7. **Unmapped Sites:** Some sites in BioAudit may be tagged as un-mapped where attribute information has been collected but no mapping has occurred. This occurred due to opportunistic data collection and the project's desire to retain a record of this in BioAudit. Similarly, some sites can be mapped in the GIS but may not have corresponding sites in BioAudit for similar reasons;

8. **Condition Domain:** The condition domain manages information regarding temporal assessments of the condition of a site using a variety of methods (e.g. Habitat Hectares, habitat complexity, Biometric etc.) and site photographs. The condition assessment method is not prescribed to allow for user flexibility, but the database does require users to define the method which was used. One would expect this domain to be the most dynamic of all domains;
9. **GIS Domain:** The GIS domain contains data derived from the related GIS files including the area and perimeter of an enhancement activity;
10. **Complimentary Fencing:** In some case studies funded fences are used to create a remnant protection region where existing fence lines exist. In such scenarios the existing fence line is combined with the new funded fence to create a new region. In such situations, the *BioAudit* protocol requires that the entire region be mapped as one polygon and be defined as a site in the database. *BioAudit* can manage such data as it stores a value for the amount of funded fencing, which when combined with the GIS data provides a complete picture of the activity;
11. **Spatial Expansion of Existing Sites:** If a site is spatially expanded in future years owing to a new enhancement activity such as additional revegetation, the protocol recommends that in the interests of retaining historical information, the old site boundary be retained, and a new site be established which contains the new action. Most GIS data models such as Shapefiles support the use of overlapping polygons; and
12. **Site Photography:** Site photographs are a critical element of an effective biodiversity monitoring program, particularly for longitudinal assessment of changes to vegetation structure. Although they do not contain the analytical information inherent in a quantitative site assessment, they nevertheless provide important temporal information not necessarily available in a site assessment for little field effort. BioAudit accommodates site photographs which are linked to latitude and longitude information and a photograph orientation. A file naming convention is used which incorporates the coordinates of the photographs expressed using a spherical coordinate system and specified datum (e.g. WGS84), the photo orientation and a photo date. This ensures that the photograph is useable even if separated from the BioAudit database. Appendix Figure 3 shows example site photographs for eight study sites.



wgs84_0361726_14777909_NE_19012006.jpg



wgs84_02665634_1169405_SE_12052006.jpg



wgs84_02599521_11698311_W_09052006.jpg



wgs84_0361905_14772926_SE_20122005.jp



wgs84_03621974_1477501_N_10012006.jpg



wgs84_0362193_14773431_E_19012006.jpg



wgs84_0172921_14560503_W_25012006.jpg



wgs84_03562064_13263297_NW_22052006.jpg

Appendix Figure 3 Example site photographs showing respective file names.

Appendix Table 3. Summary table showing BioAudit domains and the domain priorities based on results from the Biodiversity Benefits Project Phase 3.

Domain	Domain Priority	Element Name	Element Priority Exceptions
Administrative	Level 1	LandHolderName	
		DistrictName	
		PropertyName	
		ObserverName	
Project Information	Level 1	ProjectName	
		ProjectCode	
		FundingSourceName	
		Investment	
Objectives		ObjectiveName	
		ObjectiveTypeName	
Sites	Level 2	AuditDate	
		SiteNumber	
		SitePrepName	
		SiteSizeName	
		SiteTypeName	
		SiteExperienceName	
		RemVegTypeName	
Enhancement Activity (inputs)	Level 2	FenceLength	
		CommonName	
		CountTubeStockTrees	
		CountUnderstorey	
		KgSeeds	
		KmDirectSeeding	
		YearEstablished	Level 1
		SiteConditionName	
		GrassProvenanceName	
		TreeProvenanceName	
		USprovenanceName	
		RevegTypeName	
Outputs	Level 2	Gsurvivorship	
		USsurvivorship	
		DSsurvivorship	
		Regeneration	
		Tsurvivorship	
Condition Assessment	Level 3	ScoreMethodName	
		SiteNum	
		ScoreValue	
Coordinates	Level 1	WaypointTypeName	
		Easting	
		Easting	
		Northing	
		Northing	
		ProjectionName/Datum	
Photopoints	Level 1	PositionNames	
		PhotoFile	
		PhotoTime	
		OrientationName	

The tables below (Appendix Table 4 to Appendix Table 13) show the major BioAudit domains and their respective elements with examples for the BioAudit data model. Appendix Figure 5 provides a Microsoft Access 2003 entity-relationship diagram for BioAudit.

Appendix Table 4. BioAudit Database - Administrative Information Domain

Domain	FieldName	Element Description	Example	Notes
Administrative Information	LandHolderName	name of landholder	<i>Smith, B.</i>	
	DistrictName	name for district	<i>Yass Landcare Group, NE Victoria, Avon, Wet Tropics etc.</i>	This can be any administrative entity
	NHTRegion	NHT region	<i>Rangelands, NE Victoria</i>	
	PropertyName	name of property	<i>Belview</i>	

Appendix Table 5. BioAudit Database - Sites Domain

Domain	FieldName	Element Description	Example	Notes
Sites	AuditDate	date/time site assessed by the observer	<i>10/12/2005 04:06</i>	
	SiteID	autonumber	<i>1, 3001</i>	System generated auto-number that links to the GIS.
	SiteNumber	number of site on the property; simple element identifier	<i>1 etc.</i>	
	SitePrepName	name for site preparation method	<i>bulldozing, ripping, spraying, stock exclusion, contour banking</i>	
	SiteSizeName	name for site size category	<i>2-10ha, 10-50ha, 50-100 ha, etc.</i>	
	SiteTypeName	name for site type	<i>BioAudit or Other</i>	Most sites will be BioAudit but we can collect data to assist landholders
	SiteExperienceName	name of site experience	<i>flood, drought, grazing, animal pests, insect pests, weeds, fire, other</i>	
	RemVegTypeName	name for remnant vegetation type	<i>Shrubby Woodland,</i>	
	Site_Ext	external site identifier		Links to stakeholder database
	ObserverName	name of observer	<i>Brown, P.</i>	Person conducting the assessment

Appendix Table 6. BioAudit Database - Objectives Domain

Domain	FieldName	Element Description	Example	Notes
Objectives	ObjectiveName	name for objective	salinity abatement, erosion prevention, linking remnants, aesthetics, wind breaks, farm forestry, riparian habitat etc	This does not have to be unique for each district or each property. These can be any project codes used by the funding organisation
	ObjectiveTypeName	name for objective type	primary, secondary, tertiary, additional	

Appendix Table 7. BioAudit Database - Enhancement Activity (inputs) Domain

Domain	FieldName	Element Description	Example	Notes
Enhancement Activity (inputs)	FenceLength	length of fencing in metres	2500, 1200, etc	
	CommonName	common name for species	River Oak, Yellow Box, Manna Gum etc	
	CountTubeStockTrees	number of tube stock planted	100, 500, 1000 etc	
	CountUnderstorey	number of understorey plants planted	100, 250, 300 etc	
	KgSeeds	kilograms of seed	10, 21, 43 etc	
	KmDirectSeeding	kilometres of direct seeding	0.5, 2.3 etc	
	YearEstablished	year action established	2002, 2003, 1984	
	SiteConditionName	name of site condition	intact remnant, exotic pasture, bare soil, eroding etc.	
	GrassProvenanceName	name of provenance category	local native, non-local native, exotic, unknown	
	TreeProvenanceName	name of provenance category	local native, non-local native, exotic, unknown	
	USprovenanceName	name of provenance category	local native, non-local native, exotic, unknown	
	RevegTypeName	name for planting type	multi-species, monoculture farm forestry, mixed species farm forestry, n/a	

Appendix Table 8. BioAudit Database - Project Information Domain

Domain	FieldName	Element Description	Example	Notes
Project Information	ProjectName	name for project	<i>Pindari Creek Drought Recovery Management</i>	This does not have to be unique for each district or each property. These can be any project codes used by the funding organisation. If funding is in-kind add 'in-kind'. We aggregate funding information at the project level.
	ProjectCode	code for project (usually NHT project codes)	<i>EF39640</i>	
	FundingSourceName	name of funding source amount of investment in the project from the funding source(s) (\$)	<i>NHT, CMA, Landcare, Landholder, Other etc</i>	
	Investment		<i>23,000</i>	

Appendix Table 9. BioAudit Database - Outputs Domain

Domain	FieldName	Element Description	Example	Notes
Outputs	Gsurvivorship	% survival rate of grasses (null if GrassProvenanceID = n/a)	10, 20, 50 % etc	Some landholders plant both understorey and overstorey. This is a subjective classification of understorey versus overstorey.
	USsurvivorship	survival rate of understorey per100 (null if CountUnderstorey = 0)	10, 20, 50 % etc	
	DSsurvivorship	survival rate of direct seeding per100 (null if KmDirectSeeding = 0)	10, 20, 50 % etc	
	Regeneration	amount of regeneration per 10 metres (null if not a remnant)	1, 2, 3 etc.	Purely natural regeneration (grazing management, fencing). Survival rate of planted trees.
	Tsurvivorship	survival rate of trees per 100 (null if CountTreeStock = 0)	10, 20, 50 % etc	

Appendix Table 10. BioAudit Database - Condition Assessment Domain

Domain	FieldName	Element Description	Example	Notes
Condition Assessment	ScoreMethodName	name/description of scoring method	Habitat Complexity, Habitat Hectares, Biocondition, etc	Depends on the method used for a particular region Incremental auto number showing the condition site relative to the overall site
	SiteNum	site order number for this site on this patch	1,2 etc	
	ScoreValue	score value for the score category	10 etc.	

* The current version of BioAudit supports a data model which allows direct input of Habitat Complexity score data (Newsome and Catling, 1979) and this data are populated for the case studies where data were collected. The database could be expanded to accommodate other condition assessment systems in the future.

Appendix Table 11. BioAudit Database - Coordinates Domain

Domain	FieldName	Element Description	Example	Notes
Coordinates	WaypointTypeName	name for waypoint type	mapping reference only, reference & photo, photo only	Mapping reference waypoints are used as a check to ensure we are in the correct mapped polygon. It can be a centroid or an edge of a polygon. The PositionName should also be recorded to help identify this site/patch at a later stage.
	Easting	longitude of condition site	140.4	This can be a reference, waypoint or condition site
	Northing	latitude of assessment site	36.5	This can be a reference, waypoint or condition site
	CoordinateSystem	coordinate system	geographic, UTM56, UTM55	
	Spheroid	spheroid for coordinate system	AGD66, GDA95, WGS84	
	Parameters	specific parameters for unique projections	VICMAP paremeters	

Appendix Table 12. BioAudit Database - Photopoints Domain

Domain	FieldName	Element Description	Example	Notes
Photopoints	PhotoFile	file name of photograph .jpg; Use following file naming convention <i>coordinatesystem_latitude_longitude_orientation_orientation_date</i> (where latitude and longitude are eight digit number adopting a spherical coordinate system expressed in decimal degrees to five decimal places; the orientation is one of 16 directions [n, nne, ne, ene, e, etc.] and the date is in the format ddmmyyyy).	wgs84_03606567_14789985_NW_25012006.jpg	Unique names for each photograph. Multiple photographs can be taken for each site or each condition assessment site.
	PhotoTime	date and time of photo to enable observer to match photograph with photofile	date and time	
	OrientationName	name for photo point orientation	n, nne, ne, ene, e etc.	Direction the observer was facing when taking the photograph.

Appendix Table 13. BioAudit Database – GIS Domain

Domain	FieldName	Element Description	Example	Notes
GIS	PolygonNumber	When multiple polygons share the same SiteID delineate polygons by this incremental number. A default value of '1' is used when SiteID is unique.	1,2,3	This commonly occurs for shelter belts etc. which are the same activity but are mapped as different spatial entities (polygons).
	Perimeter	Perimeter of the polygon expressed in meters		Derived using a GIS
	Area	Area of the polygon expressed in meters		Derived using a GIS
	Hectares	Area of the polygon in hectares		Derived using a GIS
	ShapefileName	Name of ESRI Shapefile which stores the activity polygons	Nullamanna_Veg_Enhancement.shp	

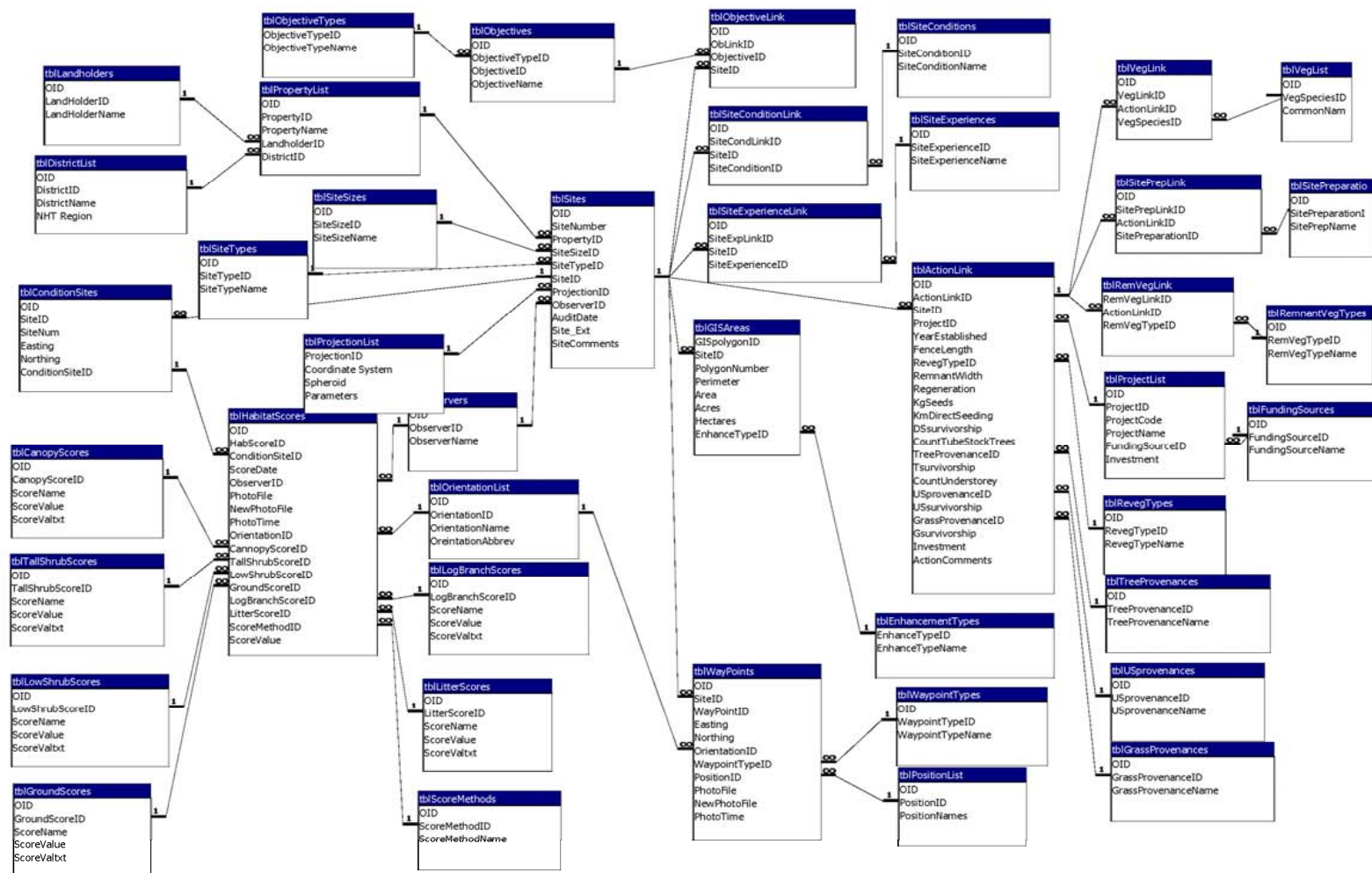
FieldAudit Tool

In addition to the development of BioAudit, the Biodiversity Benefits Project Phase 3 has developed a prototype data entry tool called *FieldAudit* which allows assessors to rapidly enter BioAudit data in the field using handheld computers (PDAs) linked to a wireless GPS receiver (Appendix Figure 4). This was developed in Visual CE software which can run on a PDA and allows assessors to rapidly collect vegetation enhancement data via a graphical user interface and structured forms which mirror those available in the PC version of BioAudit. Data from the PDA can be automatically synchronised with the *BioAudit* database removing the need for manual transcription of data. The system also has the capacity to connect to a wireless (Bluetooth) GPS unit to collect waypoint information in real-time during an assessment. Waypoints can identify the boundaries of an enhancement activity, the location of a photopoint or the location of a condition assessment site which can be visited over time. Alternatively an assessor could walk the perimeter of an activity and collect a series of waypoints which could be used to generate an activity polygon rather than using on-screen digitising methods.

The *FieldAudit* tool has been tested for four of the case studies and has introduced some important efficiencies to the project. In one of the case studies the unit was sent to the mapping team in Queensland to conduct their data entry and the resulting data files were returned via e-mail and synchronised with BioAudit. This represents an important outcome for the project as it means relatively affordable tools can be rapidly deployed from a central location to allow assessors to efficiently collect structured Biodiversity Benefits data. Synchronising FieldAudit data with BioAudit takes approximately one hour and it does require some specialist input. However, relative to manual or paper-based data entry and transcription, some efficiency improvements have been achieved.



Appendix Figure 4. BioAudit FieldAudit PDA field mapping system



Appendix Figure 5. BioAudit Microsoft Access 2003 Entity Relationship Diagram

Appendix C: Landscape Metrics for Assessing Biodiversity Benefits

Owing to the spatial nature of vegetation enhancement activities assessed in this project, a key challenge is to summarise the change which has occurred across a landscape and to assess whether we have seen an improvement or decline in some element of biodiversity. At the scale of the patch, the Biodiversity Benefits Framework recommends detailed monitoring programs targeted towards individual components of biodiversity (e.g. bird and invertebrate surveys, dieback assessments & botanical surveys etc) (Freudenberger and Harvey 2003). At the landscape and regional scale however, it logically argues that it would be easier, and hence more feasible to assess how the vegetation enhancement activity has benefited the structure of habitat, for example for local birds, rather than counting the birds themselves. A key method for assessing changes in structure at the landscape (i.e. sub-catchment) and regional (i.e. IBRA, NHT region, CMA) scale is to use *landscape metrics*. As the primary objective of this project is to develop methods for rapidly mapping vegetation enhancement activities across a landscape, the use of suitable landscape metrics is a core element of the research. This discussion examines the role of landscape metrics, it discusses their limitations and provides a taxonomy for their appropriate use for conducting a Biodiversity Benefits assessment. The findings from this discussion are then used to guide the application of specific landscape metrics to conduct a landscape scale assessment of biodiversity benefits for each of the case studies examined in this project. We apply a variety of metrics for the respective case studies to assess their utility, limitations and appropriateness.

Many metrics exist to quantify the spatial change which has occurred across a landscape (for a detailed synthesis of available methods see Goodwin 2003). Metrics can also be used in a planning environment to design landscapes which achieve a particular biodiversity outcome. In such work the metric is the primary indicator of 'success' (Botequilha and Ahern 2002). The recent availability of software tools such as Fragstats (McGarigal and Marks 1995) combined with the ready availability of GIS data has enabled the rapid use of a variety of metrics. Most methods assume that vegetation has been mapped as polygons similar to the approach used in this study, although point-pattern analysis can also be applied. Methods range from simple metrics which describe the change in area or perimeter post the landscape modification, to methods which require significant computational time or parameterisation such as the use of cost-distance surfaces and graph theory to assess the level of connectivity in a landscape. McGarigal and Marks (1995) make an important distinction between *patch*, *class* and *landscape* metrics in their implementation of FRAGSTATS. This study is only concerned with landscape scale analysis and reporting and hence the taxonomy developed below focuses on this scale alone. Although this apparently reduces the number of metrics available, McGarigal and Marks (1995) note that the number of metrics which are useful is significantly less than those listed in FRAGSTATS as the higher level metrics (landscape and class metrics) are derived from patch-scale metrics and are hence highly correlated.

For the purposes of this study a simple typology has been developed to examine the range of metrics which can be applied to study the change in landscapes from on-ground vegetation enhancement activities. Appendix Table 14 provides a more detailed taxonomy of these methods by breaking these down into specific methods. This refers to the unique application of the general method using different analytical techniques, and requiring different spatial and attribute data to conduct an analysis. The following broad groupings are used in the taxonomy:

- Character – These are the simplest measures to apply and simply summarise the total representativeness of a particular patch, or group of patches in a landscape. These methods do not account for relationships between patches and other patches;
- Pattern – These measures examine the spatial arrangement in a landscape and may report on elements such as connectivity and clustering; and
- Spatial relationships – These measures extend the use of pattern metrics one order by also accounting for the 'value' observed at a location. Typical methods including kriging, spatial autocorrelation analysis and measures of dispersion of particular variables.

Appendix Table 14. A taxonomy of landscape metric analyses

General Grouping	Specific Grouping	Specific Method	References
Landscape Patch Character (composition)		Total area & perimeter changes, edge-area ratios, complementarity, patch exposure, patch length, patch size distribution, total habitat edge, mean shape index.	Gustafson & Parker (1992) McGarigal and Marks (1995), Tischendorf (2001), Lee and Thompson (2005), Manson <i>et al.</i> (2003), Watson <i>et al.</i> (2005), Heikkinen <i>et al.</i> (2004), Botequilha Leitão, A. and J. Ahern (2002), Radford <i>et al.</i> 2005.
Pattern	Matrix based (*non binary landscapes)	Requires definition of habitat quality, species range, and threshold inter-patch distances. Cost-distance surfaces.	Theobald (2002), Chardon <i>et al.</i> (2003)
	Cell immigration methods (*non binary landscapes)	Accounts for <i>inter</i> and <i>intra</i> patch species immigration (dispersal success, search time and cell immigration)	Tischendorf & Fahrig (2000), Moilanen and Hanski (2001), Goodwin and Fahrig (2002)
	Euclidean distance (*binary landscapes)	Nearest neighbour index , k-nearest neighbour index, Voronoi polygons , proximity index, habitat buffers, distance to core areas, graph theory (alpha indexes of connectivity)	Bender <i>et al.</i> (2003), Chardon <i>et al.</i> (2003), Lee and Thompson (2005), Apan <i>et al.</i> (2002), Lausch, A., and Herzog, F. (2002).
	Euclidean distance (*non-binary landscapes)	Functional nearest neighbour index	
	Area based proximity methods	Habitat buffers, area weighted nearest neighbour analysis, total edge.	Bender <i>et al.</i> (2003)
	Graph theory methods	Gamma index, alpha index	Petit and Burel (1998), Bunn <i>et al.</i> (2000), Cook (2002).
Relationship		Dispersion (are like patches clustered),), Cluster detection (e.g. spatial autocorrelation)	McGarigal and Marks (1995), Heikkinen <i>et al.</i> 2004.

* Binary landscapes are those where features are represented in terms of their presence or absence. For instance a layer showing the presence or absence of woody vegetation is one such example. Non-binary landscapes are where categorical or continuous representations are used, for instance in the case of vegetation community maps or digital elevation data.

A vigorous debate has centred on the merits of using landscape metrics and drawing unfounded ecological inferences from the data they generate (see Moilanen and Hanski, 2001 and Tischendorf and Fahrig, 2001). Theobald (2002) argues for more of an 'organism-centric' approach for defining landscape connectivity rather than a purely structural approach to analysis. As such, an important distinction needs to be made between 'functional' and 'structural' applications of landscape metrics. Chardon (2003) define structural metrics as methods for assessing connectivity 'irrespective of a species' movement behaviour in the landscape while functional connectivity explicitly takes movement behaviour into account' (Tischendorf and Fahrig 2000, in Chardon *et al.* 2003). McGarigal and Marks (1995) have similarly argued that *Structural Metrics* 'can be defined as those that measure the physical composition or configuration of the patch mosaic without explicit reference to ecological processes. The functional relevance of the computed value is left for interpretation during a subsequent step'. Typical techniques which account for functional responses include cost-distance

methods, functional nearest neighbour analysis and edge-exposure methods, and graph theory methods.

A suite of studies have attempted to examine functional responses using empirical data in regard to landscape change and hence landscape metrics. A major limitation of some of these is their reliance on simulated data designed to test the sensitivity of the metric rather than the applicability of the metric (e.g. Cook, 2002, Li et al. 2005). However, there are a number of studies which have examined landscape metrics from a functional perspective, primarily for faunal species. These include metrics for mink (Bunn et al. 2000), lynx (Theobald 2002), birds (Cushman and McGarigal 2003, Radford et al. 2005, Watson et al. 2005), seagrass (Sleeman et al. 2005) and small mammals (Bennett 1990) to name only a few examples.

This is an important distinction for this project given the general unavailability of conceptual or empirical models of species specific habitat preference data and other species dispersal parameters. Indeed Bender et al. (2003), in reference to isolation metrics, noted that 'it is actually quite difficult to evaluate patch isolation metrics empirically because there is an incredible paucity of movement data available in the literature'. Functional approaches are certainly appealing, if not preferable, if vegetation enhancement activities target an individual species, however from the case study assessments, this is rarely the case and most objectives are elucidated at only a general level. Consequently the use of landscape metrics will be applied initially at a structural level, unless case study specific data allows for a functional analysis.

The suitability of each landscape metric method may also need to be assessed with regard to the primary objective of the vegetation enhancement activity. For instance, when assessing a landscape where the primary vegetation enhancement activity has been for salt abatement, there may be little merit in using a technique which assesses landscape connectivity or isolation. The objective in this case is aspatial risk mitigation while the metric focuses on spatially explicit connectivity objectives. Although an activity may have a primary objective which is unrelated directly to spatial objective, there may indeed be some secondary spatially explicit biodiversity benefit (e.g. less fragmentation or a greater representativeness of a particular threatened ecological community). Ideally a metric needs to be selected on the basis of enhancement objectives, available spatial data to support an analysis and on the existence of a conceptual model relating the metric with some specific element of biodiversity (e.g. fragmentation of native vegetation and the abundance of woodland birds). In this study we argue that although the primary objective of an activity may be non-biodiversity related, there are nonetheless biodiversity benefits which emerge. Further, after a detailed examination of stakeholder responses for all case studies, most vegetation enhancement activities have multiple objectives which almost always include biodiversity. For instance, almost all salinity related projects had some biodiversity objective defined.

Limitations of Applying Landscape Metrics

The use of landscape metrics such as isolation and connectivity indices is a controversial science. As discussed above, debate focuses on whether metrics have ecological significance. However, we have argued that although the question of ecological significance is indeed valid (Bender et al. 2003), at the least the metrics are a useful summary of structural change rather than functional change and hence they are a useful tool. In addition to the conceptual or theoretical issues associated with these measures, there are some technical issues which warrant further attention. These limitations include the following:

- They are scale dependent. For instance, landscape metrics calculated at the sub-catchment scale can vary greatly from those calculated at the scale of the group (e.g. study site or Landcare group). Applying metrics which are stable to scale is problematic and hence we recommend metrics be used to assess intra-study site change. For example, when using the nearest neighbour statistic through time it is essential that the study area boundary remains constant. These limitations are known as scale and zonation effects (Langford and Unwin 1994);
- They are dependent on the quality and availability of the input GIS used in an assessment. The scale and accuracy of existing vegetation mapping in the study area can significantly affect the result which is generated. For instance, 1:100K vegetation mapping will generate different mean nearest neighbour values from those derived using 1:25K mapping. Consequently the key concern for managers is in understanding these limitations and ensuring that any temporal monitoring is using identical input databases. Later sections of this report examine the problems of vegetation mapping accuracy in further detail;

- Some of the indices are sensitive to outliers. For example, one relatively small vegetation enhancement activity placed far from all other activities in a study area can result in an increase in the overall nearest neighbour distance, even if many new plantings have occurred in an already densely vegetated area. This results in a net decrease in connectivity as expressed statistically. Hence the issue here is one of interpretation. A net decrease in the mean nearest neighbour index may simply indicate that distal plantings have occurred, rather than that connectivity has decreased. As such it may be appropriate to look further into the data, or ensure that additional statistics such as standard deviations are provided to aid an interpretation;
- Indices generally treat landscapes as binary phenomenon and do not account for the continuous nature of 'habitat'. For instance, vegetation is either present or absent as defined in mapping protocols when in fact habitat may be continuous, but of varying 'suitability' to a particular species. A related limitation is that the metrics often assume Euclidean and linear relationships between parameters and this may not be appropriate; and
- There are analytical limitations with some of the metrics. Namely, the mean nearest neighbour index uses the polygon centroid to calculate its proximity to other polygons. This may be appropriate when vegetation enhancement activities are relatively small, but can generate misleading results in the case of large activities (Theobald 2003). In such situations it may be more appropriate to use a 'habitat-buffers' algorithm which analytically incorporates the polygon boundary into its calculations.

Modified Habitat Buffers Algorithm

As discussed earlier, there are limitations associated with the use of the mean nearest neighbour index and some of the other methods described in Appendix Table 14 have similar limitations. For example, the Voronoi polygon method also relies on polygon centroids to calculate distances (problematic for larger polygons) and is also sensitive to outliers. Many of the other methods require a detailed understanding of functional relationships between biodiversity and landscape structure and are therefore prohibitively complex to be applied across multiple case studies. To overcome these limitations a new approach has been developed for communicating analytically the change which has occurred in a landscape. The method is called the Modified Habitat Buffers Approach which produces a histogram showing the change which has occurred across a landscape at different distance classes. It contains the major properties of the other methods, while overcoming many of their scale and zonation limitations.

This section describes the development of the Modified Habitat Buffers Algorithm for summarising structural change from on ground vegetation enhancement activities. The algorithm calculates the change in vegetation area which is observed in increasing larger distance classes and represents this change as a bar plot. Appendix Figure 7 schematically shows how increasing buffer distances are used to calculate the total amount of vegetation in a buffer region. The final bar plot (Appendix Figure 6) provides an effective representation of the magnitude of vegetation enhancement activities and their relative location relative to other patches in the landscape. The ability to summarise relative change is important as it overcomes some of the zonation limitations inherent in the other algorithms. Where buffer increments are the same, study sites can be easily compared. The approach combines a number of properties of the other metrics discussed earlier in addition to overcoming some of their limitations. This includes the following:

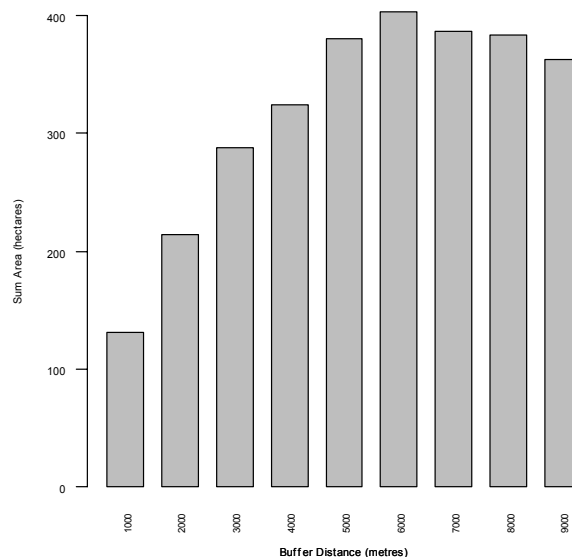
- It calculates the amount of vegetation surrounding a patch from the patch edge rather than a centroid hence overcoming the problem with large patches;
- It summarises the change which occurs at different distance classes by using incrementally larger buffer zones. As such it tells us at which average inter-patch distance the greatest amount of vegetation change has occurred. This is important if we are attempting to achieve connectivity, or enhance vegetation proximal to other vegetation;
- It accounts for the area of the new vegetation enhancement activities rather than simply whether the patch is present or absent; and
- It is robust to outliers as it calculates the amount of vegetation at various distance classes rather than only calculating the mean of all distances;
- It calculates the amount of vegetation which is found in incrementally larger buffer zones.

The algorithm has been developed in the Python language utilising ArcGIS geoprocessing functions (ArcGIS 9.1) and R-Package for plotting results. It combines both vector and grid algorithms to calculate the amount of vegetation in each buffer zone. As an input the algorithm requires two GIS

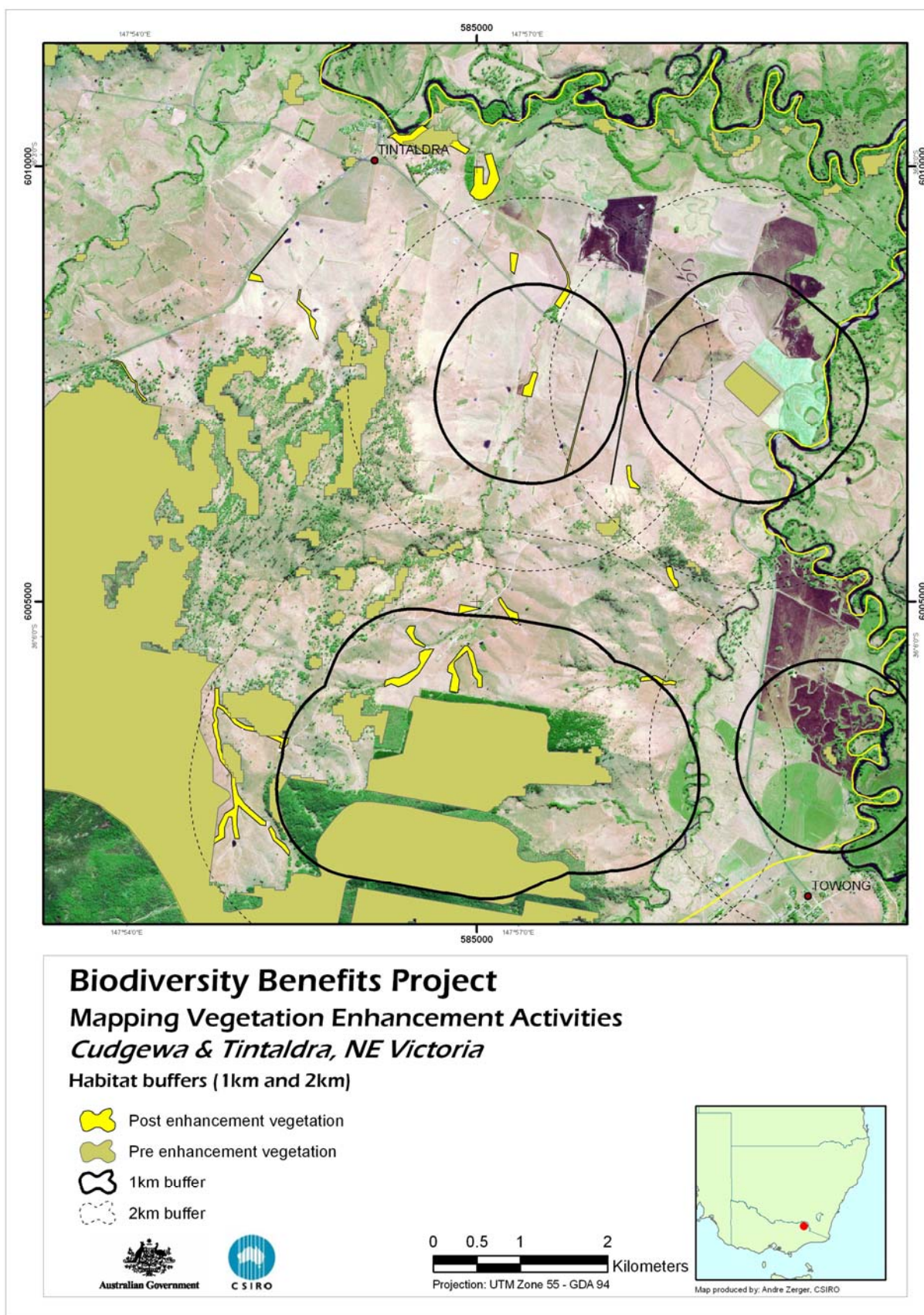
datasets. The first is a layer showing vegetation polygons prior to vegetation enhancement activities and the second is a layer showing vegetation polygons post the vegetation enhancement activity. Although when implemented in the Python programming language the algorithm is quite complex, it can be described conceptually by the following broad steps:

- The user selects analysis buffer distances and increments (e.g. 1km to 10km in 1km increments). This may vary depending on the dimensions of the study area. For computational efficiency a larger increment and higher maximum distance may be required;
- The algorithm calculates for each vegetation polygon the amount of vegetation found within one buffer increment for both the pre-enhancement and post-enhancement GIS data;
- For each buffer distance, it sums the total amount of vegetation found in this region;
- Subtract the amount found in each buffer distance for the pre-enhancement activities from the post-enhancement activities; and
- Plot the differences as bar plots where the x-axis shows buffer distances and the y-axis contains the amount of change in vegetation which has occurred for each buffer distance.

It is important to note that the area of vegetation shown along the y-axis is not the total amount of vegetation added into the landscape, but the total amount of vegetation found within another patch of vegetation in a landscape. Hence the value is higher than the actual amount of vegetation added. Appendix Figure 6 shows a hypothetical bar plot showing in which distance class the greatest amount of on ground vegetation enhancement activities have occurred (within 5 to 6 km of all vegetation).



Appendix Figure 6. Example habitat buffers algorithm output showing amount of vegetation found in each distance class after on-ground vegetation enhancement activities for a hypothetical dataset.



Appendix Figure 7. Cudgewa and Tintaldra – map shows 1km and 2km buffer zones for selected vegetation polygons.

Landscape Metrics for Assessing Biodiversity Benefits

The primary suite of landscape metrics used in this study is the landscape patch character (composition) measures listed in Appendix Table 14. These include measures such as total increases in patch area and perimeter and patch size distributions before and after vegetation enhancement activities. Second, for some of the case studies pattern metrics have been used through the calculation of nearest neighbour distances and indexes to examine whether the addition of vegetation enhancement activities such as revegetation has improved the landscape-scale connectivity in these study areas. The average nearest neighbour distance calculates the distance between each activity and its nearest neighbour and calculates the mean of these for the entire landscape (between polygon centroids only). The nearest neighbour index calculates the ratio between the observed distance divided by the expected distance. The expected distance is calculated for a theoretical 'most-dispersed' arrangement of patches within a set boundary and consequently it does not take into account the practical limitations of on-ground vegetation enhancement activities. If the index is less than one, we assume that the pattern is clustered and if the index is greater than one, the trend is one of dispersion. The index is best applied when the study area is fixed and can be used to assess the temporal change in clustering and connectivity by calculating it separately for a number of epochs. Distance-based measures such as the nearest neighbour index are not suited to all study sites and have only been used where appropriate (Nullamanna, Cudgewa and Tintaldra, Kangaroo Island & Avon). Where appropriate the modified habitat buffers approach documented above has also been applied.

Appendix D: Mapping of Existing Vegetation – Issues and Improvements

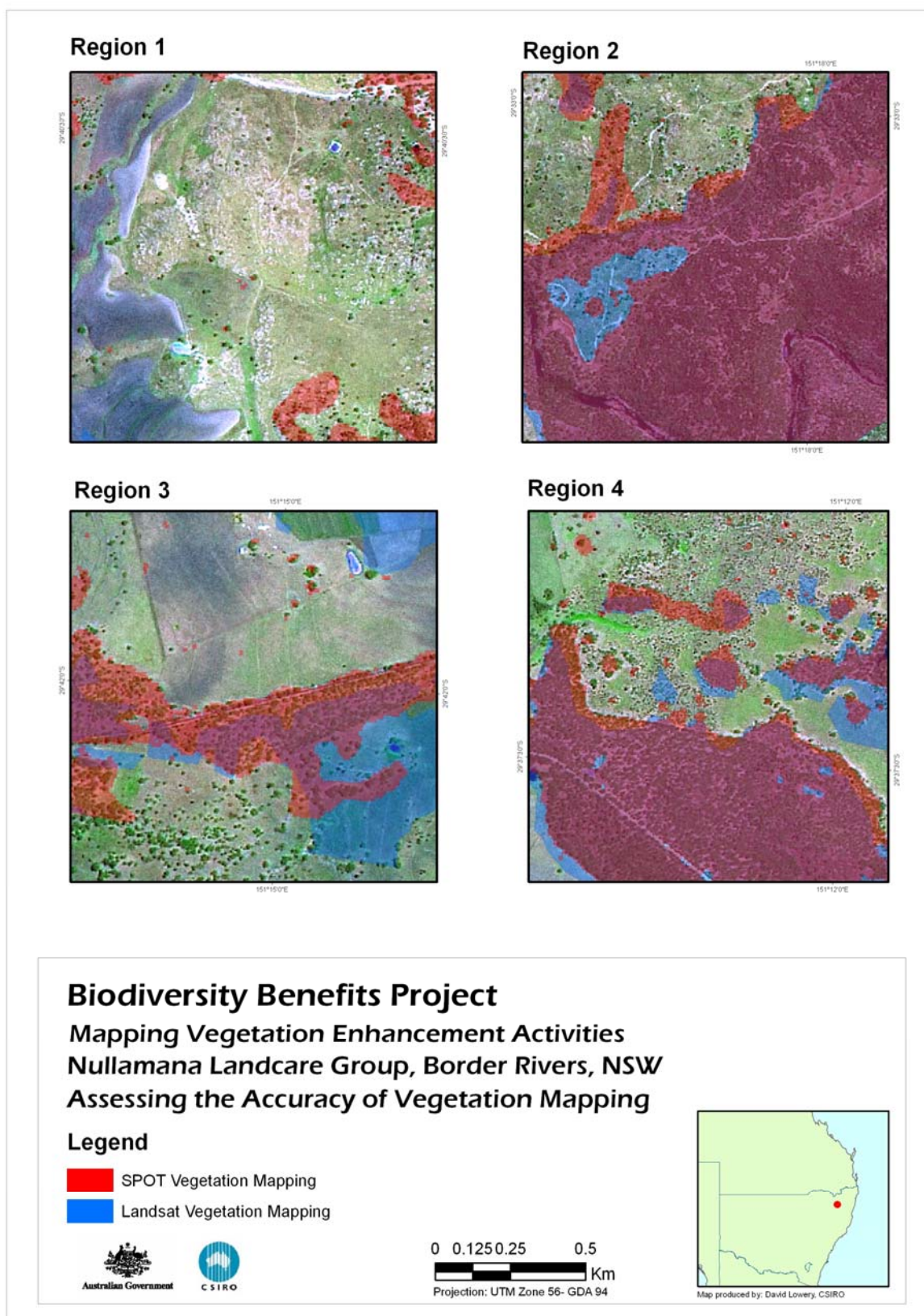
Developing An Improved Vegetation Extent Map

The existing vegetation mapping for the Nullamanna region was produced using classified Landsat 5 imagery and soils information (Steenbeeke 2001). Initial visual assessment of this product indicated that significant areas of woody vegetation had been missed and that differentiation between woody and non woody vegetation was poor in some areas. The likelihood of errors in the calculation of patch metrics calculated using this data necessitated the creation of a new vegetation cover dataset. To overcome the spatial limitations of this data, a geo-referenced SPOT5 multi-spectral and panchromatic image acquired over the study area on 15 November 2004 was obtained from NSW DIPNR. The spatial resolution of this multi-spectral data are 10 metres compared to the Landsat resolution of 30 metres, allowing the crowns of individual large trees to be distinguished. While Landsat has more bands, particularly in the thermal and shortwave infrared, the increased spatial resolution of the spot vegetation sensor should more than compensate for the lacking bands when vegetation classifications are undertaken.

The method used to create the new vegetation layer combined a supervised classification of SPOT5 Xi multi-spectral data, with head up interpretation and raster processing using SPOT5 pan-chromatic imagery. Unsupervised and supervised classifications were undertaken using ENVI 4.1 while ArcGIS 9.0 and ArcScan were used for error and noise removal. An initial unsupervised K-means classifications indicated that bare soil and water was a significant component of the image. These areas could easily be identified on examination of a spectral plot and were removed from the image using an NDVI mask. The NDVI, or Normalised Vegetation Difference Index, is the ratio of near infrared to red fraction in the radiated or reflected spectrum. Positive values indicate vegetation while negative values indicate water. Values of zero indicate bare dry soil such that areas with an NDVI equal to or less than zero must be bare soil or water that can be removed from the analysis. These features include paved and gravel roads, rivers, lakes, reservoirs, farm dams and ploughed fields and paddocks. NDVI masks can also be used to identify roads and tracks, either by themselves, or in combination with directional filters that identify linear features.

Regions of interest for four classes were created by determining spectral end-members, viewing these regions using different band combinations and growing them to encompass other similar points. Land cover in the image area consists of scattered woodland, forest, cropping, and grazing. A single class was created for woody vegetation, using homogenous areas of forest, where only canopy was visible, as seeds. The other land cover types fell into the remaining classes, which could best be described as vigorous non woody vegetation corresponding to rapidly growing crops and improved pasture, senescent non woody vegetation, and post senescent non woody vegetation. Separability for each region of interest was calculated after the addition of each polygon to ensure classes did not overlap and were adequately separated. A maximum likelihood classification with an error threshold of 0.05, was used to produce five classes, the four above and one class for areas not classified, before being reduced to three, woody, non-woody and not classified, and finally to two which included woody and non-woody vegetation. This binary classification was exported to ArcMap for further classification error correction and noise removal.

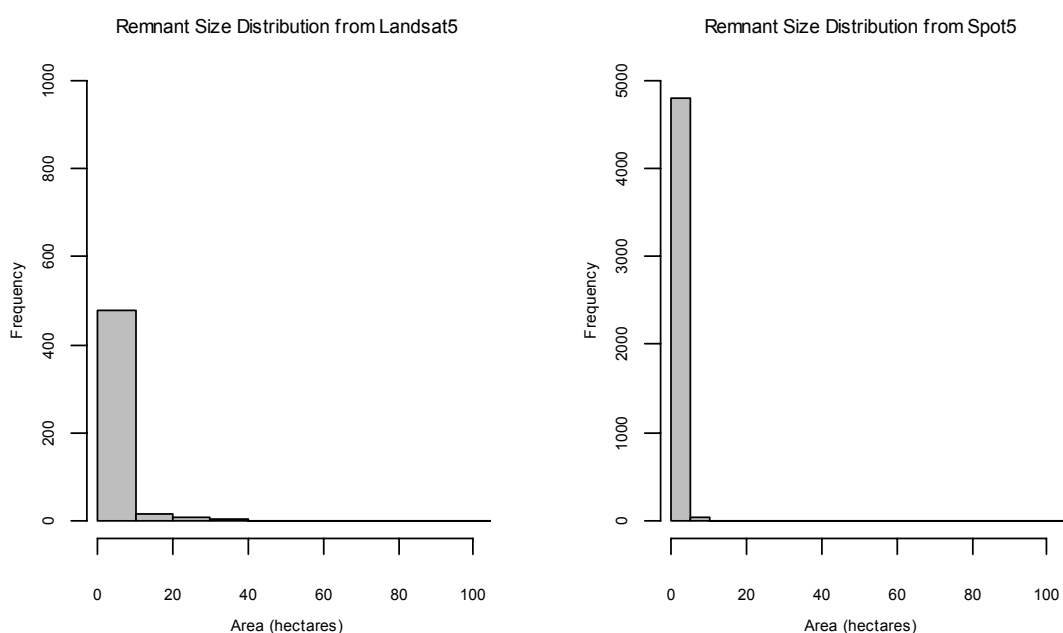
Owing to seasonality effects, the SPOT5 classification misclassified areas of cropping or improved pasture as woody vegetation. It is worth noting here that this problem still occurred after changing the classification method, regions of interest and error thresholds and that the pre-existing vegetation data also suffered from this error. These gross errors were manually removed using the raster painting tool in ArcScan. The binary classification was draped over the panchromatic and pan sharpened colour composite spot images and areas that were undoubtedly not trees were classed as non-woody vegetation. Over the relatively small study area, this time consuming process yielded reasonable results. Over larger areas, where the time required and the probability of mistakes occurring increases, manual editing is likely to be an unsuitable method for limiting these classification errors. In these cases the use of multi-temporal imagery should be considered. Using a selection of images, taken at different times of the year and subsequent years, provides additional information on seasonal changes in the spectra of a cover type to be included in the classification. Of course using multiple images will increase the project cost so that the lower spatial resolution, but greater extent, Landsat images, become more attractive.



Appendix Figure 8. Location of four validation regions across the Nullamanna study area showing SPOT5 woody vegetation mapping and Landsat 5 woody vegetation mapping.

Appendix Table 15. Confusion matrix for Nullamanna vegetation mapping accuracy assessment showing four validation regions. Values show the area (square metres) of agreement and disagreement.

		Landsat Mapping		SPOT5 mapping	
Region 1	Predicted +	Actual +	Actual -	Actual +	Actual -
	Predicted -	0	0	0.728	1.51
Region 2	Predicted +	2.56	97.43	1.83	95.91
	Predicted -	61.71	14.72	64.19	12.06
Region 3	Predicted +	5.05	18.51	2.38	21.34
	Predicted -	8.81	15.75	19.19	4.89
Region 4	Predicted +	16.58	58.85	6.25	69.65
	Predicted -	44.27	2.67	48.92	1.02
	Predicted +	26.60	26.45	21.95	28.10
	Predicted -				



Appendix Figure 9. Remnant patch area histograms for Landsat 5 mapping and SPOT5 mapping of woody vegetation across the Nullamanna Landcare Group.

Appendix Table 16. Nullamanna case study: Nearest neighbour indexes for vegetation enhancement activities based on two scales of vegetation mapping (SPOT5 and Landsat 5).

Vegetation Enhancement Activity	Mean Nearest Neighbour Distance (metres)	Mean Nearest Neighbour Index
Landsat 5 based mapping	255.00	0.56
SPOT5 based mapping	67.23	0.45

Noise in the remnants and along remnant edges was reduced while keeping small patches and individual paddock trees using an adaptive modal filtering algorithm. The focal majority function in ArcGIS, which assigns the modal value of a neighbourhood to a central cell, was applied to all patches greater than 500m². In order to achieve this, patches smaller than 500m² were selected and set aside before the focal majority function was applied in a five by five cell rectangular window. The patches which had been set aside here then added to the filtered product before it was converted to a final vector layer showing woody vegetation across the study area. But how accurate is this map relative to the smaller scale mapping (Landsat 5) described earlier? The following discussions highlights the importance of conducting a rigorous accuracy assessment examine the relative merits of various vegetation map products.

Assessing Mapping Accuracy

In order to compare various mapping scales, it was necessary to create an estimate of the truth which is acquired independent of the SPOT5 or the Landsat 5 imagery. To create an estimate of the truth, expert interpretation of SPOT5 imagery was used with on-screen digitising to identify the presence or absence of woody vegetation at random sites. Four 1 km² test areas were selected within the study area to conduct the mapping. Four sites were selected to ensure that a variety of vegetation densities were represented in the validation as the use of one site may not be representative of the broader classification accuracies (e.g. from sparse woodlands to densely vegetation reserves). To achieve this vegetation percentage cover layer was developed and this was divided into four zones representing a transition from extensive vegetation cover to fragmented regions. A random point was placed in each zone and this formed the lower left corner of the test area. Appendix Figure 8 shows the location of the test areas across the study area with percentage vegetation cover progressively increasing as we move from region one to region four. To ensure consistency of mapping, remnants/patches greater than 10 metres in area where mapped as this was the twice the spatial resolution of the input imagery. Mapping was conducted at a scale of 1:10,000.

Using a GIS overlay (union function) provided and area estimate of each of the errors (omission and commission errors). The methodology can also be implemented using point observations rather than areas, however a problem with this is that areas of sparse vegetation are unlikely to be selected unless a sensible stratification is used and hence the assessment is biased towards assessing larger patches of vegetation. For this reason an areal method of assessing accuracy has been implemented. The possible classification errors for both the SPOT5 and Landsat 5 imagery include the following categories:

- Area predicted to be woody vegetation and were classified as this by the expert (Predicted+ and Actual+);
- Area predicted to be woody vegetation but were not classified as this by the expert (Predicted+ and Actual-);
- Area predicted to be non-woody vegetation and were classified as this by the expert (Predicted- and Actual-); and
- Area predicted to be non-woody vegetation and were not classified as this by the expert (Predicted- and Actual+).

Results and Discussion

As can be seen from Appendix Figure 8, Landsat mapping significantly under predicts in areas of low vegetation cover by ignoring most of the smaller remnants. Similarly, it has a tendency to over predict in more densely vegetated areas. SPOT5 mapping has more predictive power in scattered woodlands, and provides a much better delineation of remnant boundaries. The region of greatest concern in the study is region three which shows the highest differential between predicted vegetation and actual for both maps (8.8 and 19.2 square metres for Landsat and SPOT5 respectively). Across the entire study area the SPOT5 vegetation map identifies 5300 hectares of the study region as woody vegetation. In

contrast, the Landsat 5 mapping identifies 4556 hectares of the study area as woody vegetation. This equates to a 16% under prediction in woody vegetation cover across this study area. However, being global estimates, these statistics do not adequately highlight the problem of scale as errors of commission are partially compensated for by errors of omission in the Landsat mapping. Consequently, in some regions of the study area the under-prediction is likely to be much greater (e.g. region three). Although global over predictions are informative, of particular interest is the information contained in Appendix Figure 9 which provides a patch area histogram for both map products. The figure highlights the inability of Landsat 5 imagery to adequately identify remnants smaller than 20 hectares in size (approximately 450 remnants mapped compared to 4500 for the SPOT5 mapping) and supports the findings provided in Appendix Table 15. The impact of mapping scale and accuracy is also highlighted in Appendix Table 16 which highlights the difference in mean nearest neighbour distances and indexes which occur. Although this also highlights the limitation of the mean nearest neighbour index in that the index does not account for patch size. Further, it shows that scale and accuracy in vegetation mapping must be assessed, communicated and often kept constant between analyses to enable comparability of results.

What are the implications of these findings for the type of analyses conducted in the Biodiversity Benefits Project Phase 3? First, it is important to recognise that the findings are not a criticism of the Landsat 5 mapping, but rather they are an attempt to quantify its limitations given it was designed for a particular scale of assessment. For instance, Landsat mapping is generally regional scale mapping designed to map large areas using fully automated digital image processing techniques. On the other hand, SPOT5 mapping is local scale mapping that in this instance has been produced using standard image classification tools, and extensive human intervention. Bearing this in mind, the argument is that quantitative vegetation map accuracy information is required to contextualise the results of a Biodiversity Benefits assessment. For instance, studies commonly report on the total amount of vegetation in a landscape yet these figures will vary depending on the source of mapping (16 % global discrepancy in Nullamanna). Further, this study also reports on the total amount of vegetation protected by funded fencing, or compares these results across study sites which have inherently different scale vegetation mapping available. And of additional concern is the use of landscape metrics such as nearest neighbour measures which can generate different results depending on the input vegetation

Vegetation enhancement activities are commonly guided by regional targets which are inherently spatial. For example, typical targets in south eastern Australia will range from about 10% to 25% vegetation cover across a catchment management area. However, bearing in mind the Nullamanna case study which identified a 16% variance in estimated vegetation cover, which data do we use to set targets and monitor progress to targets? In such instances the mapping error is almost the same as the upper limit of the revegetation target. Similar issues could be expected in other landscapes as regional scale vegetation mapping is commonly used to support NRM planning. Consequently, the scale and accuracy of the vegetation mapping may mean that targets are already achieved, or almost impossible to achieve within the intended timelines. In this study, it is argued that it is critical that NRM agencies articulate their targets relative to a particular mapping scale and accuracy. Without this caveat, the vegetation targets are less than useful. The accuracy assessment conducted above leads to the following conclusions:

- NRM agencies that utilise vegetation mapping to support their NRM planning must be provided accuracy information to evaluate the suitability of a particular mapping product. Accuracies can be reported using the methods described above and should be conducted over a number of test areas to ensure that both high density and sparsely vegetated regions are assessed as results will differ between regions;
- In cases where NRM agencies are developing new extent vegetation maps, accuracy thresholds should be included in the product specifications. For example, it is possible to set error thresholds quantitatively as shown in the confusion matrix in Appendix Table 15. For example, a map specification may state that map producers need to attain greater than 85% prediction accuracy and a greater than 75 % false negative rate for all patches greater than 20 ha in size. This way future map products can be specified to achieve equal or improved accuracies and hence the error can be built into an analytical assessment of progress towards targets; and
- It is not valid to compare increases in native vegetation cover between study areas from on-ground vegetation enhancement activities if they are reported in terms of an increase relative to extant mapping when scale or accuracy information is not provided. This is particularly significant as NHT-type revegetation activities can contribute less than a 1% increase in native vegetation cover to a region and this is well below the accuracies identified. If comparisons

need to be made then map accuracies and scales need to be reported, or new maps generated at a comparable scale and accuracy;

Although this component of the study is an aside to the broader task of developing methodologies and collecting data to inform the Biodiversity Benefits Framework, it is a core issue facing most agencies given the critical role of vegetation mapping to support natural resource management targets. When applying the Biodiversity Benefits Framework at the landscape scale it is second only to the on-ground vegetation activity data in its importance. The issue of map accuracy and scale can be readily addressed if accuracy assessments are conducted. These are not onerous and can be conducted for a large number of regions ($< 10\ 1\text{km}^2$ regions) in less than a day. For limited effort such information is critical to the way analyses and reporting on progress towards regional conservation targets is conducted.

Appendix E: Defining landform position of on-ground activities

Landform data provides managers an alternate way to examine the distribution of enhancement activities and to plan future activities. For instance, it can determine whether the distribution of activities favours agriculturally unproductive land such as hilltops and ridges or whether fertile flat landscapes or riparian zones have received adequate attention. Take as an example the Cudgewa study site, where most of the clearing has taken place low in the catchment. If the purpose of vegetation enhancement is to protect or increase the area of poorly represented communities, then one could expect enhancement activities to take place in areas classified as foot slopes, valley flats and riparian gullies. If however, the intended purpose was controlling groundwater recharge, most of the enhancement activities should take place higher in the catchment, on ridges and upper slopes. Landform can also provide a clue as to what soils and vegetation to expect. On ridges and upper slopes, soil profiles are generally shallower, stonier and drier than those on flats and lower slopes. Plants that grow in these areas are often better suited to these conditions than those which grow on deeper, more fertile soils of floodplains. Landform data can also provide an indication of where certain landscape processes, such as erosion and deposition, are likely to occur.

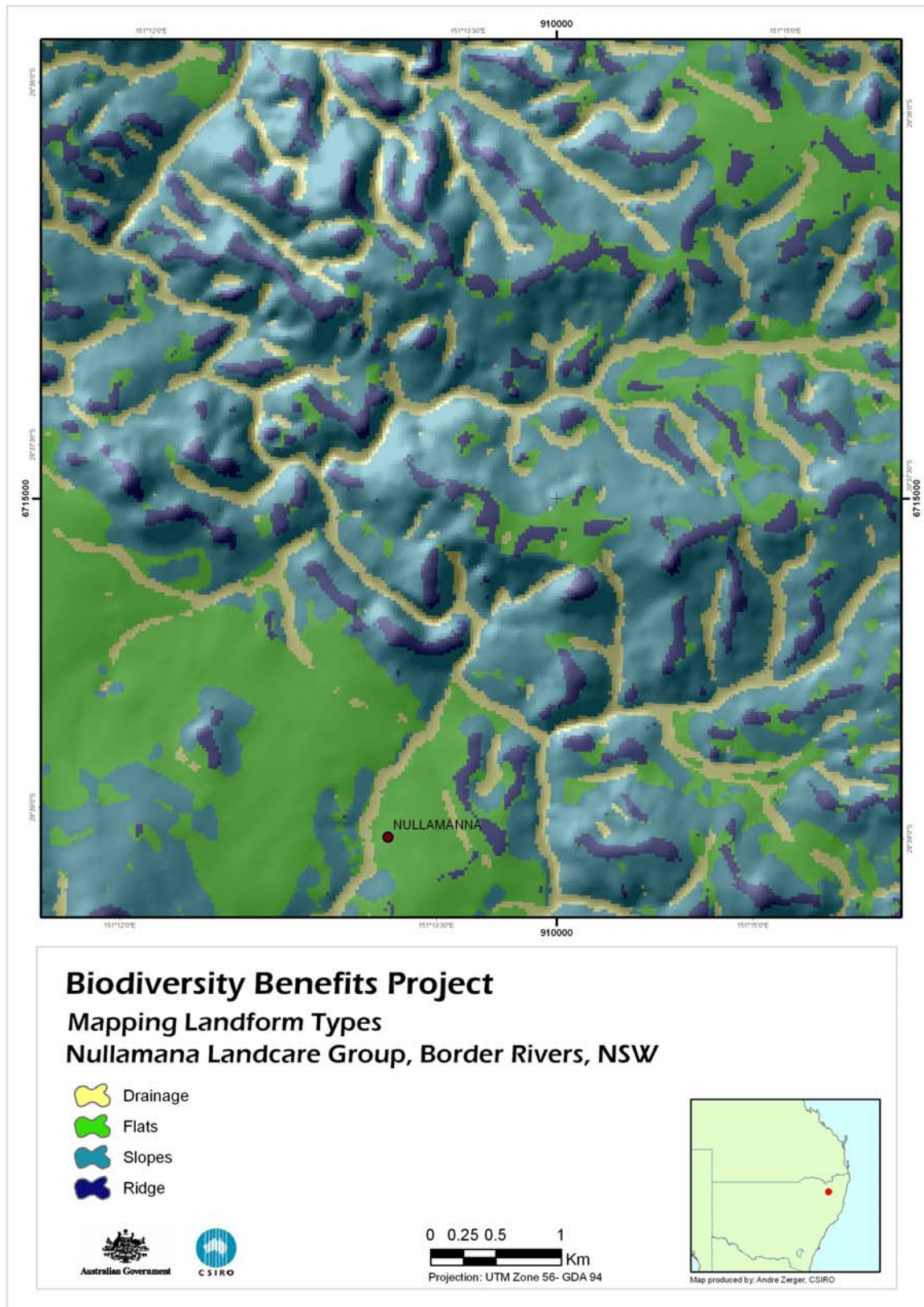
Site landform can be characterised in the field using simple rules, however this introduces potential inconsistencies between study sites and assessors. Further, it tells us nothing about the broader landforms in the study area which if available could be used for planning and assessing site context. Consequently an automated GIS-based landform technique for defining landforms has been applied to three of the case studies. These study sites were selected as enhancement activities had taken place over more than one landform and no existing landform layers were available. For Peterson Creek, all the enhancements took place along a small section of creek line, located in an open gully. For Gascoyne-Murchison, integrated rangelands and landform mapping has already been undertaken, while in Avon, topographic variation is low, such that a landform classification may not yield any useful information. By contrast with these three sites, localised topographic variation is high for Kangaroo Island, Cudgewa and Nullamanna.

A key requirement for generating accurate landform layers are accurate digital elevation models. AUNDEM 4.6.2 was used to generate new digital elevation models for three of the study sites as the available DEMs were found to be un-reliable in their ability to delineate landforms. ANUDEM can generate a gridded digital elevation model from a variety of data sources including contour lines and point elevation data. By imposing drainage enforcement conditions, whereby each cell in an input streamline dataset is lower than those upstream of it, the ANUDEM algorithm is able to remove spurious sinks and pits. This overcomes one of the main weaknesses of other interpolation algorithms that can have streams flowing uphill. For the Kangaroo Island study site, ten metre contours were generated from the existing triangulated irregular network (TIN) using 3D analyst (3D Analyst 9.0, ESRI) before the DEM was generated. For the Nullamanna and Cudgewa Study sites, 10m contours and a drainage layer were available while spot heights were also available for the Cudgewa study. These additional datasets enabled a high quality DEM to be produced using the drainage enforcement option in ANUDEM. The DEMs for Cudgewa and Nullamanna were then clipped to the extent of contour data before a landform layer was developed.

For the sake of simplicity and consistency across study sites landform was represented with a maximum of four classes: (1) ridges, (2) slopes, (3) flats; and (4) drainage. Landscape position was calculated from input DEMs using the elevation percentile algorithm described by Gallant (in Wilson and Gallant 2000). Areas high in the landscape, as determined from the algorithm, were classified as ridges. These included hilltops, peaks, and ridges. The algorithm also enabled identification of drainage features or gullies, which were low in the landscape. The remaining area was classified either as a flat, if the slope was less than 2 degrees, or as slopes. While these classes may not be able to differentiate between stream lines and dry gullies, or between steep and gentle slopes, or between isolated hilltops and ridgelines, they can be easily and repeatedly classified using slope and the elevation percentile algorithm and are able to capture most of the variation in landscape types and processes.

The landform layers were produced using an Arc Macro Language script implemented in ArcInfo Workstation. The first stage in the landform classification was to identify ridges and gullies. This was done using the elevation percentile algorithm. For each study site, the minimum elevation percentile for ridges and maximum elevation percentile for gullies were chosen after visual interpretation of the elevation percentile layer draped over the hill shaded DEM. Cells greater than the minimum percentile for ridges, and cells less than the maximum percentile for gullies were classified as ridges and gullies and output to a raster layer. In the second stage, cells with a slope less than 2 degrees were classified as flats, and all other cells were classified as slopes and output to a second grid. In the final stage, these grids were added and reclassified such that areas classified as gullies and ridges remained as

ridges, while those areas not previously classified as a gully or a ridge were classified as a flat or slope. For each vegetation enhancement activity, frequency histogram was generated showing the distribution of landforms for each case study. An example landform classification developed using these methods is shown in Appendix Figure 10.



Appendix Figure 10 Example GIS-based landform classification for Nullamanna Landcare Group

Appendix F: Vegetation Condition Assessment for Wet Tropics Case Study

Site: 1 **Monitoring plot no.:** 1 of 9
Age of revegetation: 8 yrs **Assessed by:** AFCBSB **Date:** 10.05.2006

Description of monitoring plot: Mostly flat levee area above creek, some impeded drainage areas, basaltic soil with some alluvial influence (fine organics and silt).

Canopy cover (5 m diameter above point) and ground cover (1 x 1 m quadrat at point)

Attribute	10 m	20 m	30 m	40 m	50 m
Canopy cover	80%	75%	50%	60%	85%
Ground cover					
- leaf litter	20%	10%	80%	15%	30%
- grass/ weeds	75%	90%	5%	65%	60%

Tree species richness & structure (count of stems >2 m high in three 5 x 10 m quadrats)

Species Note: mark exotics with an asterisk (*)	Height class (m)			
	2 - 5 m	5 - 10 m	10 - 20m	>20 m
1 Alphitonia petriei			5	
2 Terminalia sericocarpa		3	2	
3 Euroschinus falcatus var. falcatus		1		
4 Blepharocarya involucrigera		2		
5 Alstonia scholaris	1	3		
6 Scolopia braunii	2			
7 Elaeocarpus grandis			3	
8 Cryptocarya triplinervis var. riparia		2		
9 Darlingia darlingiana	1			
10 Homalanthus novoguineensis		1	2	
11 Castanospora alphandii		1		
12 Pararchidendron pruinsum	2			
13 Ficus pleurocarpa		1		
14 Syzygium australe	1			
15 Davidsonia pruriens	1			
16 Syzygium sayeri		1		
17 Guioa acutifolia		1		
18 Mischocarpus stipitatus	1			
19				
20				
35				
Tree species richness = 18	If >35 species recorded, tick here <input type="checkbox"/> & attach extra sheet			
Total no. of stems per height class =	9	16	12	0
No. of stems 1 – 2 m high (count)	Quadrat 1 2	Quadrat 2 5	Quadrat 3 0	
Largest diameter tree:	Quadrat 1 23 cm	Quadrat 2 19 cm	Quadrat 3 30 cm	
Canopy top height (tallest tree):	Quadrat 1 14 m	Quadrat 2 18 m	Quadrat 3 16 m	

Special life forms: note presence ('1') in quadrats (if not in quadrats, does it occur on site?)

Life form	Quadrat			Total	On site?
	1	2	3		
Robust vines (>5 cm diameter)	0	0	0	0	
Slender vines (<5 cm diameter)	0	0	0	0	
Wait-a-while/ lawyer cane	0	0	0	0	
Stem climbers, e.g. pothos	0	0	0	0	
Epiphytic ferns (staghorns, etc)	0	0	0	0	
Tree ferns	0	0	0	0	
Ground ferns	0	0	0	0	Y
Palm trees	0	0	0	0	
Understorey palms	0	0	0	0	
Strangler figs	0	0	0	0	
Other (Native Grasses)	1	0	0	1	

Woody debris (counts of intercepts on two 50 m transects by diameter class)

Diameter class	1 st transect	2 nd transect	Total/ 100 m
10 - 50 cm	0	0	0
>50 cm	0	0	0

General comments on progress of revegetation: including growth and development of planted trees, composition of the understorey, recruitment of native and exotic species and their relative abundance

Trees mostly growing well, although maybe too many pioneer species (??). Some recruitment occurring of off-site species in understory. Good sward of *Oplismenus* in areas. Pioneers such as *Alphitonia* aren't providing much shade anymore. Some additional plantings obvious, and these have been slow to establish. Understorey mostly consists of weedy species (see below). There is evidence that off-site species will be dispersed eventually, as they are present throughout the whole area, but in very low numbers at present. The inundated areas would present an ideal situation to plant *Lomandra hystrix*, which grows locally anyway. Has been infilled/underplanted on N side of creek only, to minimise grassy areas.

Any specific weed or maintenance issues:

Drymaria is rampant, but is a good soil stabiliser and enjoys inundated soils and soils with poor drainage. It does have the ability of smothering new recruits however as it is shade tolerant, but is an annual and only appears towards the end of the wet season and into winter/spring. Some *Mimosa*, some *Ageratum* also. Need to consider under planting again or some weed control around existing recruits and poor performing plants. The inundated areas would present an ideal situation to plant *Lomandra hystrix*, which grows locally anyway. A concerning weed is *Asparagus plumosus*, which is bird dispersed. It was observed as seedlings only but quickly establishes and is one to watch.

Photopoints	Location (note: mark location on map of site)	Direction of photo
1. Site (transect)	-17.29214, 145.60503	284 degrees (W).
2. Landscape (waypoint)	-17.29209, 145.60516	228 degrees (SW).

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