# 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/Tintaldra, 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 discussions 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 deal. 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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# Appendices (A to F)

## Appendices List of Figures



## Appendices List of Tables

## 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 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 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

disagregation 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.

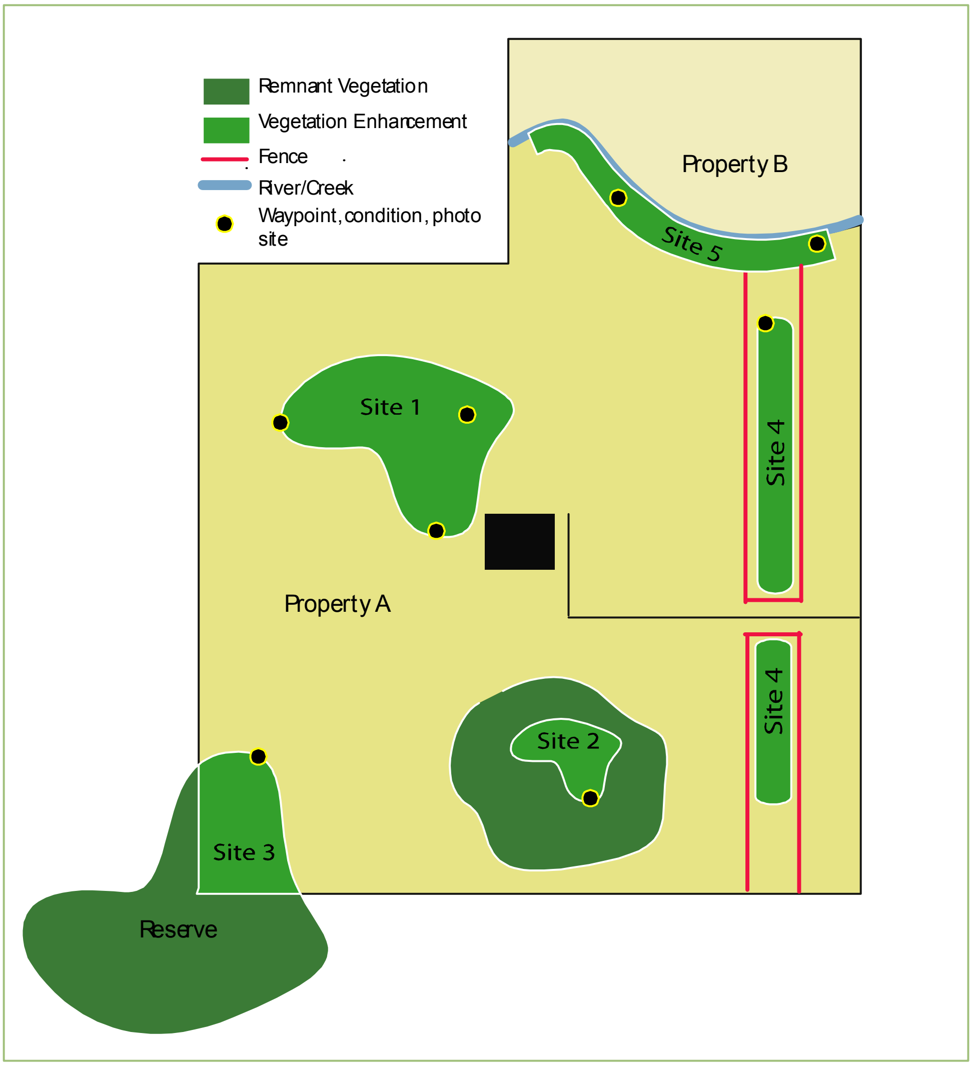
Specific protocols based on different enhancement scenarios:

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 disagregation 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. |
| | 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* | 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. |
| **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 |
| | CentroidY | numeric double | Y 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 |
| **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.

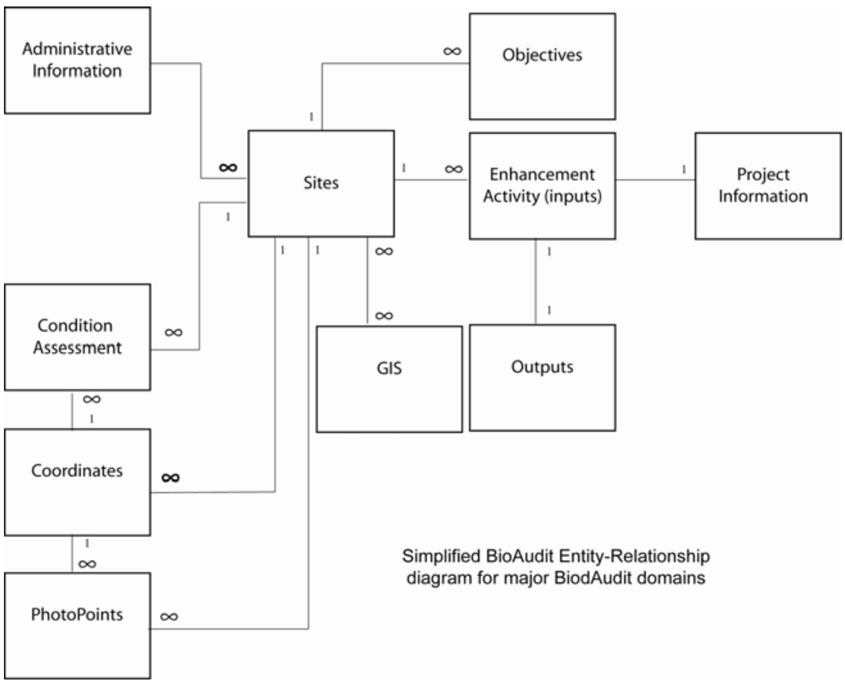
| Enhancement Type | Definition |
|---|---|
| remnant protection | a remnant polygon which has been fenced in whole or in part |
| remnant enhancement | a remnant polygon where additional planting has been undertaken and which has not been fenced |
| remnant enhancement and protection | a remnant polygon 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 O*bjectives* 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 have 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<br>DistrictName<br>PropertyName<br>ObserverName | |
| Project Information | **Level 1** | ProjectName<br>ProjectCode<br>FundingSourceName<br>Investment | |
| Objectives | | ObjectiveName<br>ObjectiveTypeName | |
| Sites | **Level 2** | AuditDate<br>SiteNumber<br>SitePrepName<br>SiteSizeName<br>SiteTypeName<br>SiteExperienceName<br>RemVegTypeName | |
| Enhancement Activity (inputs) | **Level 2** | FenceLength<br>CommonName<br>CountTubeStockTrees<br>CountUnderstorey<br>KgSeeds<br>KmDirectSeeding<br>YearEstablished<br>SiteConditionName<br>GrassProvenanceName<br>TreeProvenanceName<br>USprovenanceName<br>RevegTypeName | <br><br><br><br><br><br>**Level 1** |
| Outputs | **Level 2** | Gsurvivorship<br>USsurvivorship<br>DSsurvivorship<br>Regeneration<br>Tsurvivorship | |
| Condition Assessment | **Level 3** | ScoreMethodName<br>SiteNum<br>ScoreValue | |
| Coordinates | **Level 1** | WaypointTypeName<br>Easting<br>Easting<br>Northing<br>Northing<br>ProjectionName/Datum | |
| Photopoints | **Level 1** | PositionNames<br>PhotoFile<br>PhotoTime<br>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 | *Smith, B.* | |
| | DistrictName | name for district | *Yass Landcare Group, NE Victoria, Avon, Wet Tropics etc.* | This can be any administrative entity |
| | NHTRegion | NHT region | *Rangelands, NE Victoria* | |
| | PropertyName | name of property | *Belview* | |

Appendix Table 5. BioAudit Database - Sites Domain

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

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

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 | |
| | USsurvivorship | survival rate of understorey per100 (null if CountUnderstorey = 0) | 10, 20, 50 % etc | Some landholders plant both understorey and overstorey. This is a subjective classification of understorey versus overstorey. |
| | 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) |
| | Tsurvivorship | survival rate of trees per 100 (null if CountTubeStockTrees = 0) | 10, 20, 50 % etc | Survival rate of planted trees |

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 |
| | SiteNum | site order number for this site on this patch | 1,2 etc | Incremental auto number showing the condition site relative to the overall site |
| | 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 *coordinatesystem_latitude_longitude_orientation_orientation_date (*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. |

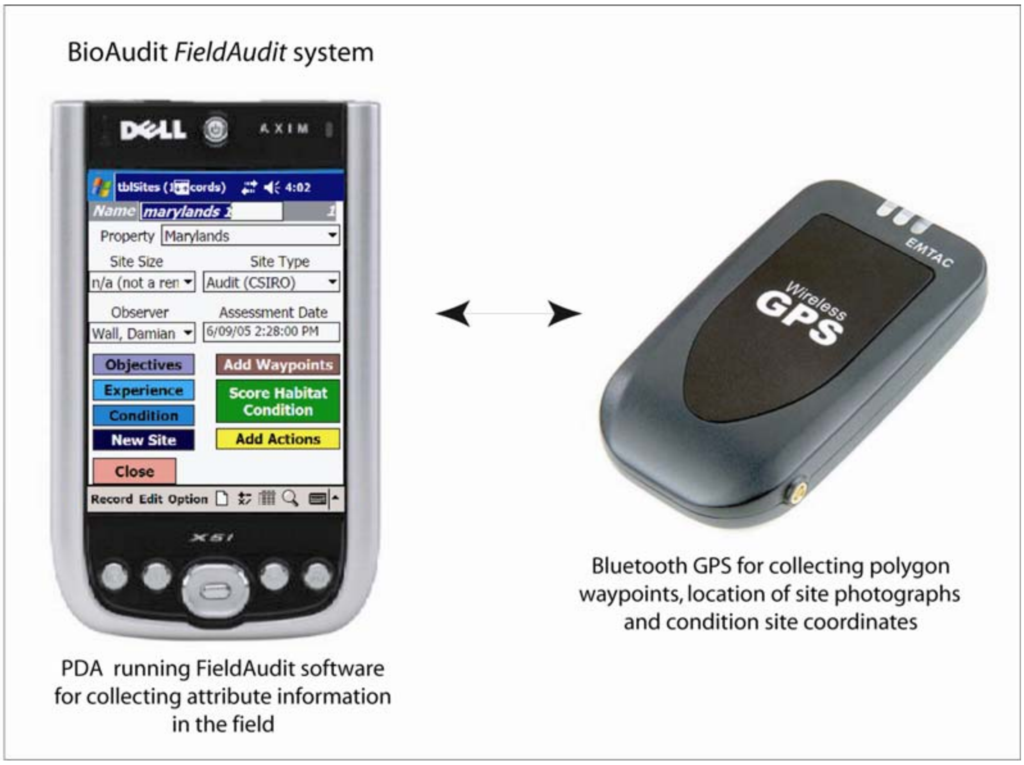
Appendix Table 13. BioAudit Database – GIS Domain

| 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 | |

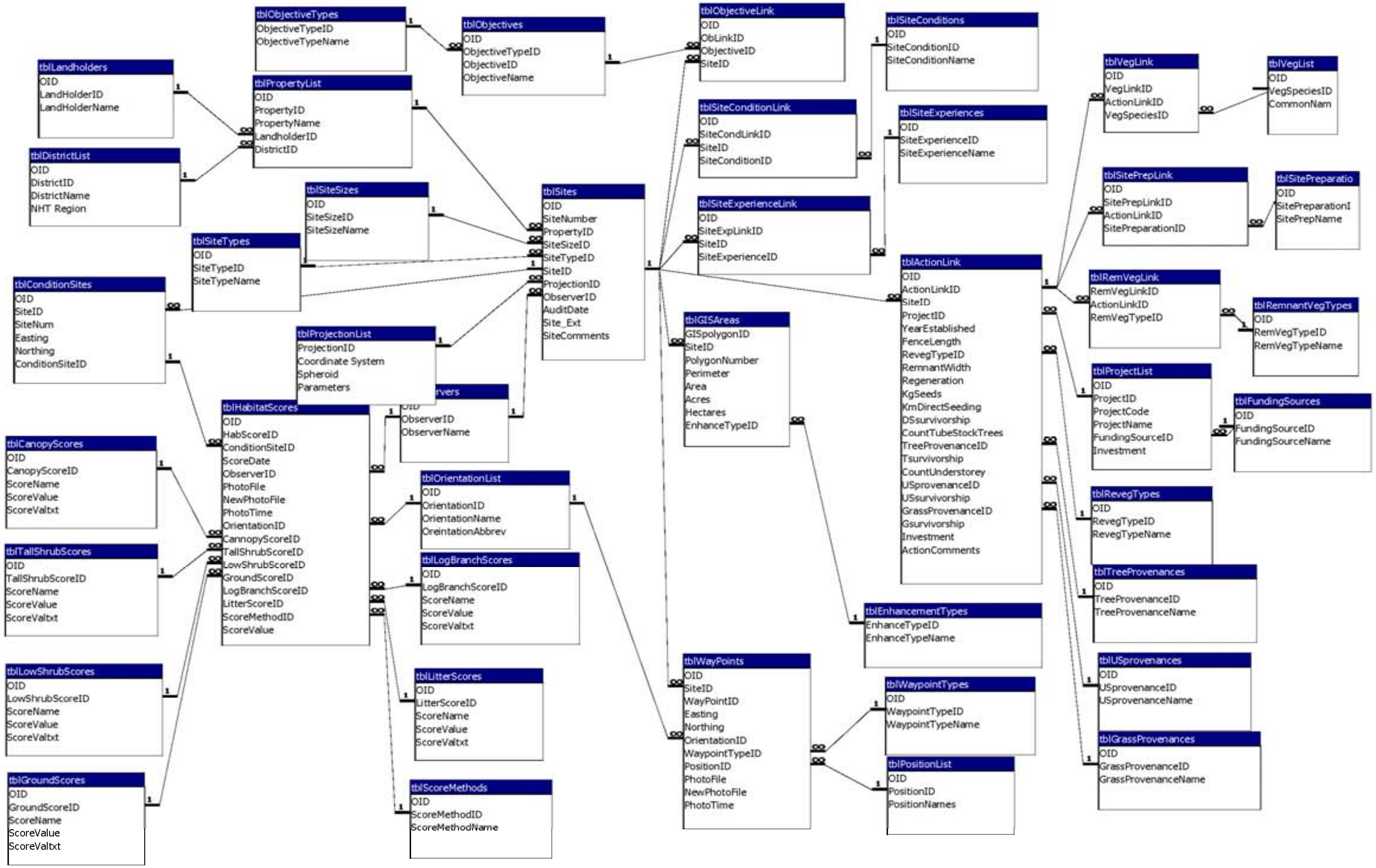
### *FieldAudit Tool*

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 representativenes 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 *et al.* (2003), Watson et al. (2005), Heikkinen et al. (2004), Botequilha Leitão, A. and J. Ahern (2002), Radford et al. 2005. |
| **Pattern** | Matrix based (*non binary landscapes) | Requires definition of habitat quality, species range, and threshold inter-patch distances. C**ost-distance surfaces.** | Theobald (2002), Chardon et al. (2003) |
| | Cell immigration methods (*non binary landscapes) | Accounts for *inter* and *intra* 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 et al. (2003), Chardon et al. (2003), Lee and Thompson (2005), Apan *et al.* (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 et al. (2003) |
| | Graph theory methods | Gamma index, alpha index | Petit and Burel (1998), Bunn et al. (2000), Cook (2002). |
| **Relationship** | | **Dispersion (**are like patches clustered), ), ***Cluster detection (e.g. spatial autocorrelation)*** | McGarigal and Marks (1995), Heikkinen et al. 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 representativenes 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 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 infact 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 apply 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.

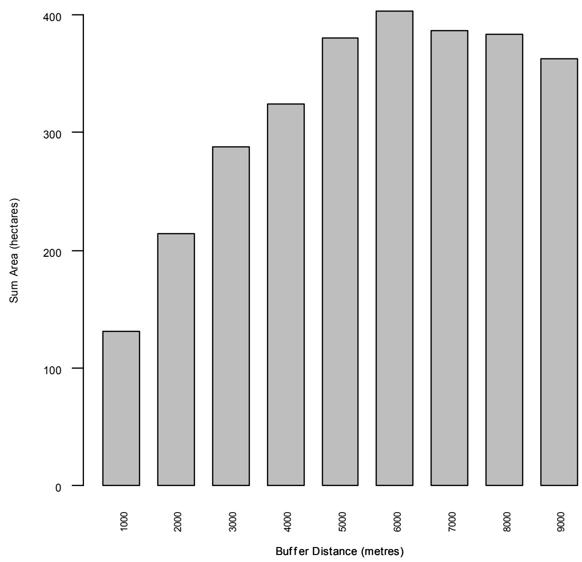
This section describes the development of the Modified Habitat Buffers Algorithm for summarising structural change from on ground vegetation enhancement activities. The algorithm calculates the change in vegetation area which is observed in increasing larger distance classes and represents this change 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.

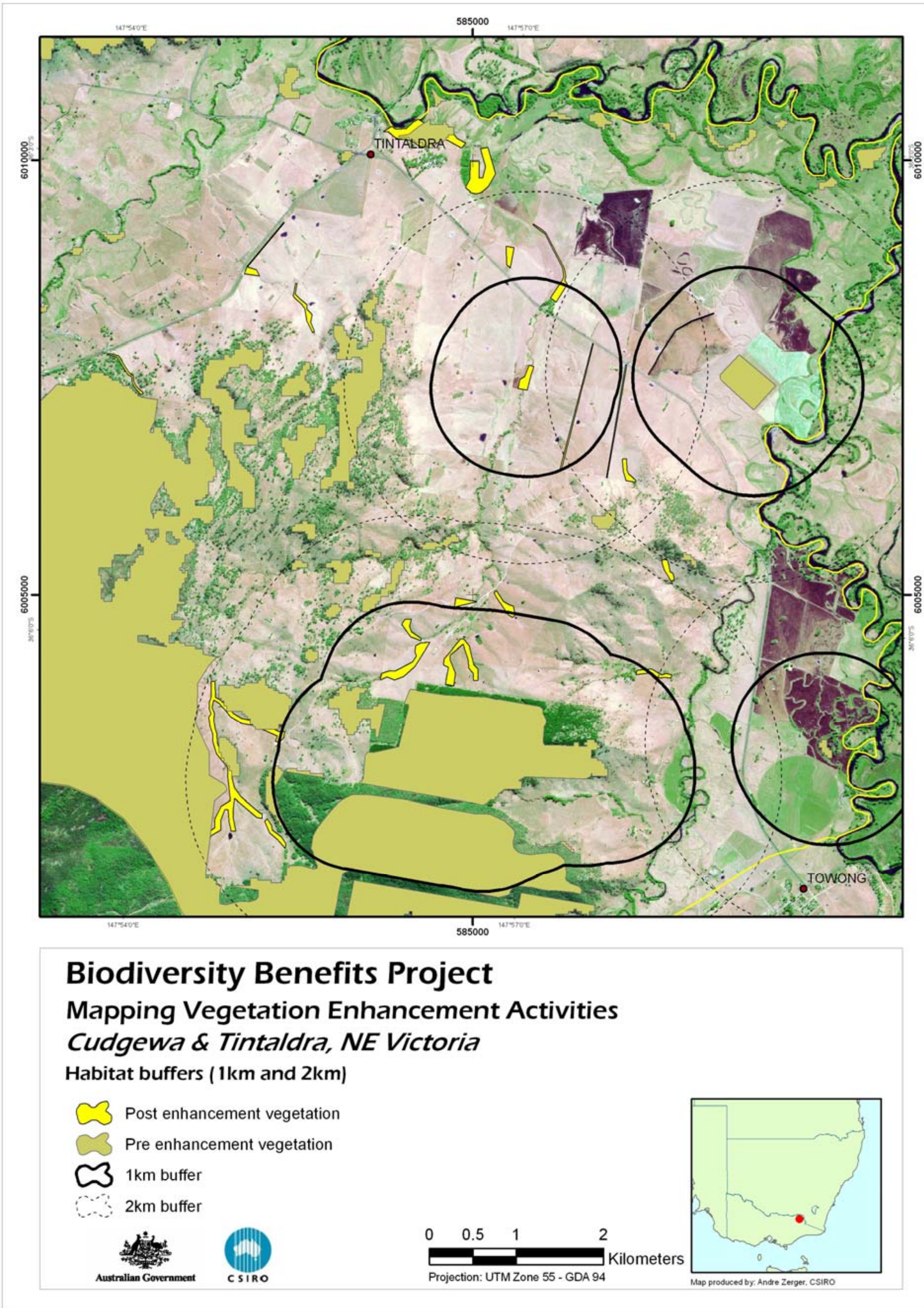
The algorithm has been developed in the Python language utilising ArcGIS geoprocessing functions (ArcGIS 9.1) and R-Package for plotting results. It combines both vector and grid algorithms to calculate the amount of vegetation in each buffer zone. As an input the algorithm requires two GIS datasets.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

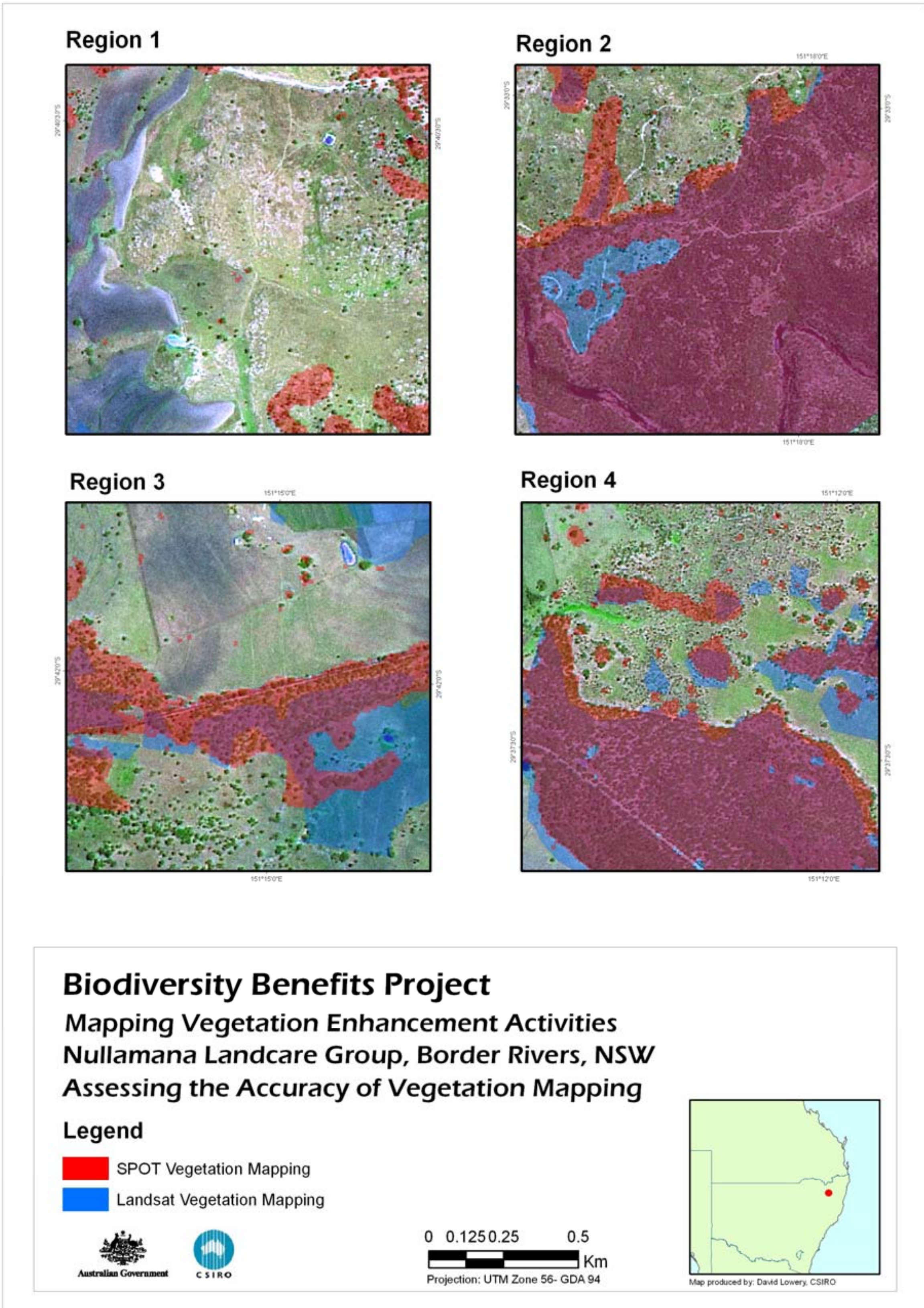
### *Developing An Improved Vegetation Extent Map*

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.

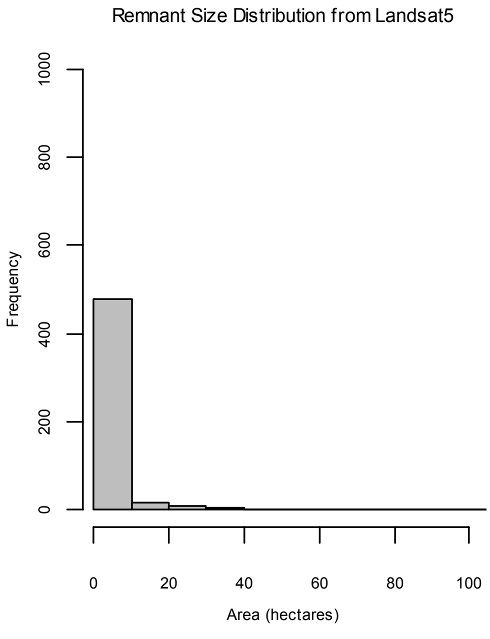
Owing to seasonality effects, the SPOT5 classification misclassified areas of cropping or improved pasture as woody vegetation. It is worth noting here that this problem still occurred after changing the classification method, regions of interest and error thresholds and that the pre-existing vegetation data also suffered from this error. These gross errors where 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 where 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.

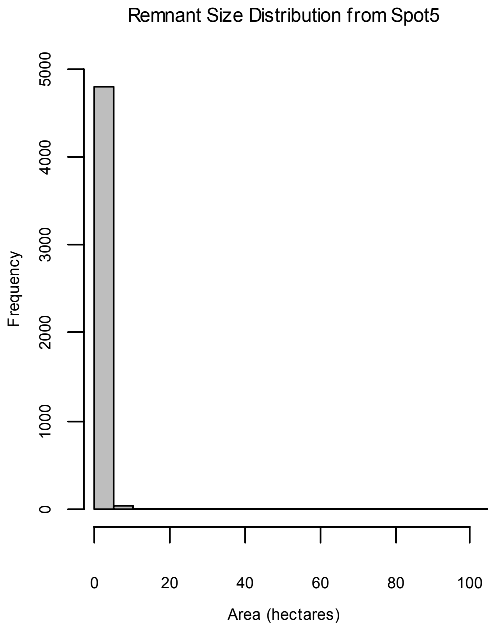



Appendix Figure 8. Location of four validation regions across the Nullamanna study area showing SPOT5 woody vegetation mapping and Landsat 5 woody vegetation mapping.

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




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 500m$^2$. In order to achieve this, patches smaller than 500m$^2$ 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 km$^2$ 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 1km$^2$ 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

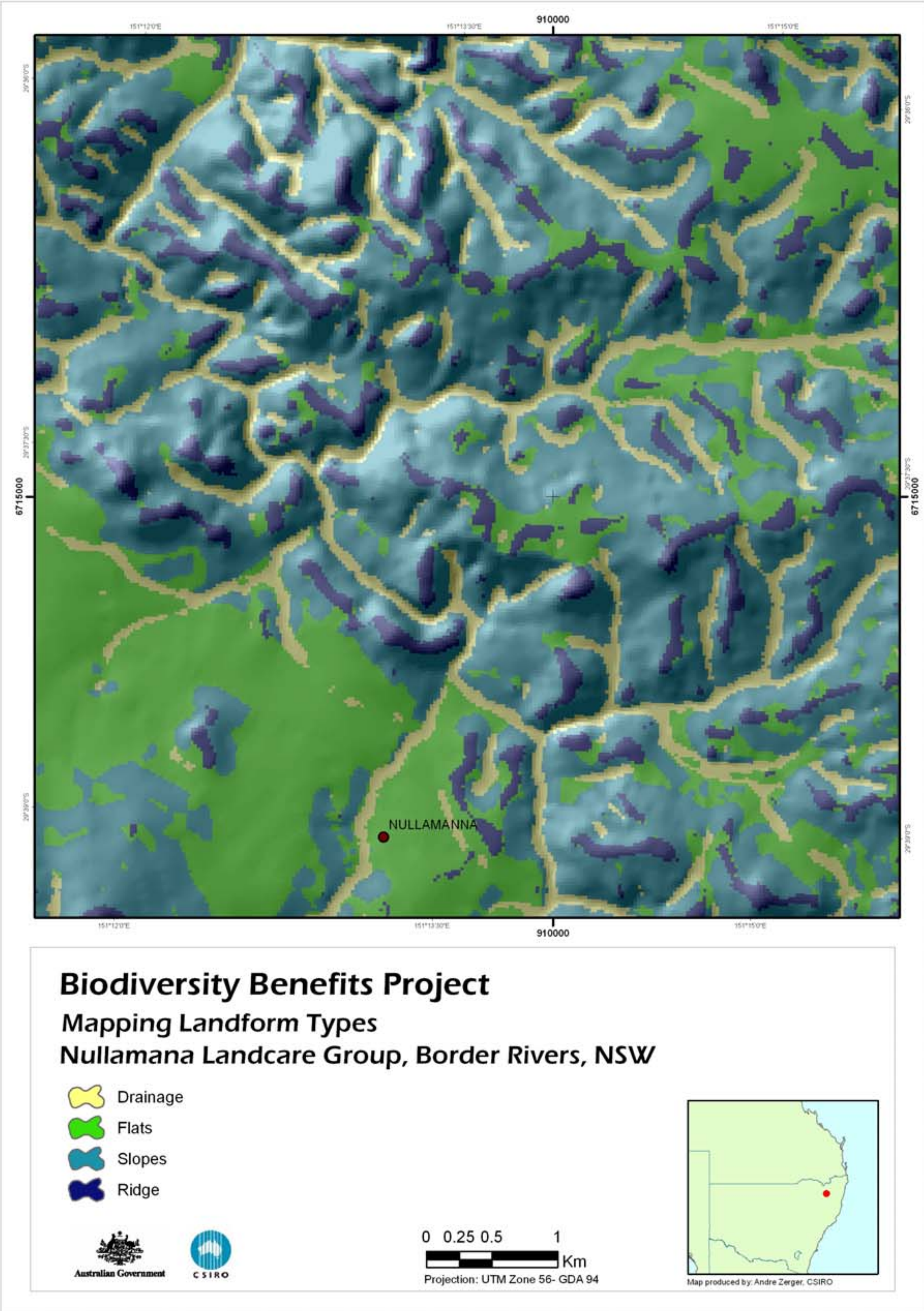
Landform data provides managers an alternate way to examine the distribution of enhancement activities and to plan future activities. For instance, it can determine whether the distribution of activities favours agriculturally unproductive land such as hilltops and ridges or whether fertile flat landscapes 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 where 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 where 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<br>- leaf litter<br>- grass/ weeds | <br>20%<br>75% | <br>10%<br>90% | <br>80%<br>5% | <br>15%<br>65% | <br>30%<br>60% |

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

| **Species**<br>Note: mark exotics with an asterisk (*) | **Height class (m)**<br>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 pruinosum | 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* ☐ *& 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 | 1st transect | 2nd 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. Understory 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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