NSW WESTERN REGIONAL ASSESSMENTS

Nandewar

Landscape Conservation

Final report
November 2004

PROJECT NO NAND01

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

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Nandewar

Landscape Conservation

Department of Environment and Conservation

Project Number NAND01

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

INFORMATION

This project has been funded and coordinated by the Resource and Conservation Division (RACD) of the NSW Department of Infrastructure, Planning and Natural Resources and Department of Environment and Conservation, for the Resource and Conservation Assessment Council (RACAC)

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Preface

This project has been funded by the New South Wales Government through the Resource Assessment and Conservation Council (RACAC) and Department of Environment and Conservation (DEC), and coordinated by the Resource and Conservation Division (RACD) of the Department of Planning, Infrastructure and Natural Resources (DIPNR).

The project has been undertaken by staff of the Conservation Assessment and Data Unit and GIS Research and Development Unit of the Department of Environment and Conservation. For their contribution to the implementation of this project, special acknowledgment is due to the following people:

Dr Simon Ferrier for scientific expertise and methodological development.

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Jill Smith for running of species model for Coolatai grass.

Kellie Mantle for GIS assistance and map preparation.

Staff of RACD for general project support.

The project has been overseen and the methodology has been developed through a Technical Working Group including representatives from RACD, DIPNR, DEC, State Forests of NSW, Department of Mineral Resources, New South Wales Agriculture and Biotrack Pty Ltd.

Project Summary

The Nandewar Landscape Conservation project is one of several projects involving regional stakeholders and government agencies within a broader Western Regional Assessment (WRA) program. The WRA considers environmental, economic and social values of forest and non-forest land systems to advise on conservation, land management and planning.

The Nandewar WRA study area encompasses some 2.7 million hectares including all of the Nandewar Bioregion and parts of the western New England Tablelands Bioregion in New South Wales that had not been assessed previously. Nandewar occupies a temperate climatic zone that is a transitional area between semi-arid inland and moist tablelands and coastal land systems. The bioregion is geologically complex supporting diverse and distinctive forest and woodland vegetation communities. Nandewar is significant for biodiversity due to the distributional overlap of temperate and semi-arid flora and fauna and the presence of many species of conservation concern.

The Landscape Conservation project involves a GIS analysis in combination with computer driven decision support tools. The project aims to develop a method by which conservation options within the Nandewar WRA study area can be placed within a bioregional context by assessing the broad-scale distribution and configuration of biodiversity values and conservation priorities across all tenures.

The project relies on a new modelling approach for predicting how much of a region's biodiversity is likely to persist into the future, given a particular land use scenario. This provides a basis for measuring conservation effectiveness of various land use scenarios, which in turn allows conservation priority to be estimated and mapped.

The Nandewar Landscape Conservation project built on earlier applications of the modelling approach by utilising more detailed data sources and deriving mapped estimates of current vegetation condition and threats to biodiversity persistence. The project developed risk layers that map an estimated relative risk (to biodiversity persistence) of land clearing, land degradation, logging, firewood collection and invasion of Coolatai grass.

The modelling employed vegetation communities as a broad surrogate for the spatial distribution of biodiversity across the region. Future condition of vegetation is predicted as a function of current condition, land use and likelihood of exposure to threatening processes. An effective habitat area is calculated for all surrogate units to account for spatial configuration (effects of fragmentation). The conservation status of the landscape in terms of these biodiversity surrogates could then be determined and mapped, and preliminary landscape conservation priorities developed and displayed.

Acronyms and abbreviations

API	Aerial Photograph Interpretation
BBS	Brigalow Belt South
BDI	Regional Biodiversity index
CRA	Comprehensive Regional Assessment
DEC	Department of Environment and Conservation (the National Parks and Wildlife Service is now part of DEC)
DEM	Digital Elevation Model
DIPNR	Department of Infrastructure, Planning and Natural Resources (which includes the former Department of Land and Water Conservation)
EHA	Effective habitat area
GIS	Geographic Information System
IBRA	Interim Biogeographic Regionalisation of Australia
NP	National Park
NR	Nature Reserve
RACAC	Resource and Conservation Assessment Council
RACD	Resource Assessment and Conservation Division (of DIPNR)
SFNSW	State Forests of New South Wales
WRA	Western Regional Assessment
ha	hectares

i Background

The New South Wales Government recently initiated a regional assessment of western NSW to guide future planning and encourage partnerships to protect the environment. The assessment is being coordinated by the Resource and Conservation Assessment Division (RACD) and involves several government agencies including State Forests of NSW, Department of Environment and Conservation, Department of Infrastructure, Planning and Natural Resources and Department of Mineral Resources, as well as local and regional stakeholders.

The western assessment is considering environmental, economic and social values of forest and non-forest land systems focusing on conservation, land management and regional planning.

The aim of the Western Regional Assessment (WRA) is to deliver the following outcomes:

- adequate and complete core data layers to inform regional land use planning and conservation and resource management;
- enhanced partnerships between core agencies and interest groups concerned with natural resources and ecological sustainability, to increase sharing of information and to reduce duplication; and
- the identification of a comprehensive, adequate and representative network of protected and managed areas for the Central and Western Divisions (http://www.racac.nsw.gov.au/rfa/wra/).

The Nandewar Western Regional Assessment follows that previously undertaken for the Brigalow Belt South Bioregion. The Nandewar WRA encompasses all of the New South Wales section of the Nandewar Bioregion and parts of the western New England Tablelands Bioregion that had not been assessed previously during the coastal Comprehensive Regional Assessments (CRA). Nandewar WRA projects include biodiversity surrogates (vegetation and fauna), conservation criteria, invertebrates, wood resources, geology, mineral prospectivity, socioeconomic studies and Aboriginal heritage and community consultation.

This report describes the Nandewar WRA Landscape Conservation project.

1 Introduction

1.1 STUDY AREA

The Nandewar Western Regional Assessment (WRA) study area (**Figure 1-A**) encompasses the New South Wales Nandewar IBRA[1] Bioregion and the western edge of the New England Tablelands IBRA Bioregion. The Study Area encompasses the north-western slopes of the Great Dividing Range in NSW. The study area encompasses approximately 2.7 million hectares, extending 350 kilometres north to south from the Queensland border to the Liverpool Range, and 160 km east to west from the North East Comprehensive Regional Assessment (CRA) areas to the Brigalow Belt South (BBS) WRA area.

The 2.7 million hectare study area includes 240 000 hectares of land previously assessed in coastal CRAs and BBS WRA that lie within the Nandewar IBRA bioregion (see hatched areas **Figure 1-A**). These previously assessed areas are included on maps to provide a bioregional context only.

The Nandewar WRA study area includes all of the major Nandewar provinces of Peel, Inverell Basalts, Northern Complex and Kaputar, as well as part of five New England Tableland provinces: Severn River Volcanics, Glen Innes-Guyra Basalts, Tingha Plateau, Walcha Plateau and Eastern Nandewars. A previously unassessed part of the Upper Hunter is also included.

The Nandewar region is geologically complex. It comprises an underlying basement of ancient metasediments, intruded in the higher elevation eastern margins by granitic uplift, and over-laid in many areas by tertiary basaltic flows. Superheating at the sediment-granite interface produced several grades of volcanised or metamorphosed sediments, in addition to unique areas of serpentinite and limestone.

Eighty-five percent of the Nandewar WRA study area is in private ownership with a further 11% leasehold land. State forests comprise 35 678 hectares (1.45 % of the study area) and current formal reserves (national park estate) occupies 61 711 hectares, or 2.3% of the study area. The area of formal reserves not previously considered by coastal CRAs or BBS WRA is 21 850 hectares, only 0.9% of the study area (see **Figure 1-B**). The majority of the public land estate supports woody vegetation (with travelling stock reserves containing the best examples of some vegetation communities) whereas only 22.8% of freehold land retains forest or woodland cover.

[1] Interim Biogeographic Regionalisation of Australia

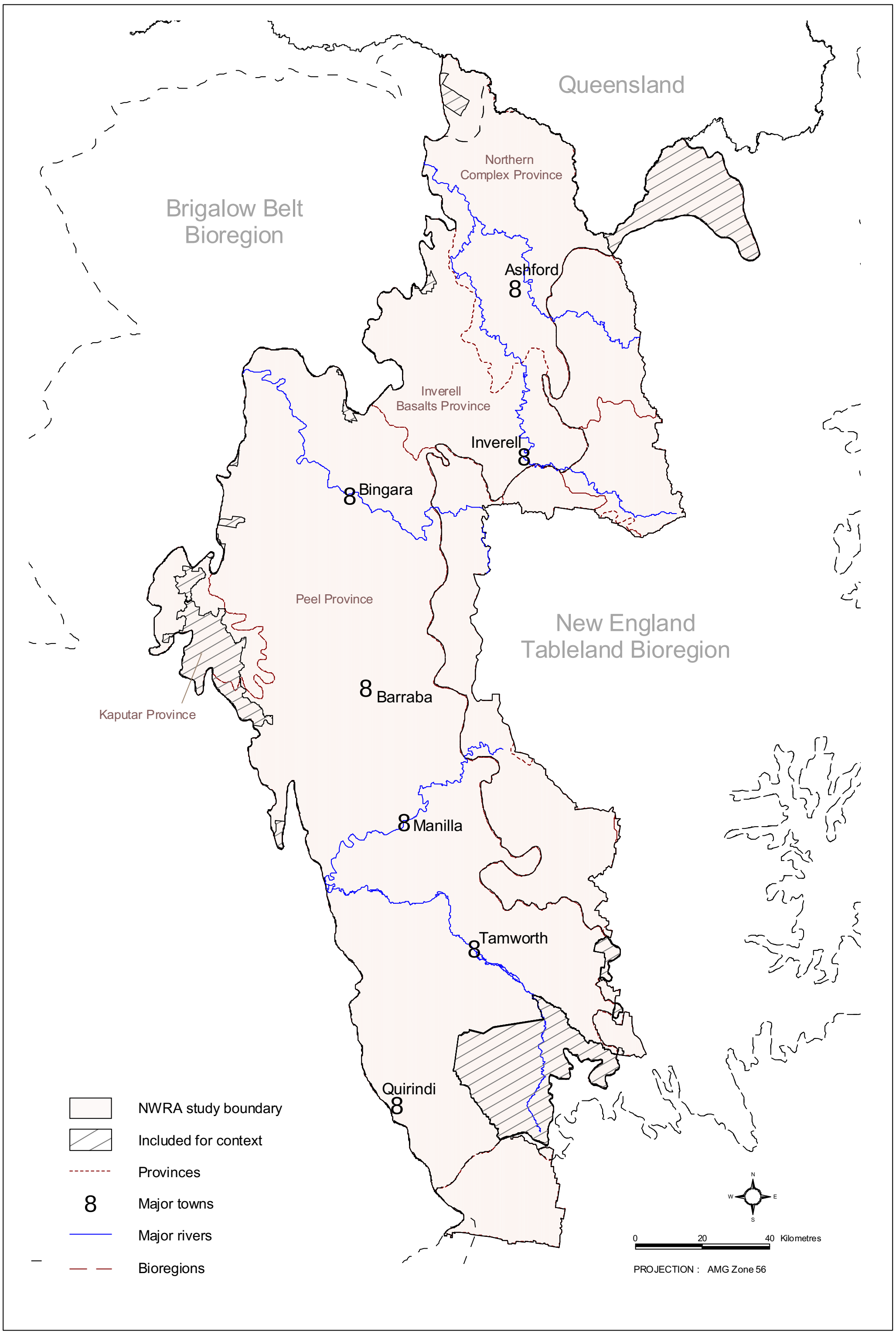


FIGURE 1-A

Nandewar WRA study area

The residual nature of land set aside for conservation is reflected in the high proportion of reserved land that is rugged in terrain, particularly biased to high elevation granite areas in the east. In contrast a very low proportion of reserved land has moderate or high land use capability with further reservation options being minimal in agriculturally productive areas such as the heavily cleared Inverell Basalts and central Peel provinces.

Vegetation of the Nandewar WRA study area is influenced primarily by geology in conjunction with topographic, rain shadow and edaphic effects. Temperate climatic conditions prevailing over the transitional zone between semi-arid inland and moist coastal and tablelands forests help shape the distinctive dry open forests and woodlands of the western slopes. Nandewar is characterised by box forests and woodlands, particularly white box, typically at low to mid elevation in agriculturally productive areas, and cypress pine - ironbark - tumbledown red gum woodlands and open forests occupying much of the less-productive parts of Nandewar and often dominated by regrowth cypress stands. The region is of significance for biodiversity due to its location at the distributional overlap of many temperate and semi-arid flora and fauna species. Refer to the Biodiversity Surrogates reports for detail: Nandewar Vegetation report (DEC 2004) for detail on the vegetation patterns of the bioregion and Vertebrate Fauna report (Andren 2004) for information on the vertebrates of Nandewar. The Biotrack report (Prior & Dangerfield 2004) provides information on invertebrates of Nandewar in relation to local consequences of land use for biodiversity.

1.2 OBJECTIVES OF THE PROJECT

The main objective of the Nandewar Landscape Conservation project is to develop a means by which conservation decisions on public and private land in the Nandewar WRA study area can be placed within a bioregional context, by evaluating the broad-scaled distribution and configuration of conservation values and priorities across all tenures.

Component objectives of the project are to:

- determine likely current broad patterns of land use and the associated threats and benefits to biodiversity and their impact on conservation;
- estimate and map relative levels of conservation priority (areas of significance in terms of biodiversity) across the Nandewar WRA study area;
- evaluate given land use (or management) scenarios for the study area based on how much of the region’s biodiversity is predicted to persist into the future under a particular scenario; and
- provide a landscape spatial context for the Nandewar WRA study area to assist conservation decision making on public land and recommendations for promoting landscape rehabilitation across the study area, including additions to the conservation reserve system.

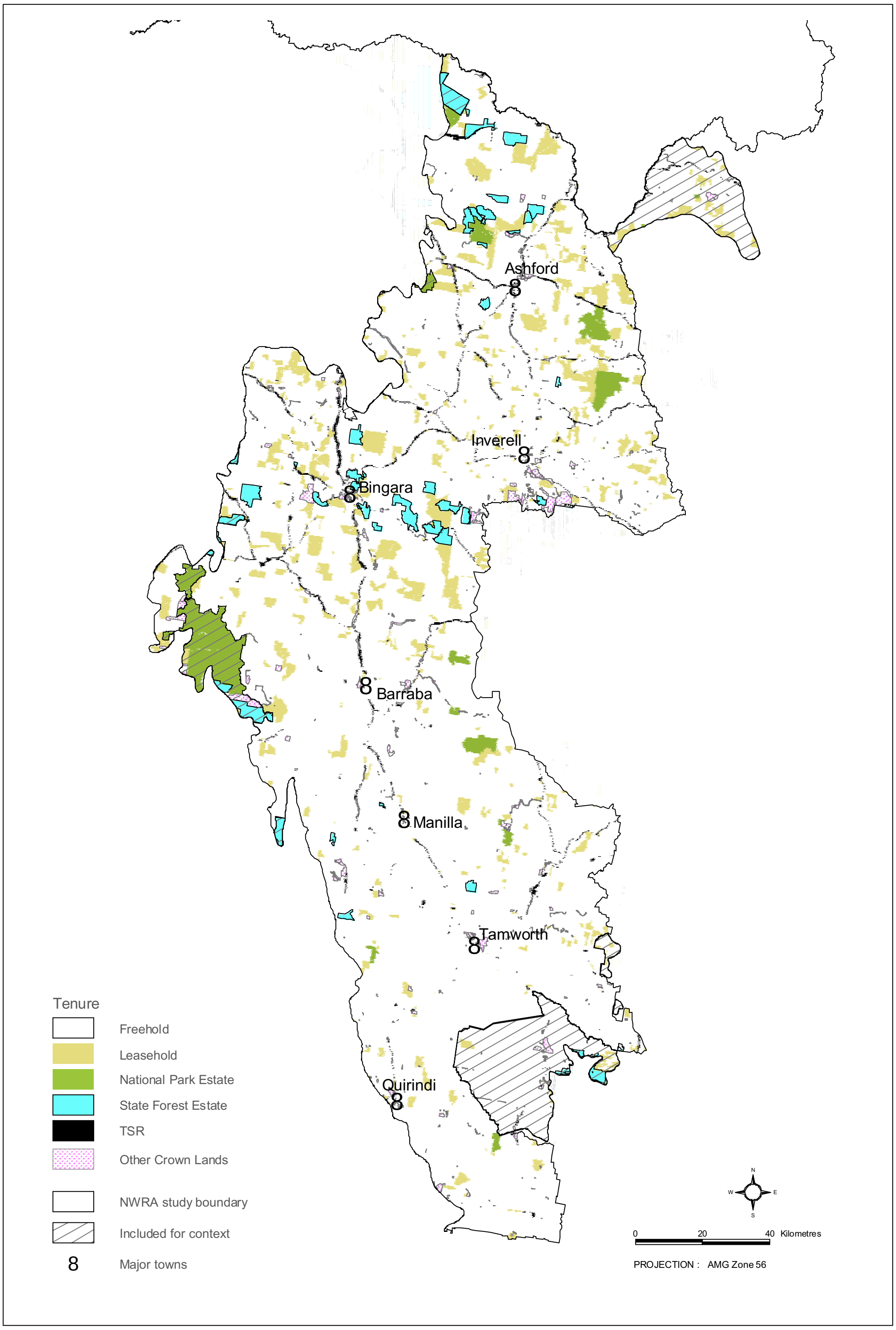


FIGURE 1-B

Land tenure across the Nandewar WRA study area

1.3 SCOPE OF THE PROJECT

The Nandewar Landscape Conservation project was confined in geographical extent to the New South Wales Nandewar IBRA Bioregion plus adjacent areas of the New England Tablelands Bioregion not previously included in Upper and Lower North East Comprehensive Regional Assessments. Areas within the RACD-defined study area that have been previously assessed during coastal CRA and BBS WRA processes are included to provide a bioregional context only.

The project consisted principally of GIS analysis and operation of computer-based decision support tools. The project collated existing datasets and derived new data layers required to identify bioregional landscape features and units important for determining conservation and rehabilitation priorities. *The scope is limited to consideration of biodiversity values and does not extend to other environmental values such as ecosystem functions and services, nor to economic or social factors.*

The project provides a tool that can be used to evaluate biodiversity outcomes in relation to:

- identified biodiversity values and conservation priorities across the Nandewar WRA study area;
- conservation issues such as identification of significant native vegetation, corridors and habitats, landscape units;
- existing and potential land use, tenure and broad restoration potential; and
- appropriate combinations of conservation options and landscape management.

2 Modelling framework

2.1 OVERVIEW

The modelling approach employed in this project was adapted from that previously used in the Bioregional Landscape Conservation Framework Project for the Brigalow Belt South WRA. The approach is built around a set of "biodiversity assessment tools" developed by the GIS Research and Development Unit within the NSW Department of Environment and Conservation.

The capabilities of these assessment tools, as being applied in Brigalow Belt South and Nandewar, are summarised in **Figure 2-A**. The tools are designed to do three main things:

- Evaluate the overall effectiveness of any given land use (or land management) scenario for the region of interest, in terms of how much of the region's biodiversity is predicted to persist into the future under this scenario. A "land use scenario" is simply a spatially defined configuration of land use classes (or land management zones). In addition to evaluating the existing configuration of land use within the region (i.e. the status quo), the tools can evaluate the effectiveness of any proposed scenario of changed land use. Such scenarios may be derived independently of the tools, or can be developed intellectively within the tools themselves using a capability described in the third point below. Regardless of how a scenario is developed the tools can produce tabular and graphical reports on the predicted implications of the scenario for biodiversity as a whole, or for individual vegetation communities within the region.
- Estimate and map relative levels of conservation priority across the region. Conservation priority is estimated for every location (grid cell) in the region by calculating the marginal gain in overall conservation effectiveness that would be achieved if the current land use scenario were modified to protect (or restore) vegetation at that location and that location only. The land use change at each location is applied independently of changes at other locations (i.e. the changes are non-cumulative). The calculated priorities at all locations can then be depicted as a map with different colours indicating varying levels of conservation priority.
- Develop alternative land use (or land management) scenarios. The tools provide a powerful capability for development and exploration of land use scenarios through interactive editing, or addition of boundaries, within a mapped land use layer superimposed over the mapped conservation priority layer.

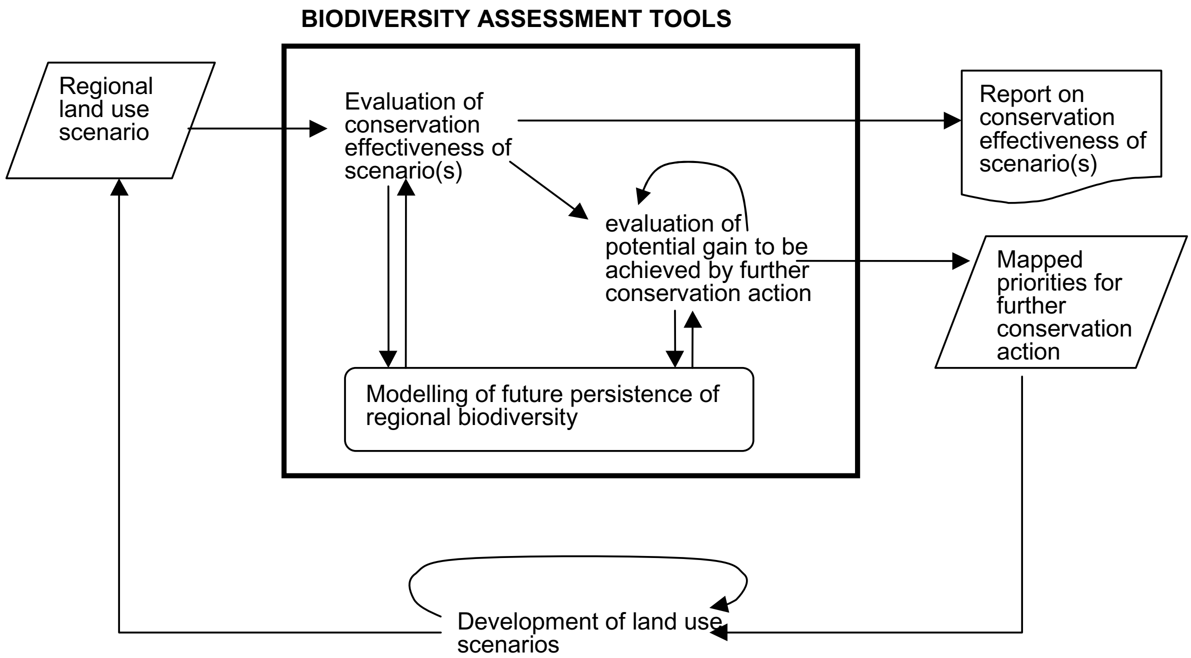


FIGURE 2-A

Broad capabilities of the biodiversity assessment tools

The capabilities described above are all underpinned by a new modelling approach for predicting how much of a region's biodiversity is likely to persist into the future, given a particular land use scenario. This provides the basis for measuring the conservation effectiveness of different scenarios, which in turn allows the conservation priority of individual grid cells to be estimated and mapped.

The current project in Nandewar has focussed mainly on setting up the underlying biodiversity model, with particular emphasis on establishing the necessary spatial data-sets to support this model. The model has then been used to trial the mapping of conservation priorities within Nandewar, thereby demonstrating the potential applicability of such mapping to conservation assessment and planning within the region.

However it should be noted that many of the parameters used in these preliminary trials are subjective approximations based largely on expert knowledge (within the Department of Environment and Conservation) in lieu of relevant supporting data. There is considerable potential for these parameters to be refined in the future through further consultation with external experts, and accompanying endorsement by other agencies and stakeholders. Such refinement and endorsement is an essential precursor to any application of the model to developing and/or assessing real land use scenarios for the region. For example, in the future the type work conducted by Biotrack Australia Pty Ltd (Prior & Dangerfield 2004) on invertebrate diversity and abundance could be refined and used to inform parameters relating to expected condition for biodiversity under different landuses.

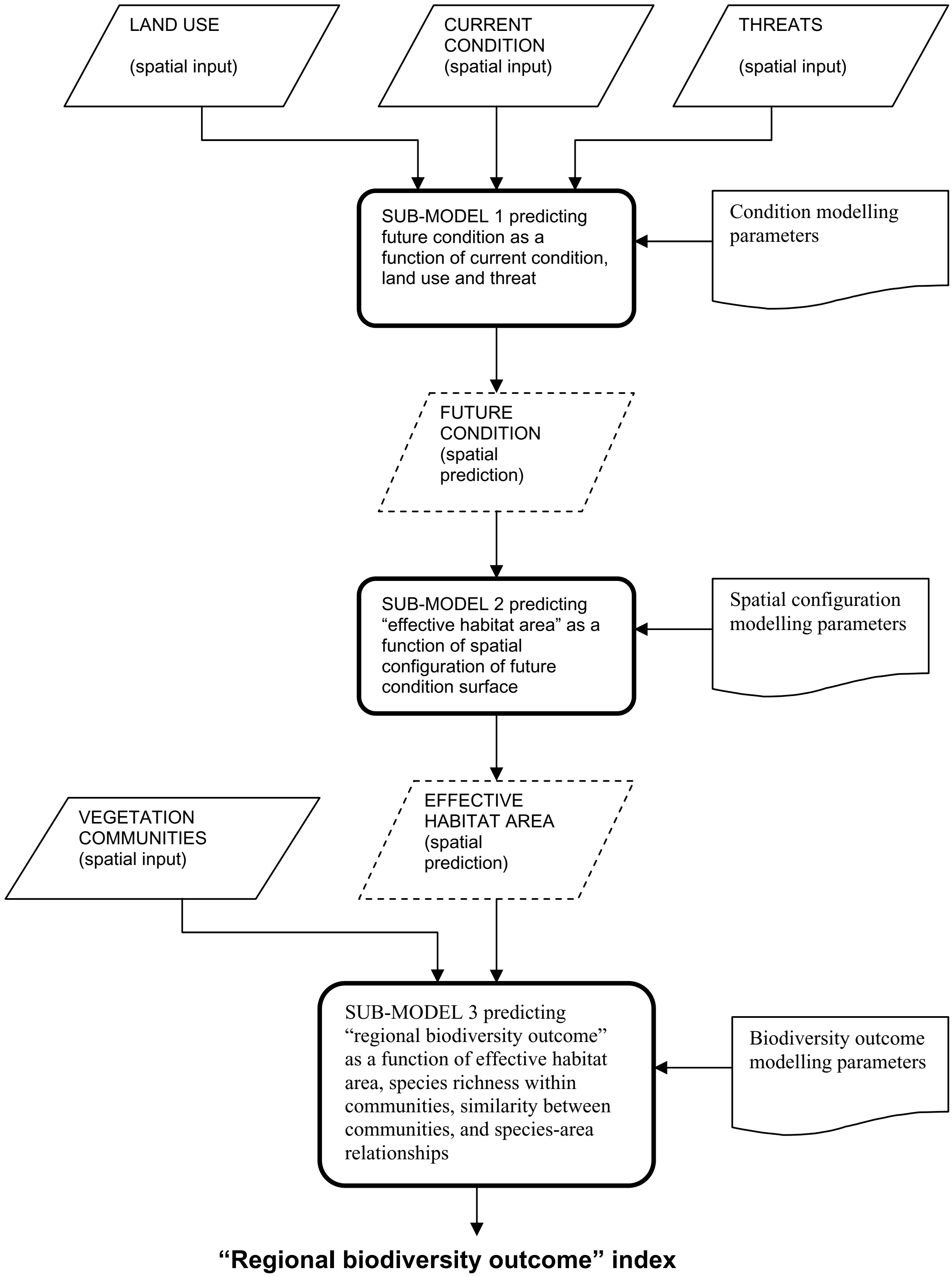


FIGURE 2-B

General approach to modelling persistence of biodiversity

2.2 MODELLING PERSISTENCE OF REGIONAL BIODIVERSITY

Modelling persistence of biodiversity is a daunting challenge. It requires consideration both of patterns in the spatial distribution of elements of biodiversity across the region (eg. distributions of species and communities), and of processes that are likely to affect these elements over time (eg. the effects of different land uses and threats on habitat condition, and the effects of habitat fragmentation and isolation on population viability). Clearly our knowledge of these patterns and processes is grossly incomplete. The resolution and accuracy of the information currently used in the modelling is therefore often far from ideal, but the work at least provides an initial assessment framework based on “best available” information that can then be progressively refined in the future.

A diagrammatic overview of the approach used to model persistence of biodiversity in this project is presented in **Figure 2-B**. In general terms, the modelling employs vegetation communities as a broad surrogate for the spatial distribution of biodiversity across the region. It was originally intended that the habitat needs of individual vertebrate fauna species and assemblages would also be integrated into this model. Unfortunately habitat modelling and mapping for these species within Nandewar was not completed in time for such information to be included in the current project. There is considerable potential, however, for this information to be incorporated into any future refinement of the model. The integrated use of vegetation and vertebrate species as surrogates for biodiversity has already been demonstrated in applications of this general modelling approach to vegetation planning projects in Moree Plains and Southern Mallee.

The model predicting persistence of biodiversity, as depicted in **Figure 2-B**, essentially consists of three linked sub-models. These three sub-models are applied sequentially, with output from the first sub-model providing the input to the second sub-model, the output from which then serves as the input to the third sub-model.

In the first of these sub-models, the future condition of vegetation in each and every grid cell in the region is predicted as a function of current condition, existing or proposed land use, and likelihood of exposure to threatening processes.

In the second sub-model, the effects of habitat fragmentation (patch size, condition and connectedness) on species diversity are factored in by converting the area of vegetation predicted to remain in each community to an “effective habitat area” in which the contribution to biodiversity persistence of small isolated remnants is downgraded relative to large well-connected blocks of vegetation.

In the third sub-model, an approximate estimate of the proportion of the region’s original biodiversity (i.e. all species of plants and animals) predicted to persist into the future is then derived by combining the information on effective habitat area with information on levels of species richness within communities, biological similarity between communities, and species-area relationships.

Each of these sub-models, and their associated modelling parameters, are described in greater detail below.

2.2.1 Sub-model 1: Predicting future condition

The methods used to derive a spatial layer of current vegetation condition are described in Section 3.2. In this project current condition is used as an indicator of the quality of vegetation in respect to a hypothetical 'pristine' state of any vegetation community. Condition values range between zero and one hundred.

It was intended that as far as possible a single model would govern the modelling of both current vegetation condition and the predictive modelling of future vegetation condition. Due to the unavoidable consequences of relying on a range of different API data sources (see section 3.2), the attributes available to derive current vegetation condition varied significantly across the region. Although these attributes, un-aggregated, would ideally be used as the basis for the prediction of future condition, it was impractical with such variation of data sources across the region to do so and a separate method for predicting future condition was adopted.

The model for predicting future vegetation condition recognises three vegetation condition components: canopy cover, understorey condition and the amount of coarse woody debris. As a baseline to modelling future condition, the current condition of each gridcell (with values ranging between 0-100), was apportioned to the three condition components in a fixed ratio of 45:45:10 respectively. ie canopy (45%; maximum 45); understorey (45%; maximum 45); and coarse woody debris (10%; maximum 10), regardless of how current condition was originally derived. For example a gridcell with an API derived vegetation condition of 50 would be assumed to have canopy condition of 22.5, understorey condition of 22.5 and coarse woody debris condition of 5. In the process of modelling future condition the dynamics of each component was modelled separately then aggregated to yield a measure of overall future condition.

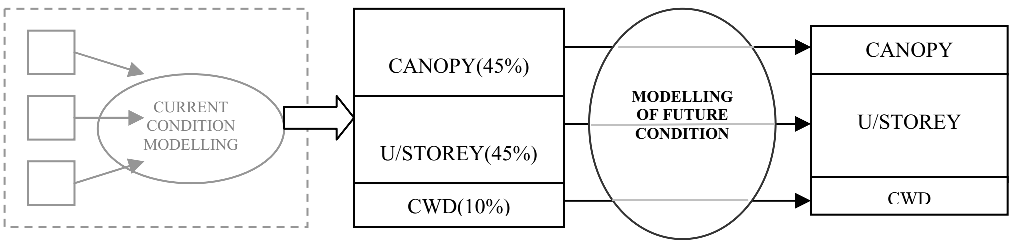


FIGURE 2-C

Derivation of future condition based on condition components

The modelling framework incorporates both the improvements to vegetation condition (regeneration) arising from natural regeneration as well as the loss of vegetation condition due to threatening processes (degradation). Using a decision tree approach (see **Appendix 2.1**), a prediction of future condition for each gridcell within the region is derived from the current condition for that cell and the combined pressures of regeneration and degradation.

Threatening processes

The method has extended previous approaches by incorporating into the modelling a range of threatening processes, or risks. The following threatening processes were included in the modelling: land clearing, land degradation, logging, firewood collection, and invasion by Coolatai grass. Derivation of these coverages is described in Section 3.4.

Within the future condition calculations the condition of each component is allowed to vary independently (of the others) in response to threats. For example the effect of firewood collection is particularly relevant to the coarse woody debris component but doesn't affect the canopy and the understorey in this model (see **Table 2-A** and **Appendix 2.1**).

TABLE 2-A

Summary of parameters used for predicting future condition

THREAT	T_{low} (years)	t_{high} (years)	P_{low}	P_{high}	Q CANOPY (max. 45)	Q U/STOREY (max. 45)	Q COARSE WOODY DEBRIS (max. 10)
Clearing	500	25	0.01	0.17	2.25	11.25	-
Degradation	100	20	0.05	0.21	29.25	15.75	-
Logging	100	30	0.05	0.14	27.00	36.00	-
Coolatai	100	15	0.05	0.26	40.50	2.25	-
Firewood	100	5	0.05	0.6	-	-	5.00

t_{low}	Time required to remove confidence of a site being unaffected (P = 0.01) where site has minimum threat
t_{high}	Time required to remove confidence of a site being unaffected (P = 0.01) where site has maximum threat
P_{low}	The annual probability of threat affecting areas of minimum threat
P_{high}	The annual probability of threat affecting areas of maximum threat
Q	The condition that a component will be reduced to if the threat were to take effect (Only applies to places where the current condition is above Q)

Initially threat layers were produced with arbitrary value ranges (see section 3). The time that sites at the upper and lower extremes of threat could be expected to be free from the effects of each threat (with 99% confidence) were derived from expert opinion in lieu of appropriate data. These estimates were then converted to annual probabilities (see **Table 2-A**). A range transformation was then applied to the raw threat layers to produce maps of annual probability.

Regeneration

In the absence of significant threatening processes, degraded areas, subject to appropriate management, are assumed to eventually return to a pristine state. A sigmoid function was chosen as a general function to describe the dynamics of vegetation restoration (see **Figure 2-D**). The sigmoid function is useful because of its inherent quality of providing a slow take-off (i.e. after major disturbance such as loss of soil, loss of seed bank); a relatively rapid recovery after minor disturbance (eg. recovery of the understorey, recruitment of trees); and a slow recovery as condition approaches equilibrium (eg. recovery of aged trees, fallen logs, hollows). The form of the function is governed by a transition time parameter which has been set globally to 220 years. (With further parameter development transition times could be varied, eg. by vegetation community.)

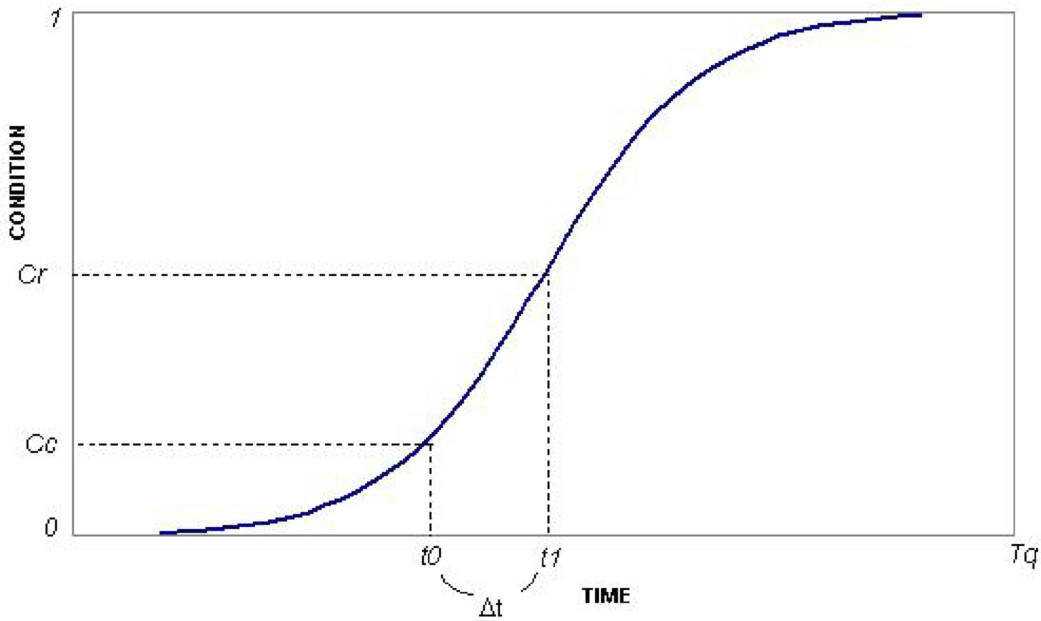


FIGURE 2-D

General function for regeneration component of future condition

The function has been applied to each one hectare grid cell in the region. Each grid cell responds individually according to its current condition (Cc) that determines $t_{0,}$ the quasi-successional stage. The future condition (Cr) after a time interval of Δt (taking the stage to t1) can be then be determined.

The probability of regeneration occurring is the probability of no threats eventuating. Regeneration therefore is the default outcome in the absence of any other pressures. In practice regeneration pressure contributes to the level of future condition in all parts of the region, but in most areas the effect of threatening processes results in a net reduction in condition over time: exceptions include degraded areas within reserves and State forests where threats are relatively low.

2.2.2 Sub-model 2: Predicting "effective habitat areas"

The effects of the spatial configuration of habitat (fragmentation, connectivity) on biodiversity has been incorporated into the modelling using a neighbourhood habitat area analysis by means of the cost-benefit approach (RACAC 2002, Drielsma *et al*. in prep). Neighbourhood habitat area is a measure of the amount of habitat (measured via vegetation condition) that is effectively connected to a particular location (the focal grid cell). The effectiveness or level of connectivity between two grid cells is dependent on the *effective* distance between them (i.e. distance as well as the nature of the intervening habitat).

Distance and intervening habitat measurements in this application are based on least cost paths. In order to increase the speed of the spatial configuration calculations a technique is employed that aggregates neighbourhood cells into clusters before the least cost paths are calculated. To minimise added error associated with decreased resolution in this process, clusters close to the focal cell (those with most significance to spatial configuration) are kept small. Clusters then increase in size with distance from the focal cell as can be seen in **Figure 2-E**. The clusters reduce the original 21x21 size window to a 7x7 matrix.

Neighbourhood habitat area (N) is calculated as:

$$N = \left(\sum_i A_f A_i e^{\frac{-d}{\alpha}}\right)^{0.5}$$

(Hanski 1999) where A_f is the condition of the focal cell, A_i is the condition of the neighbourhood cell (average for the cluster), d is the effective distance between the cells (average for a cluster) and α is the distance decay parameter that determines the rate that connectivity decays over distance[2]. Neighbourhood habitat area is a useful measure for landscape habitat analysis because in integrates the amount of habitat, its condition and the level of compactness (or fragmentation) into a single measure.

[2] α is the distance at which connectivity reduces by a factor of 1/e.

Each grid cell can then be assigned an Effective Habitat Area (EHA). EHA is a measure of the area at each grid cell weighted by proportion of the original neighbourhood habitat area remaining:

$$EHA = \left(\frac{N_E}{N_O} \right) \cdot cellsize$$

where N_E is the remaining neighbourhood habitat area and N_O is the original neighbourhood habitat area (see **Figure 4-A**).

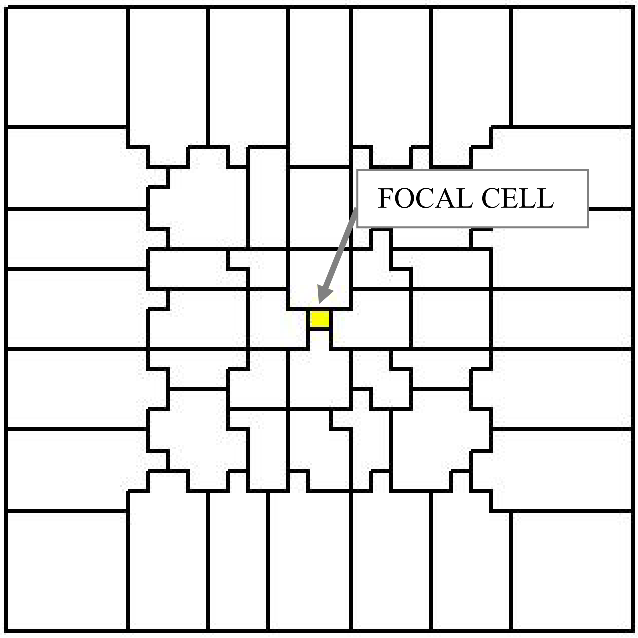


FIGURE 2-E

Cluster configuration

The permeability of individual cells is assumed here to be proportional to vegetation condition. The connectivity parameters (α values) adopted in this project were developed in the BBS WRA in 2002. These parameters are generic in so far as they are not tailored to any biological taxa; rather they are based on an analysis of the relationship between neighbourhood habitat area and vertebrate species richness. The connectivity parameters adopted range from between 2 000 meters (for minimum condition i.e. cleared vegetation) and 5 000 meters (for vegetation in 'pristine' condition) i.e. 5 000 meters of pristine vegetation provides the same degree of connectivity as 2 000 meters of cleared land. Areas with condition between the extremes are assigned α values between 2 000 meters and 5 000 meters, calculated using a linear transformation.

2.2.3 Sub-model 3: Deriving the "regional biodiversity outcome" index

The total effective area of habitat predicted to remain for each vegetation community is calculated by summing the EHA values across all grid cells within that community, weighting each value by the probability of the community of interest occurring within a given cell (as predicted by the Nandewar Vegetation project, DEC 2004). An approximate estimate of the proportion of species originally occurring in this community that are predicted to persist into the long-term future (within the remaining area of the community) is then derived through application of the species-area relationship. While the applicability of the species-area relationship to this type of prediction has been hotly debated over the past decade (eg. Simberloff 1992) the technique continues to be applied widely around the world as a rough means of predicting biodiversity loss, apparently with reasonable success (eg. Pimm & Askins 1995, Andren 1999, Rosenzweig 1999, Pimm & Raven 2000, Brooks *et al.* 2002, McAlpine *et al.* 2002). Based on the species-area relationship the proportion of species expected to persist after habitat reduction is:

$$\left(\frac{A_r}{A_o}\right)^z$$

where A_o is the original area of habitat, A_r is the remaining area of habitat, and z is a parameter reflecting the level of beta diversity, or spatial turnover in species composition, within the region of interest. In the current project EHA is used as a refined estimate of A_r that incorporates the effects of habitat configuration (based in this study on habitat configuration requirements of vertebrates as described in Section 2.2.2). We assigned a constant value of 0.27 to z for all vegetation communities (i.e. all communities were assumed to be equally variable, an approach that could, and should, be refined by future work). The value of 0.27 was based on a statistical analysis of compositional turnover in the BBS WRA floristic survey data, using generalised dissimilarity modelling (Ferrier 2002, Ferrier *et al.* 2002a) in conjunction with a technique for estimating species-area relationships from turnover data, described by Harte *et al.* (1999). This value also matches closely values for z used in similar studies around the world.

For a given land use scenario, the above analysis produces a measure of conservation effectiveness for each vegetation community in Nandewar, i.e. the proportion of species originally occurring within that community that are expected to persist into the future. In the final stage of the modelling process these individual measures are aggregated into a single overall measure of conservation effectiveness. This is achieved by calculating the quadratic diversity index Q (Izsák and Papp 2000) as follows:

$$Q = \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}\left(p_i r_i\right)\left(p_j r_j\right)$$

where n is the number of communities in the Nandewar study area, pi is the proportion of species predicted to persist in community i, ri is the relative (original) species richness of community i, and dij is the dissimilarity in species composition between communities i and j. The richness and dissimilarity values were based on an analysis of the Nandewar floristic survey datasets (Vegetation Mapping Project, NAND06) but were not included in calculations of the biodiversity index for example outputs presented in section 4.

By expressing the *Q* value calculated for a given land use scenario as a proportion (or percentage) of the maximum possible *Q* value for the region (i.e. $p = 1$ for all communities or, in other words, no habitat loss) we obtain an overall measure of conservation effectiveness (or "biodiversity outcome") for the scenario. This can be interpreted, albeit loosely, as the proportion of the region's original biodiversity predicted to persist into the future under the scenario of interest.

2.3 MAPPING CONSERVATION PRIORITIES

The cluster approach has been extended to act as a means to derive priorities for land use change across the region. The approach measures the impact to the regional biodiversity outcome index (see section 2.2.3) of hypothetically changing the management of cells and cell clusters (see section 2.2.2) across the region (RACAC 2002). At each step the biodiversity index is recalculated with the altered 'hypothetical' management taking effect to a single cell or cluster, leading to a change to the index for the region. The change to the index in each case is apportioned to the cell location(s) in an output grid corresponding to the cell or cluster that was altered. The process is systematically applied over the region so that any cell becomes part of many cluster configurations and is tested in relation to all cells in its neighbourhood acting as focal cells.

The measure of a cell's priority attained in this way is thus derived from three sources: the changed condition of the cell itself (as the focal cell); altered neighbourhood effects between the changed cell and neighbourhood cells (as focal cells); and through altered connectivity between pairs of other cells in the neighbourhood.

Examples of two priority grids are presented and further discussed in Section 4 of this report:

- Priorities for retention. The land use is altered in the model to a cleared or developed state. With each step the biodiversity index of the status quo is compared to the biodiversity index if a cluster is cleared. The priority grid provides an estimate of the current contribution of each grid cell to the regional biodiversity outcome index of the status quo.

- Priorities for conservation action. The land use is altered in the model to a conservation land use. When the conservation land use is applied most modelled threats (except Coolatai grass invasion) are removed allowing natural regeneration to occur. With each step the regional biodiversity outcome index of the status quo is compared to the index if a cluster is reserved. The output grid provides an estimate of the potential improvement provided by each grid cell to the regional biodiversity outcome index if it were to be managed for conservation.

DEC is planning to incorporate a sensitivity analysis capability in later versions of the tools. This will boost the predictive capability of the modelling when running alternate scenarios (eg. hypothetical changes to clearing rates, Government policy, land management options).

Marginal biodiversity value grid

The marginal biodiversity value (MBV) of a vegetation community is the potential gain to the regional biodiversity outcome (see section 2.2.3) that would result from the total reconstruction of that vegetation community. The MBV grid (see Figure 4-D and Figure 4-E) is a map of MBV across the region where the value of each grid cell equals the MBV of the pre-clearing vegetation community of that site. The MBV grid provides a useful measure of the status of vegetation communities in terms of biodiversity.

The 'remaining area of habitat' used to calculate MBV is based on the extent of vegetation communities across the region adjusted for local vegetation condition (degraded sites contribute less to the status of the community than pristine sites) and spatial configuration (fragmented areas contribute less than intact ones).

The MBV grid provides insights into the spatial distribution of high and low status vegetation communities without reference to local vegetation condition and spatial configuration. These additional considerations are included in the priority grids (see above, see Figures 4-F, 4-G, 4-H and 4-I).

3 Derivation of data inputs

The Landscape Conservation assessment approach employed for the Nandewar WRA consists fundamentally of a GIS analysis and implementation of computer-based decision support tools. As described in chapter 2, the modelling framework is reliant on the input of regional spatial coverages (see **Figure 2-B**). Key input themes include:

- biodiversity surrogates
- spatial context (configuration)
- an indication of condition
- information on threats

Data requirements for this landscape assessment fall into two broad categories:

- spatial (geographically specific, mappable) data
- other information/data utilised to derive modelling parameters

Spatial data sets include:

- collated existing data sets: Landsat satellite imagery, land capability mapping, tenure information, environmental surfaces such as geological climatic terrain fertility and digital elevation models, environmental linework (eg. watercourses) and infrastructural linework (eg. roading);
- resultant outputs from other Nandewar WRA projects, in particular, vegetation community mapping and modelling (DEC 2004), API canopy polygon mapping (DEC 2004), geology (Dawson *et al.* 2004) and crown land tenure (DIPNR 2004); and
- derived spatial layers developed during the course of this project (eg. cost grids of distance from roads, rivers, forest edge used as components in risk grid development).

Major data coverages derived for the Nandewar Landscape Conservation project include:

- current landcover (from satellite imagery)
- land use / land management categories
- current (vegetation) condition
- clearing risk
- land degradation risk
- logging risk
- firewood collection risk
- Coolatai grass invasion risk

The remotely developed or derived data coverages described in sections below represent regional scale information that should provide an acceptable level of either proportional accuracy or surrogacy for the respective features. In some cases these data have low spatial accuracy (eg land use categories) and should not be interpreted at the local (patch or property) scale.

Due to the advantages of high level of detail and complete regional coverage, Aerial Photographic Interpretation (API) has been extensively utilised in development of derived spatial layers for this project. However, as described in the Nandewar Vegetation report (DEC 2004), mapping specifications varied between the two main API programs conducted for the WRA and also amongst the several other (less extensive) API data sets collated. These differences in mapping specifications across the amalgamated API information have resulted in considerable variability in attribution of captured vegetation structural and floristic patterns. This data variability carries overs as inconsistencies or discontinuities into the spatial layers derived for this project. Implications of this variability include lower confidence in predictive outputs where API data was limited.

3.1 BIODIVERSITY SURROGATES

As direct mapping across the study area of various elements of biodiversity (vertebrate and invertebrate assemblages, plant species) is not available, the modelling framework employed in the Landscape Conservation assessment utilises a surrogate measure of species distributions. Surrogacy provides a means of dealing with geographical information gaps by providing complete regional coverage assuming a correlation with real species distributions (Ferrier and Watson 1997).

The Nandewar Vegetation project (DEC 2004) provided vegetation units that were adopted as the primary biodiversity surrogates. Vegetation mapping has proven to be a useful surrogate for species diversity (e.g. Braithwaite *et al*. 1988; Woinarski *et al*. 1988). The Nandewar vegetation units were derived from the numerical analysis and classification (utilising PaTN) of 2 853 full floristic (20x20m) sample sites across the region. Generalised dissimilarity modelling (GDM) was undertaken in relation to 22 abiotic environmental surfaces and interpolated across the regional landscape. The distribution models were constrained by available API mapping via candidacy or allocation matrices of the relationship between the vegetation communities derived from classification and API canopy units and understorey codes. Refer to the Vegetation report (DEC 2004) for detailed description of vegetation analysis, classification and modelling procedures. The resultant constrained probability surfaces predict the pre-clearing spatial extent of each map unit in Nandewar and have been utilised as the primary biodiversity surrogates for the landscape assessment.

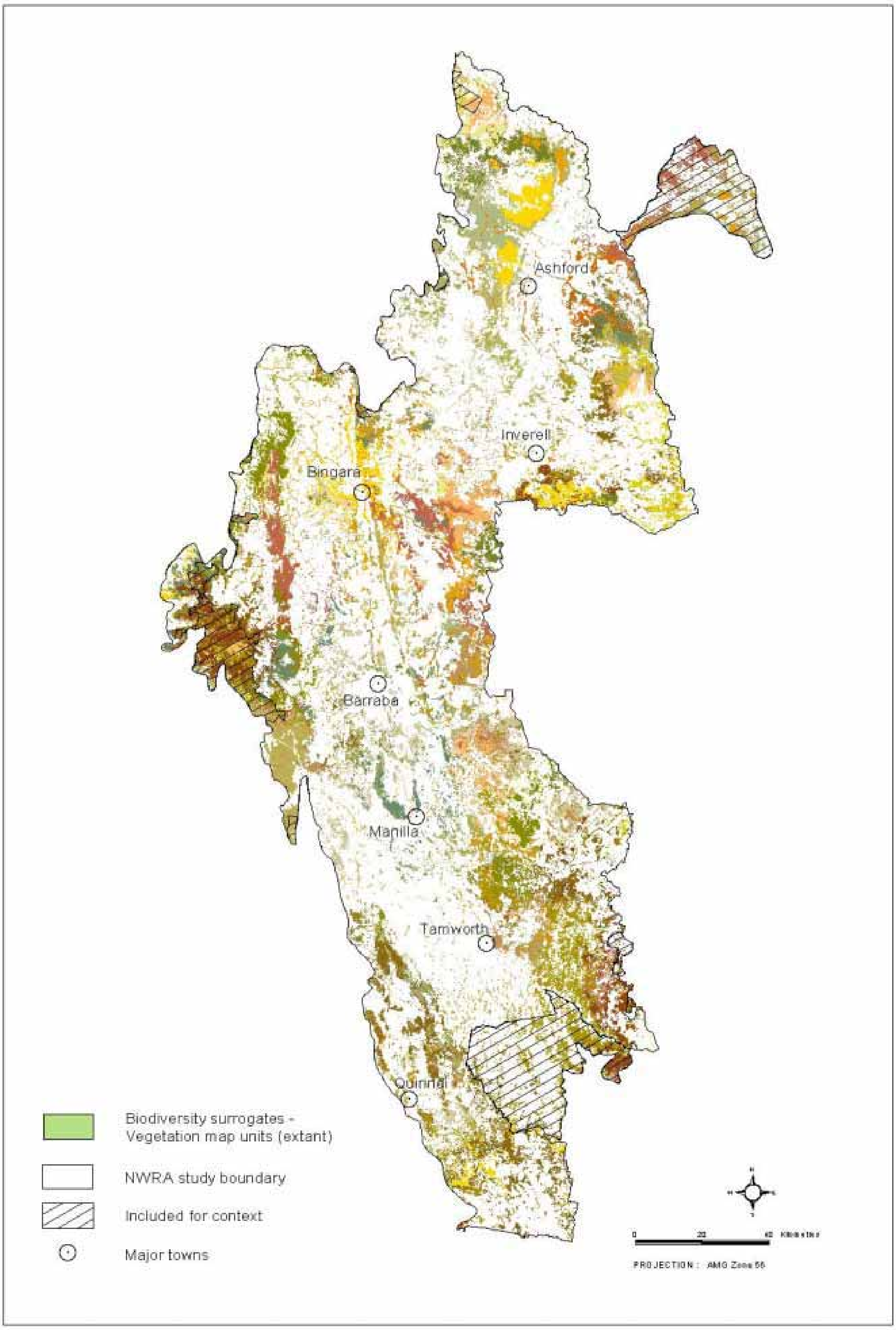


FIGURE 3-A

Vegetation community map units utilised as biodiversity surrogates

The project has not incorporated alternative surrogates (for example species models) and recognises that the vegetation community models do not cover the requirements of all species, particularly fauna and threatened species. The landscape assessment is likely to assist general rather than specific fauna conservation and have indirect and fortuitous benefit for threatened species. This should be supplemented by consideration of the needs of individual species of particular conservation concern.

Figure 3-A displays a composite map of the component vegetation units that served as the biodiversity surrogates.

3.2 CONDITION

An integral component input of the landscape conservation assessment model is some measure of vegetation condition. As condition mapping based on field/site data and documented vegetation condition benchmarks do not exist for the study area, an indicative coverage of relative condition was derived from the best available data source capable of providing some level of surrogacy: the Aerial Photographic Interpretation (API) data.

The technique relies on the assumption that general vegetation condition can be inferred primarily from interpretation of canopy condition, prominent disturbance and land use indicators. This limitation is moderated by the fact that careful API of woodland and forest vegetation of the north-west slopes includes insights from below canopy level (particularly as canopy density decreases).

API mapping attributes are used to provide an (indirect) indication of current vegetation condition. An assumption is made that vegetation condition is partitioned equally between the tree canopy and the understorey, and attributes are scored for the relevant strata affected.

API attributes used in the derivation of current condition are:

- CCP - crown cover percentage (**Table 3-A**) - the proportion of map polygon area within boundaries of (solid) tree crowns. Typically, open forest/woodland CCP = 50-80%;
- disturbance indicators (**Tables 3-B, 3-C**) - assigned where disturbance is obvious and prevalent over >30% of polygon;
- RCCP (**Table 3-D**) - regrowth relative crown cover percentage - regrowth proportion in relation to overall tree canopy cover assigned to eucalypt dominated polygons; and
- land use tag (**Tables 3-E, 3-F**) - description of prevalent land use regime if discernible, eg cropping or pasture.

TABLE 3-A

Crown cover percentage (canopy condition only)

CCP crown cover percentage	canopy condition score
>50%	50
20-50%	35
10-20%	15
5-10%	7
1-5	3
<1%	0

TABLE 3-B

Disturbance tags (canopy condition only)

Canopy disturbance indicators	canopy condition score factor
Negligible disturbance	1
General disturbance	0.8
Dieback/fire/ringbarking	0.7
Cleared/logged	0.6
Buildings/rural infrastructure	0.6

TABLE 3-C

Disturbance tags (understorey condition only)

Understorey disturbance indicators	understorey condition score factor
Negligible disturbance	1
Erosion	0.8
Weeds	0.8
General disturbance	0.8
Grazing	0.6

TABLE 3-D

Regrowth relative crown cover percentage tag

Regrowth tags	Condition score factor
Trace of regrowth only (<10% RCCP)	1.0
Some regrowth (10-30% RCCP)	0.9
High proportion of regrowth (>30% RCCP)	0.8
Very high proportion regrowth (30-50% RCCP)	0.8
Very high proportion regrowth (50-70% RCCP)	0.7
Extremely high proportion regrowth (>70% RCCP)	0.6

TABLE 3-E

Land use tags (understorey condition only)

Land use tags (impacting on understorey)	understorey condition score factor
Pasture	0.5
Erosion; clearing	0.4
Previous cropping	0.3
Cropping	0.1
Mining	0.1

TABLE 3-F

General land use tags applied to overall condition

General land use tags	overall condition score factor (direct where no CCP score)
Plantation native	0.4
Plantation pine	0.1
Urban	0.01
Forest	0.7
Non forest	0.25
Water storage (Dam)	0
Horticulture	0.01
Animal production	0.01

The detail and predicted accuracy of condition mapping is directly related to the availability and quality of mapping attributes that have been used as inputs. API data sets collated for the Nandewar WRA were drawn from several different projects (see DEC 2004) using varying mapping specifications which has resulted in incomplete availability of mapping attributes (see **Figure 3-B**). Implications of data variability include reduced confidence in condition mapping where initial data availability was low. In order to reduce differences due to data quality, API polygons (areas delineated according to mapping specifications) were grouped according to the attributes. Eleven data groups (**Table 3-G**) represent a range of data richness from a simple forest/non-forest code (limited in extent) through to much of the study area which has canopy cover, disturbance tags, land use tags and regrowth proportion coding.

TABLE 3-G

API data groups

Data group	Brief Description	Attribution
A	Negligible disturbance	Disturbance tag "N"
B	General Land Use	GLU tag
C	Canopy cover score only	CCP code only present
D	Canopy Cover & Understorey Land Use only	CCP and Land use (understorey condition) only
E	Understorey Land Use only	Land use (understorey condition) only
F	CCP and either Understorey disturbance or Canopy disturbance tag +/- regrowth tag	CCP , disturbance tag and regrowth tag (optional).
G	No CCP, Disturbance (Understorey or Canopy) and regrowth tag	Disturbance & Regrowth tag
H	CCP, Land Use (Understorey), Regrowth tag +/- Disturbance tag	CCP, Land Use (Understorey), Regrowth and Disturbance (optional)
I	Special feature - Non forest	Special Feature, disturbance tag (canopy or understorey)
J	Special feature - Forest	Special Feature only
k	CCP, Land Use (Understorey) and Disturbance (Understorey only)	CCP, Land Use (Understorey) and Disturbance (Understorey)
L	Erroneous polygons	Insufficient information

Group I contains many special features which are 'non forest' in nature such as heaths, swamps, riparian areas and grasslands while Group J consists of forested areas such as native remnants, river oak and gully complex. Where CCP is not recorded, disturbance information has been used where available or a general expected mean condition for each special feature type has been applied.

A script assesses API polygons for available attributes and assigns the polygon to the most appropriate data group (**Table 3-G**). Polygons are assessed iteratively and

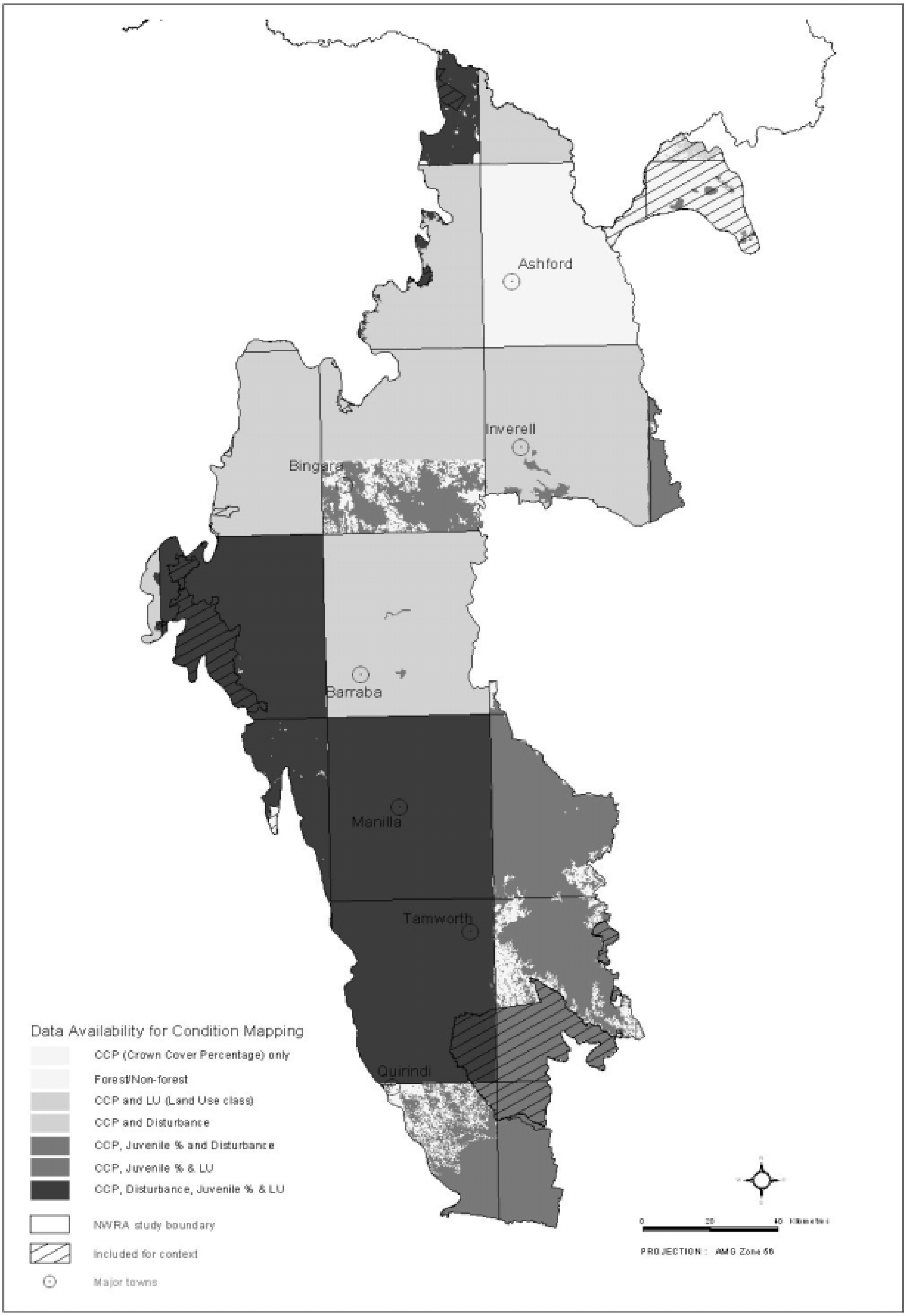


FIGURE 3-B

Availability of API mapping attributes independently of other polygons and a current condition score is calculated based on the formula:

*Current Condition score = { [CCP score] * [disturbance tag factor : Canopy] * [RCCP factor] } + { 50 * [Disturbance tag factor - understorey] * [Land use factor: understorey] }*

Modifications to this formula are required to make allowances for the absence of one or more API attributes.

In areas where only 'Non Forest' information is available or where CCP only exists, Landsat 7 data has been incorporated to identify areas of cropping, improved pastures and small remnant vegetation patches. Following integration of Landsat data the API condition polygon layer is converted to raster format (25m cells) and scaled from 0 to 100 (with 100 representing maximum ecological condition). Current condition across Nandewar WRA as estimated from available API attributes is presented in **Figure 3-C**.

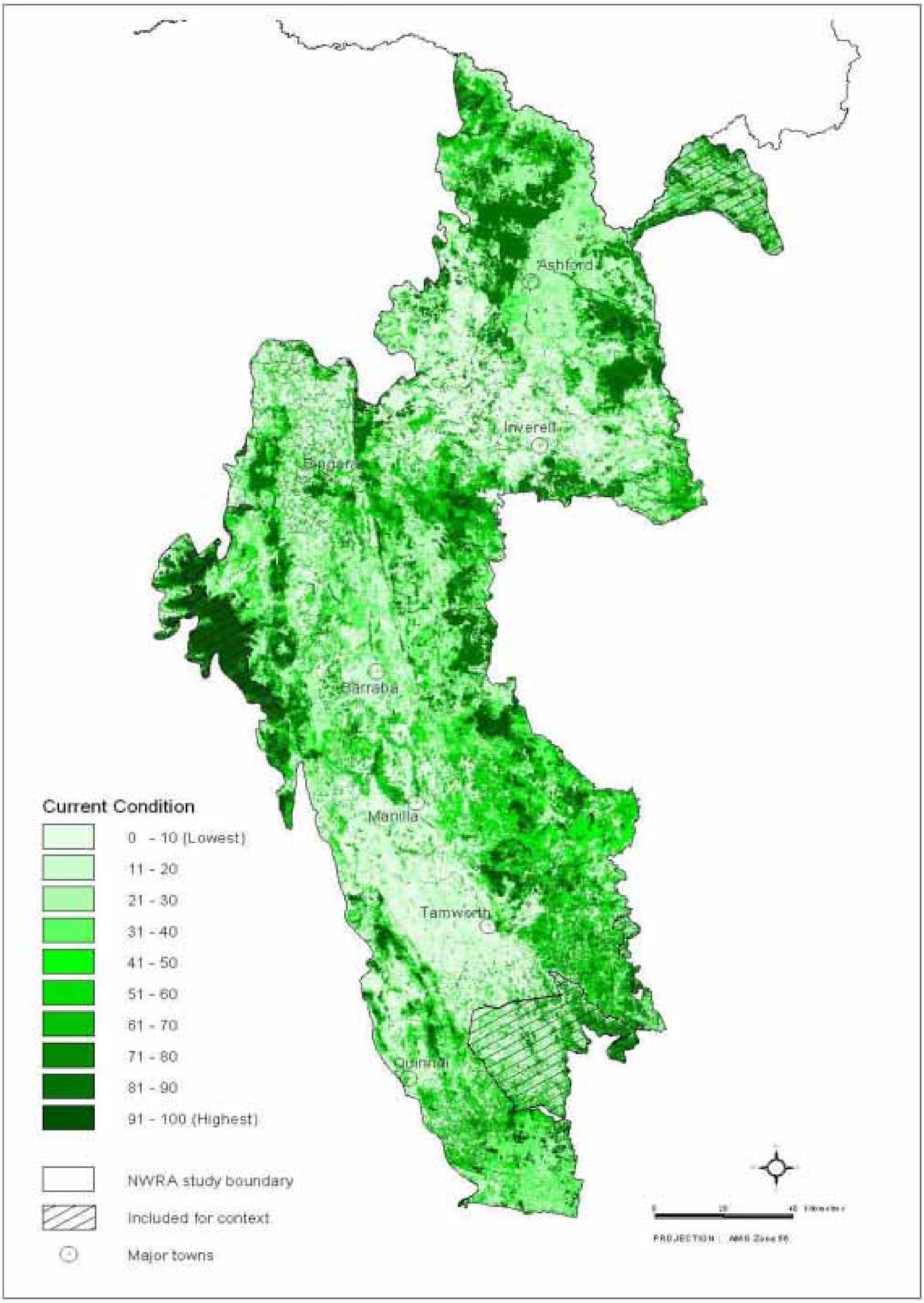


FIGURE 3-C

Current vegetation condition

3.3 LAND USE

Broad land use categories have been partitioned across the Nandewar WRA study area. They are generalised classes derived from a combination of API and Landsat classification (landcover) with consideration of land tenure (**see Figure 1-B**) and existing land capability mapping (developed by DIPNR). The principal determinant has been vegetation canopy cover (with priority typically given to the API dataset). Despite the classes being coarsely defined, they reflect a general trend of land use at the bioregional scale: there is a predictable pattern of cropping – intermittent / prior cropping and/or intensive grazing - grazed rangeland - moderate cover remnant - high cover remnant - reserve; with increasing topographic relief and decreasing fertility. The area of each of these broad land use categories within the Nandewar WRA study area is presented in **Table 3-H** and the criteria used in their derivation are listed in **Appendix 3.1**.

TABLE 3-H

Area of each broad land use category described for Nandewar study area

land use category	ha	%
Conservation (formal reservation)	28 041	1.1
Grazing (rangelands)	910 355	35.0
Informal reservation	10 336	0.4
Intensive cropping	291 205	11.2
Logging	27 245	1.0
Intermittent / prior cropping and/or intensive grazing of introduced pastures	526 134	20.2
Low intensity use	349 953	13.5
Moderate intensity use (native ecosystems)	437 203	16.8
Non natural (urban mining or dams)	19 952	0.8

These categories shown in **Figure 3-D** could be used as current land use classes in development of land use change scenarios for the bioregion. On account of the considerable heterogenity within the broad land use categories and instead of assuming uniform condition within each category, the project developed threat or influence coverages to more realistically model changes in condition.

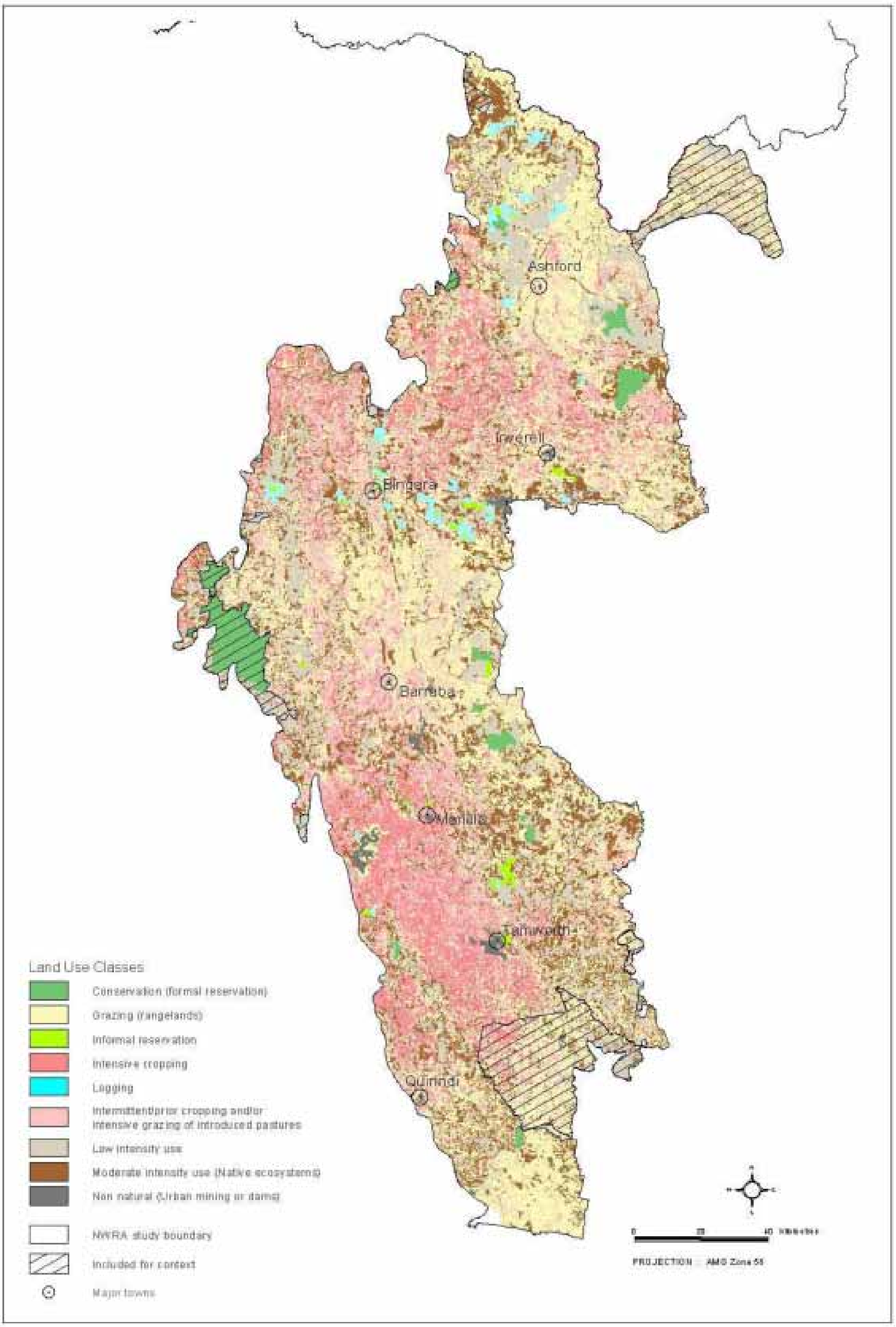


FIGURE 3-D

Land use classes

3.4 THREATENING PROCESSES

Clearing of native vegetation, fragmentation of remnant vegetation, increased salinity and firewood collection are threats to biodiversity in the highly modified regions of southern and eastern Australia (Australian State of the Environment Committee 2001, Commonwealth of Australia 2002, Benson 1999). Other widespread and pervasive threats to biodiversity include overgrazing by domestic livestock, exotic weeds, feral animals and changed fire regimes.

The project has derived probability surfaces that attempt to reflect the likely *relative* impact of threatening processes on the persistence of biodiversity across the landscape.

The probability surfaces for threats developed during this project are:

- land clearing (of native vegetation)
- land degradation
- logging
- firewood collection
- coolatai grass invasion

These are discussed in more detail below.

3.4.1 Land clearing

The Commonwealth of Australia has listed Land Clearance as a key threatening process under the *Environmental Protection and Biodiversity Conservation Act 1999* and the Australian Terrestrial Biodiversity Assessment (Commonwealth of Australia 2002) states that vegetation clearing is the most significant threat to species and ecosystems in eastern Australia. Clearing of native vegetation is also listed as a key threatening process and recognised as a major factor contributing to loss of biological diversity under the New South Wales *Threatened Species Conservation Act 1995*. It is well established and documented that removal of native vegetation represents perhaps the gravest risk to biodiversity through direct habitat loss (Glanznig A & Kennedy M 2000, MacNally 1999, SEAC 1996, see bibliography in NSW Scientific Committee's final determination for Clearing of Native Vegetation).

Recent State government policy reforms relating to native vegetation are directed towards cessation of 'broad scale land clearing'. However it is perhaps unrealistic to assume that this will directly transpire to nil loss of remnant vegetation across the landscape because of exemptions, clearing conducted under authorised consent and marginal attrition. As such, this project has maintained an estimate of the likelihood of vegetation loss in the landscape assessment.

A contemporary 'risk of clearing' coverage was derived from sparse land clearing statistics from DIPNR vegetation clearing consents database for the period mid 1995 to 2000. Areas applied for clearing were converted to an annual rate and expressed per land capability classes. DIPNR attempted to provide clearing application records for the subsequent period 2000-4. Those additional data would have strengthened confidence in clearing projections. Unfortunately technical difficulties precluded data provision. As the contemporary risk calculation was based on only few approved applications it was thought to be a poor estimate. Furthermore, records only represent clearing applied for under consent and do not account for clearing under exemptions or illegal clearing. Recent studies indicate that actual clearing rates could be eight to ten times greater than previous estimates based on interpretation of changes in vegetation cover (> 20%) using satellite imagery (Cox *et al.* 2001, Bedward *et al.* 2001). Owing to the above limitations and in consultation with land clearing / management officers from DIPNR, the risk model derived from DIPNR clearing application data described above was not considered sufficiently robust and was discarded.

On account of uncertainty associated with recent vegetation management reforms and pending development of regulations and guidelines required to support the new *Native Vegetation Act 2003*, an alternative model of areas likely to be 'susceptible to' or 'attractive' for future vegetation clearance was developed. This approach recognises that: despite the best intention of legislation, clearing continues; certain parts of the landscape are more attractive for conversion for agricultural purposes than others; and gross habitat loss has the most significant and irreversible impact on biodiversity.

The clearing model is essentially a spatial intersection of *remnant vegetation* with *fertility*, *slope* and *forest edge gradients*. Derivation involved selecting remnant vegetation (>10% canopy cover from API) on freehold and leasehold tenures in lieu of information to suggest differential clearing rates across those tenures (Ede, A., DIPNR, pers. comm., April 2004). The remnant freehold and leasehold vegetation was then intersected with fertility and slope classes and resultant combinations scored based on the assumption that fertile and flat lands will be cleared preferentially. Fertility was derived by ranking 21 geological classes along a fertility gradient and combining this with a wetness index derived from a digital elevation model.

Forest edges are regarded as areas of increased likelihood of new or further clearing on account of pragmatic constraints of access and because edges form the most immediate areas for potential addition to adjacent land uses. As such a cost grid was built which apportioned reducing likelihood of clearing with increasing distance from edge. This index (**Table 3-I**) was combined with the remnant freehold and leasehold vegetation fertility/slope combinations (**Table 3-J**) to produce the risk of

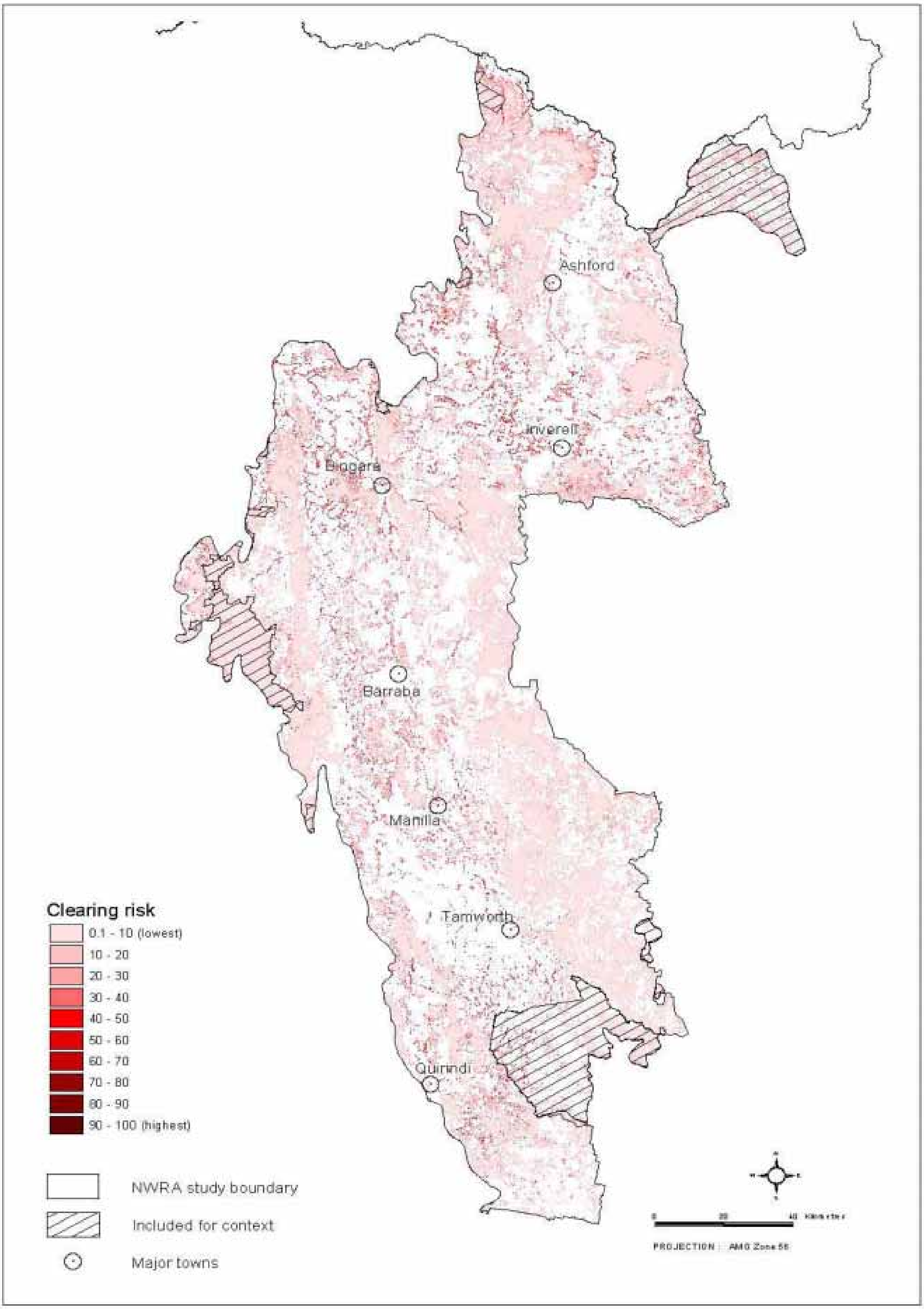


FIGURE 3-E

Land clearing risk

TABLE 3-I

Proximity to forest edge weightings

Proximity to edge (m)	Weighting
0-25	50
26-50	40
51-75	35
75-100	30
101-200	25
201-500	20
501-1000	15
>1000	10

TABLE 3-J

Slope class weightings for clearing risk

Slope class (degrees)	weighting
0-5	100
6-10	80
11-15	50
16-30	10
>30	1

land clearing surface. This was then converted to an annual probability (see Section 2.2.2) for incorporation in the landscape modelling.

Figure 3-E maps an estimated risk of land clearing across the Nandewar WRA study area (without consideration of evolving legislative constraints). New South Wales vegetation clearing reforms should afford future legislative protection to some such areas presently modelled as 'susceptible' to clearing (for example flat fertile remnants). With confidence in protection of such areas, a revised clearing risk model could be developed based on the finalised regulations and guidelines formulated for the *Native Vegetation Act 2003.* Substantial change to this (or another) risk surface would necessarily result in altered predictions of future condition and thus changes to biodiversity index calculations and prioritisation (refer section 2).

3.4.2 Land degradation

Livestock ranging across the landscape is one of the most extensive land uses on the north-western slopes of New South Wales and the most common farming system across Nandewar (Hassall & Associates 2004). Sustained grazing has impaired landscape function and may threaten the persistence of some native species in rangelands (Benson 1999, Landsberg *et al*. 1999a, Freudenberger 2000, Jansen and Robertson 2001).

Grazing by cattle or sheep can cause significant changes to the structure and composition of native vegetation. This habitat alteration impacts on native fauna due to changes in the availability of resources such as food and shelter. Heavily grazed areas can suffer from trampling, localised erosion and nutrient concentration. Impacts of grazing on vegetation arise due to selective grazing by stock and differential sensitivity to grazing between plant species. Prolonged overgrazing may result in loss of perennial grass species and a dominance of annuals, increasing susceptibility to the effects of drought and erosion.

A general land degradation risk grid was developed in an attempt to take into account the impacts on biodiversity of elevated grazing pressure, including direct removal of plant biomass and the associated impacts of weed incursion (Hobbs 2001), trampling, soil compaction and erosion (loss of sediment and nutrients by wind and water). The intent of the layer is to incorporate the land degradation effects of extensive domestic livestock grazing, principally cattle, in Nandewar.

The layer is based on *slope*, *fertility* and *proximity to water* (substantial streams and other watering points). The principal assumption is that flat or gently sloping areas of high fertility that are proximal to perennial water are the most susceptible to the degradation processes associated with livestock grazing. This impact on biodiversity is then assumed to decrease with increasing slope (topographic steepness), decreasing fertility and distance from available fresh water.

Five classes of slope were used in conjunction with the fertility gradient (described in Section 3.4.1) based on 21 broad geological types. Topography or slope is regarded as a prime determinant of the temporal and spatial distribution of livestock across the landscape (**Table 3-K**). Nonetheless steep slopes were assigned up to 50% weighting on account of the *proportionally* high impact of stock on steep terrain due to inherent sparser ground cover and more erodable soils upslope and higher resilience on flats.

A cost grid of distance from permanent drinking water was developed through ESRI *ArcInfo* based on the line features of modelled stream order (greater than 3rd order) combined with mapped non-natural watering points (small dams and bores). Stream orders 1-3 were considered ephemeral and excluded. Stock watering points were included as their provision has reduced the spatial heterogenity of grazing across the landscape (Landsberg *et al.* 1999b, Freudenberger and Landsberg 2000). Such water sources create piospheres, circular zones of grazing effect around watering points that diminish in intensity with distance. The proportional use of areas by livestock in relation to distance from water (**Table 3-L**) was taken from Lyons and Machen (2001).

TABLE 3-K

Slope class weightings for degradation risk

Slope class (degrees)	weighting
0-5	100
6-10	85
11-15	50
16-30	20
>30	10

TABLE 3-L

Use of areas by livestock in relation to distance from water

Distance from water (km)	% use*
0 - 0.8	50
0.8 - 1.6	38
1.6 – 2.4	26
2.4 – 3.2	17
3.2 – 4	12

* after Lyons & Machen 2001

Additionally, a 30m buffer was created on all mapped water courses and their associated water bodies (lagoons, anabranches, oxbows etc) to represent a riparian zone of intensive use by livestock (**Table 3-M**).

TABLE 3-M

Stream buffer weightings

Stream order buffer classes	weighting
Major rivers (+ associated water bodies)	100
Named creeks (+ associated water bodies)	80
Minor streams	60
Non-riparian	40

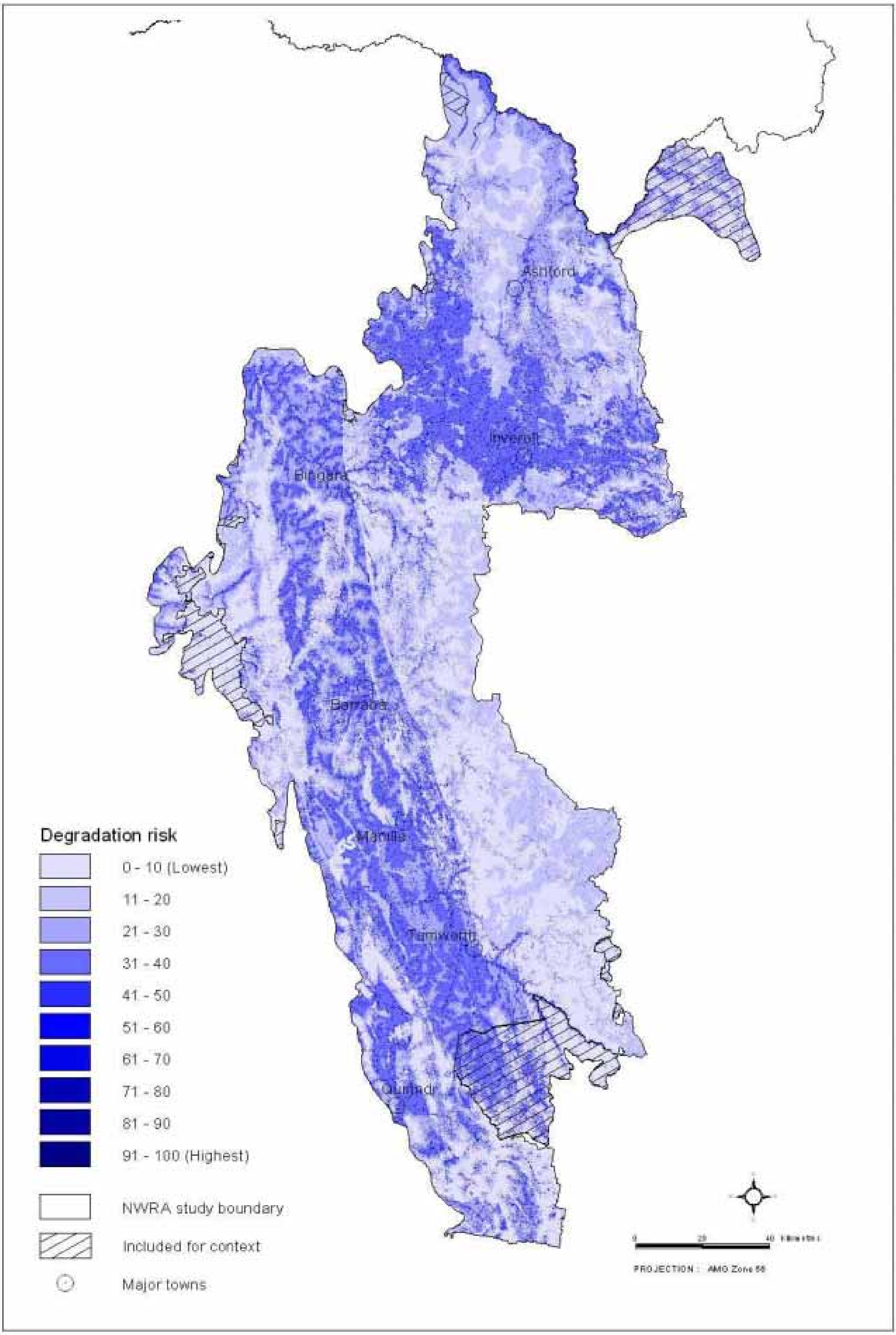


FIGURE 3-F

Land degradation risk

A degradation risk score is then calculated as:

*[Geo-fertility (scaled)] *[slope score] * [distance from water factor] * [stream buffer weighting].*

Final risk scores are indexed to 100 and subsequently converted to annual probabilities (see Section 2.2.2) for combination with other risk layers. The degradation risk derived for Nandewar WRA is illustrated in **Figure 3-F**.

3.4.3 Logging risk

An initial ruleset was developed to map the likelihood of harvesting within Nandewar State forests under the current scenario of a sawlog industry based solely on white cypress pine (*Callitris glaucophylla*). The concept of logging presenting a threat is based on the assumption that the impacts of timber harvesting may exert a variable and adverse effect on biodiversity. Some silvicultural practices can impact negatively on a range of critical habitat attributes including understorey and canopy structure, species composition and the availability of hollow-bearing and nectar producing trees (Date and Paull 2000, Gibbons and Lindenmayer 2002, Norton 1996).

To adopt a long term modelling approach the initial ruleset has been extended to reflect the relative likelihood of timber harvesting activities occurring across the landscape, i.e. across all tenures and not restricted to white cypress pine. The rational behind this is that:

- a significant amount of the timber resource has historically been derived from tenures other than State Forests (i.e. Crown Timber Lands and private property) and some timber is likely to be sourced from these tenures in the future; and
- although the sawlog industry in the Nandewar study area is based largely on white cypress pine currently, this may change within the timeframe of the landscape modelling (eg. 20-100yrs) and hardwood forests may not always be precluded from logging activities.

The primary premise of the 'logging risk' layer is that risk is directly related to *topography* (i.e. slope and access constraints), current *stand composition* and *condition*. Key attributes contained within the available API mapping were intersected with slope classes as detailed in **Table 3-N**.

TABLE 3-N

Slope classes for logging risk

Slope (degrees)	Score	risk
0-6	3	high
7-15	2	mod
15-30	1	low
> 30	0	nil

Key API mapping attributes considered informative in assessing relative logging risk were CCP (crown cover percentage, **Table 3-O**) and level of stand dominance by white cypress pine or merchantable eucalypts based on the floristic composition of the canopy. For areas other than SFNSW tenure, canopy composition (**Table 3-P**) was derived from API mapping collated during the Nandewar WRA .

TABLE 3-O

CCP crown cover classes (from API mapping)

CCP code	crown cover percentage	score	risk
3, 4	>50	3	high
2	20-50	2	mod
1	10-20	1	low

TABLE 3-P

Canopy composition (from API mapping)

Canopy composition and level of dominance	Score	risk
C. glaucophylla dominant; (or codominant with *E. crebra/E.andrewsii*)	3	high
C. glaucophylla co-dominant	2	mod
E. crebra/E. laevopinea/E. macrorhyncha/E. andrewsii/E.mckieana/E.sideroxylon dominant; (plus lesser occurrences of *E.subtilior/E.youmanii*)	2	mod
E. crebra/E. laevopinea/E. macrorhyncha/E. andrewsii/E.mckieana/E.sideroxylon co-dominant; (plus lesser occurrences of *E.subtilior/E.youmanii*)	1	low
codominant occurrence of above listed hardwoods or associated occurrence of *C.glaucophylla*	1	low
non-merchantable species	0	nil

(less extensive minor combinations not tabulated here)

As discussed at the beginning of this chapter API attribution varied across the Nandewar WRA study area with some areas having only one relevant API attribute (eg. CCP) mapped that could contribute to the component scores that made up the overall logging risk. In such areas where there was no API floristic coding (eg. parts of Ellerston, Murrirundi, Clive and Bundarra mapsheets), a general merchantable score of 1 (low) was applied in lieu of floristics. Some of the API mapping failed to distinguish between *Callitris glaucophylla* and unmerchantable black cypress pine *C. endlicheri.* Such polygons were assigned a canopy composition score:

- according to the *Callitris* species recorded in survey plots within those polygons (where point data available);
- according to common 'descriptor notes' if available with API;
- of 2 if associated with *E. crebr;* or
- as appropriate by inference from locality or geology.

Where canopy composition was deemed to be non-merchantable, a logging risk score of zero was assigned.

For State forest tenure, a canopy composition score was assigned based on the SFNSW forest type mapping provided for Nandewar State forests. A commercial status had been assigned by SFNSW to all forest type API polygons mapped across the area. This commercial status was used to provide the appropriate canopy composition score for the logging risk layer as indicated in **Table 3-Q**.

TABLE 3-Q

Canopy composition score for SFNSW API mapping based on commercial status

SFNSW commercial status	allocated merchantability for logging risk layer (ha)			
	nil	low (1)	moderate (2)	high (3)
(1) commercial spp	0	0	0	25 539
(2) non commercial species	4 178	146	0	0
(3) commercial species but low site quality or rocky	96	3 076	0	0

Probabilities were assigned to broad tenure groupings to express an estimated relative likelihood of timber harvesting occurring in **Table 3-R** below.

Individual grids for CCP, slope and canopy composition /dominance classes were created. The product of the respective scores was then intersected with the tenure mapping to produce a logging risk grid (see **Figure 3-G** over).

The logging risk score is then calculated as:

*logging risk = [tenure probability] * ([canopy composition score] *[ccp score] * [slope class score])*

This was finally converted to an annual probability of logging occurring based on the assumption that *maximum risk* areas within SF PMI4 have full likelihood of being harvested within 30 years and minimum risk areas are likely to remain unharvested for hundreds of years (see **Table 2-A**). A limitation in the resultant risk grid is that it does not discriminate variation in intensity of logging operations (no available information) and therefore associated potential impacts for biodiversity.

TABLE 3-R

Estimated logging probabilities for main tenures across Nandewar study area

Tenure	Estimated probability
State Forest PMI 4	100
Leasehold	50
Freehold	30
Crown Reserve	10
State Forest PMI 2 (& PMI 3, PMI 7)	10
Travelling Stock Reserves	10
DEC estate, State Forest Flora Reserve (ie PMI 1)	0

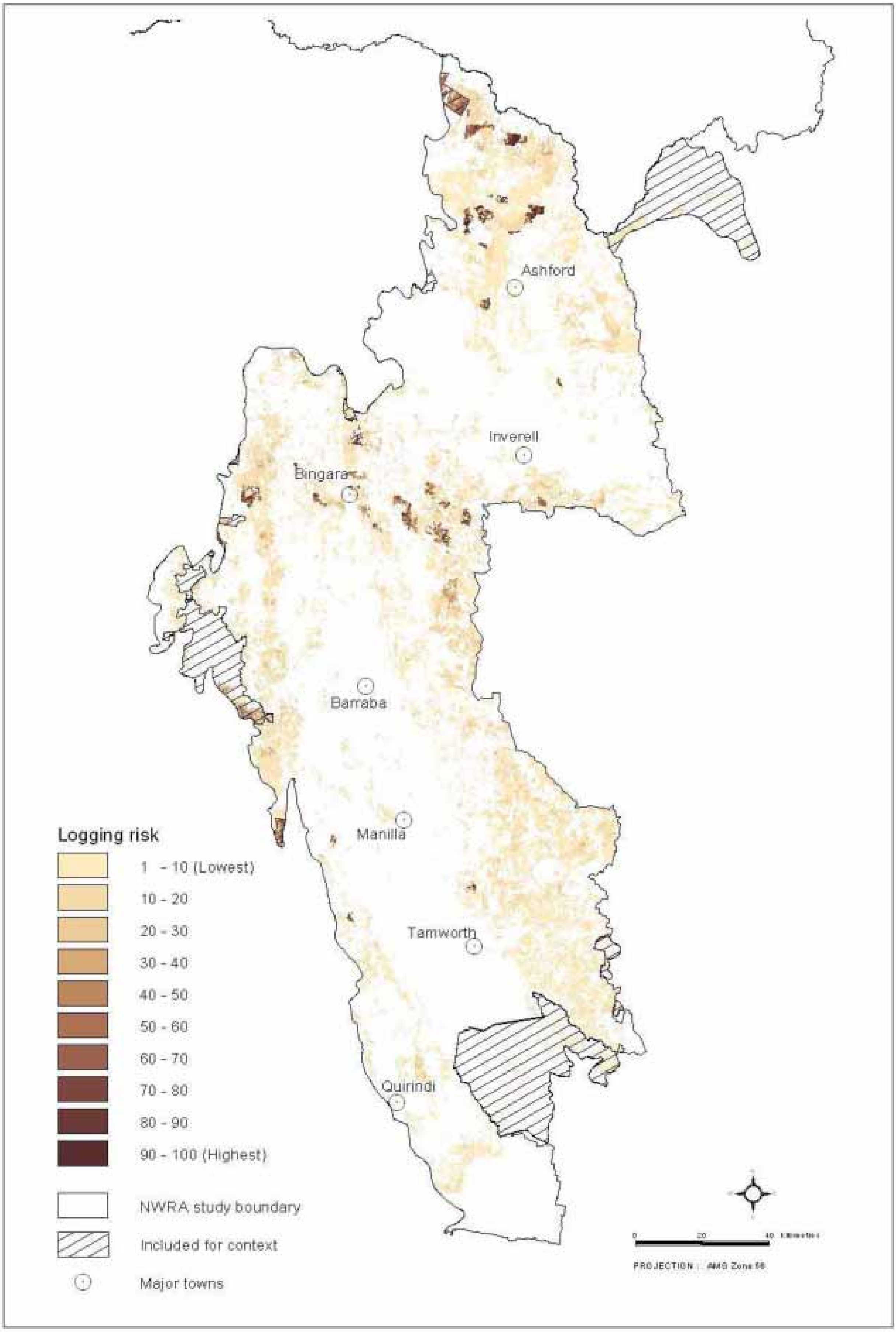


FIGURE 3-G

Logging risk

3.4.4 Firewood collection risk

Accelerated and ongoing removal of standing dead trees and woody debris on the ground caused by human activity has been recognised as a factor contributing to loss of biological diversity (ANZECC 2001). Accordingly, removal of dead wood and dead trees has been listed as a key threatening process under the New South Wales *Threatened Species Conservation Act* 1995. Evidence suggests that firewood collection exerts an impact on a whole spectrum of biodiversity (Andrew *et al*. 2000, Gunning 2000, Driscoll *et al*. 2000, Garnett and Crowley 2000, Laven and MacNally 1998, Trail 2000).

Possibly the most serious expected consequences are the likely effects on ecosystem processes such as nutrient cycling and plant establishment, because of the potential loss of highly specialised species of invertebrates and fungi (Driscoll *et al*. 2000). Inland forests and woodlands of Australia's lower rainfall zones appear to be the ecological communities most threatened by firewood collection, because they comprise popular firewood species, have been most extensively cleared for agriculture and have very slow growth rates. Some 20 species of bird are nationally threatened by firewood collection and plants may also be impacted by direct removal, alteration to micro-habitats, and introduction of competitors (weeds) and pathogens (Driscoll *et al*. 2000).

An initial firewood risk coverage was developed by categorising and rating mapped tree species (from canopy floristic coding within available API mapping) into high, moderate and low resource classes. These resources classes were based on the characteristics and desirability of those tree species as firewood and their relative dominance within the canopy (see **Table 3-S**).

The national study of firewood use (Driscoll *et al*. 2000) notes that box and red gum are the preferred species in New South Wales, and more locally and specifically, yellow box (*Eucalyptus melliodora*), Blakely's red gum (*Eucalyptus blakelyi*) and *Eucalyptus calignosa* were found to be the principal species burnt in the Armidale district (Wall and Reid 1993).

TABLE 3-S

Firewood resource value classes

Canopy species	canopy dominance	firewood value
Box: *E. albens, E. melliodora, E. microcarpa*; redgum: *E. blakelyi, E. camaldulensis*; ironbarks: *E. sideroxylon, E. crebra*	dominant or codominant	High (3)
	associate	Moderate (2)
Stringybarks (particularly *E. laevopinea, E. macrorhyncha*); *E. andrewsii*; ironbarks and redgums other than above	dominant or codominant	Moderate (2)
	associate	Low (1)
Applebox, bundys, bloodwood	any	Low (1)
Other		Nil (0)

Data on the origin of firewood collected by consumers in relation to land tenure is presented at a national scale in Driscoll *et al.* (2000) and in the context of a rural town in northern New South Wales by Wall and Reid (1993). The latter study was considered more relevant to the Nandewar study area in terms of geography, climate, scale and available fuelwood species. A tenure rating for firewood consumed in Nandewar was derived using the percentage of firewood collected from various tenures in the Armidale district as reported by Wall and Reid (1993) in relation to the proportion of resource identified (in the previous step using API mapping) across those tenures in Nandewar.

TABLE 3-T

Firewood resource tenure rating

Tenure	proportion of Nandewar fuelwood resource available	proportion of firewood collected (Wall & Reid 1993)	derived tenure bias for firewood collection
Private (includes leasehold)	91.44	30.7	0.3357
State forests	4.47	0.4	0.0895
roadsides or other public lands	4.09	4.4	1.0758
State forests, roadside and crown combined	8.56	4.8	0.5607

Note. Tenure information was not available for the 64.5% of firewood purchased, principally from small scale contractors, as opposed to collected, in the Wall and Reid (1993) study.

Leasehold land was treated the same as freehold as no distinction was made in the above studies. SFNSW issues between 75 and 100 private firewood collection licenses annually, principally from Inverell, with an average of 2 tonnes of firewood removed per licence (Hassall & Associates 2004). State forest were included in the crown lands tenure weighting class as firewood volume estimates were not available for other tenures (to compare with up to 200 tonnes per annum from State forests) and also on account of low confidence in non-licensed consumers reporting collection from State forests.

Firewood is almost always collected by vehicle and therefore road or vehicular access is considered a key factor in identification of firewood collection areas. A grid was produced of the mapped roading system buffered to 50 meters either side and this was used as a zone of high firewood collection by applying double the risk. An initial firewood risk score was derived as follows:

*Firewood risk score = ([firewood value score] * 3) * [tenure rating] * [roadside factor]*

A detailed model of access to identified firewood resources was then developed based on a time-cost analysis of the roading network. Approximate travelling times were ascribed and scaled in relation to road order (from highway to minor road, 4wd track etc) and in combination with a terrain variable (slower travel with increasing ruggedness) allowed incorporation of estimated travel time to firewood resources as opposed to simple road distances.

As firewood consumption is generally related to population size, a proximity grid was derived based on overall road distance from population centres (firewood consumers). Individual proximity grids of road distance from town in relation to town population size were derived for the seven largest towns in or adjacent to the study area (**Table 3-U**), with the remaining smaller sized towns combined together. Firewood is much more likely to be collected the closer it occurs to population centres and as willingness to travel is assumed to decrease in a non-linear manner with distance, a natural logarithmic function was applied to road distance from population centres. A logarithmic function was also applied to town population size as it's effect is thought to level out somewhat due to socio-economic differences, increased availability of alternatives, particularly gas, and new incentives to reduce burning wood in urban compared to rural situations.

Based on the assumption that on average more firewood is likely to be consumed by towns that typically experience colder winters, the mean temperature of the coldest quarter was calculated for the seven major population centres and applied as a climate factor (in relation to mean of 7.7 degrees Celcius) to population size (refer **Table 3-U**).

TABLE 3-U

Proximity and climate factors for largest towns

Town	population(1986)	log	mean temperature coldest quarter (C^0 x10)	climate factor	proximity factor
Uralla	2 250	3.35	63	1.276	4.28
Glen	5 971	3.78	66	1.241	4.69
Inverell	9 693	3.99	88	1.000	3.99
Quirindi	2 812	3.45	93	0.931	3.21
Tamworth	30 729	4.49	96	0.897	4.03
Manilla	2 017	3.30	98	0.874	2.89
Gunnedah	9 406	3.97	105	0.793	3.15

Component inputs described above were weighted to achieve a meaningful interaction between them whereby the influence of each component was evident and appeared balanced (without 'swamping' effects). Subjective visual analysis and query were used to review the analysis response to each of the input variables. The resultant equation for final firewood risk was:

*Final firewood risk = [Proximity factor]^2 * [access factor] * [firewood risk score]*

The derived firewood collection risk is illustrated in **Figure 3-H**.

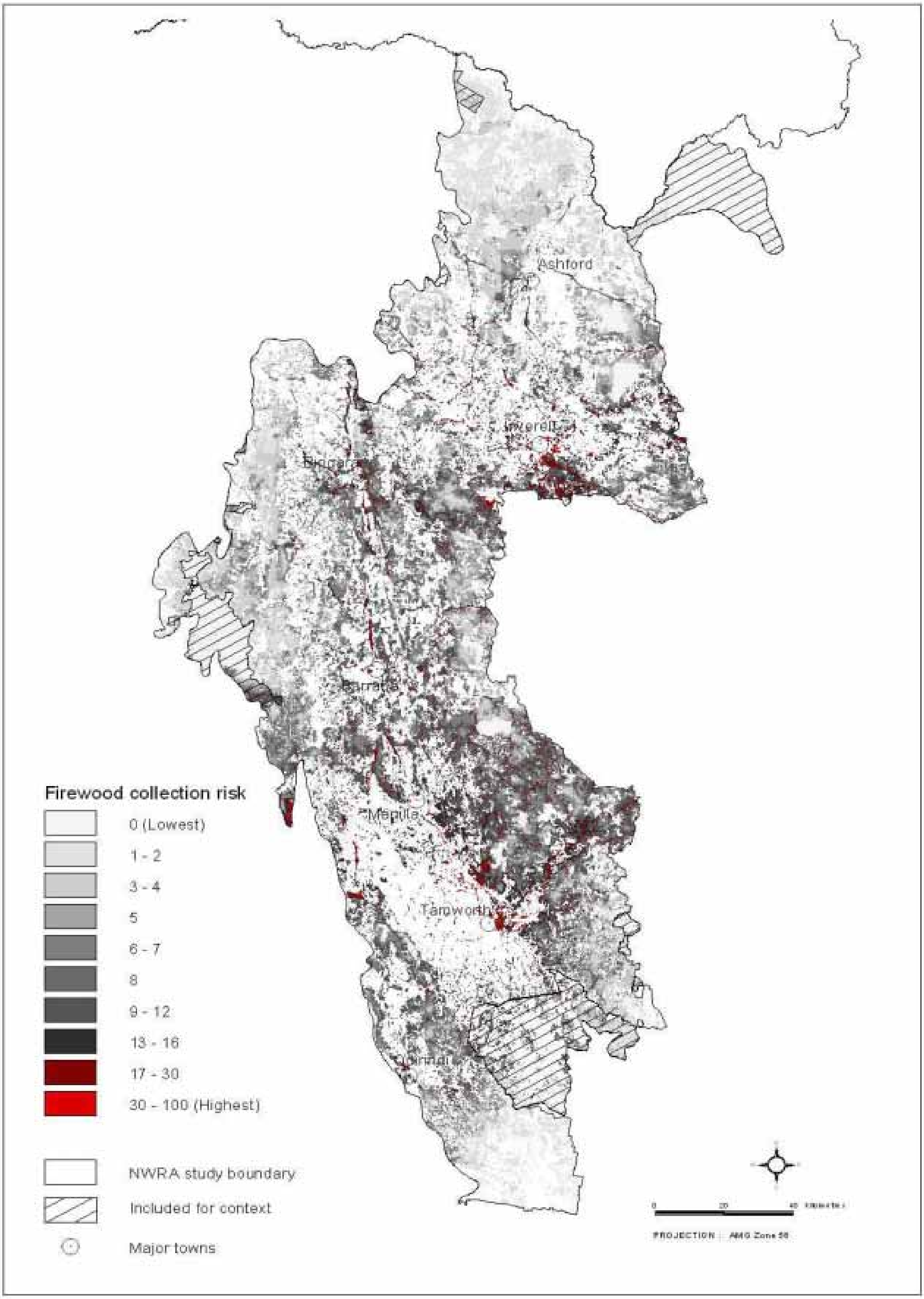


FIGURE 3-H

Firewood collection risk

3.4.5 Coolatai grass invasion risk

Invasion of native ecosystems by exotic plants is regarded as a major threat to conservation in Australia (Humphries *et al*. 1993, Adair 1995, Benson 1999). Coolatai Grass (*Hyparrhenia hirta*) is emerging as a very serious threat to Australian rangeland farming as it spreads largely unchallenged along roadsides, stock routes and grazing paddocks across a widening swathe of rural NSW. Invasion of native plant communities by exotic perennial grasses is listed as a key threatening process under the New South Wales *Threatened Species Conservation Act 1995*. The Scientific Committee's determination notes that the perennial grass *Hyparrhenia hirta* (amongst others) can invade and dominate native plant communities competing with, and displacing, many native species, including rare and threatened flora.

Introduced from Africa to the Coolatai district of northern NSW as a pasture and erosion-control plant in the 1940s, the tough, summer-active perennial has become established and dominant over large tracts of public and private land on the North West Slopes. The species is steadily spreading further afield including more distant locations in central and southern NSW.

The tall, tufted plants form dense (sometimes monocultural) swards, displacing the productive native grasses and reducing indigenous plant species diversity. Coolatai is a resilient and drought resistant grass of low digestibility that grows across a range of soil types. Dense Coolatai reduces the carrying capacity of productive soils. It is not eliminated by heavy grazing and is difficult to control with herbicides. Coolatai grass is rapidly invading stock routes because its seed is readily spread by passing vehicles and activities such as grading.

A recent study of the impact of this species on native vegetation within a national park in Nandewar (McArdle *et al.* in press) found that Coolatai Grass infestation reduced the richness of native ground strata plants and their projected cover. The reduced conservation value of invaded sites is of particular concern for national parks, TSRs and roadside reserves that contain a significant proportion of the relatively intact remnant woodlands of Nandewar.

A generalised additive species distribution model of *Hyparrhenia hirta* within the Nandewar study area was derived by analysis (in S-Plus software) of presence-absence data from regional floristic sample sites in relationship to underlying abiotic variables. Of a total of 2 865 flora sites within the modelling domain, 316 had presence records for *H. hirta*. Obvious limitations to the modelled distribution include omission of many observed or known localities not formally recorded or databased, a survey bias away from infestations, and a temporal bias of more records in areas infested for longer. Furthermore, current distributional records reflect to some extent the historic spread of the species.

Nonetheless sites were analysed against 22 environmental surfaces with 30% of the model deviance explained by statistically significant relationships with six environmental variables including fertility, lithology, mean temperature of the warmest quarter, radiation of the lowest period, northing and easting. The explanatory power of abiotic variables in a model of an introduced species is expected to be relatively low as anthropogenic factors are likely to be implicated, in the case of *H. hirta,* dispersal of seeds either by vehicles (and the wind generated by them) or by road works and maintenance of roadside verges. Therefore to derive a simplistic risk model for *H. hirta,* the species probability surface was combined with a 50 meter road buffer grid and a function ascribing declining risk with increasing distance from roads to emphasise the significance of the road and track network in the spread of the species. Risk however is not confined to roadsides and their proximity as, for example, Kwiambal National Park has continued to be invaded in the absence of any major disturbance such as fire or livestock grazing (McArdle *et al.* in press).

Figure 3-I displays the estimated risk of Coolatai spreading across the Nandewar WRA study area.

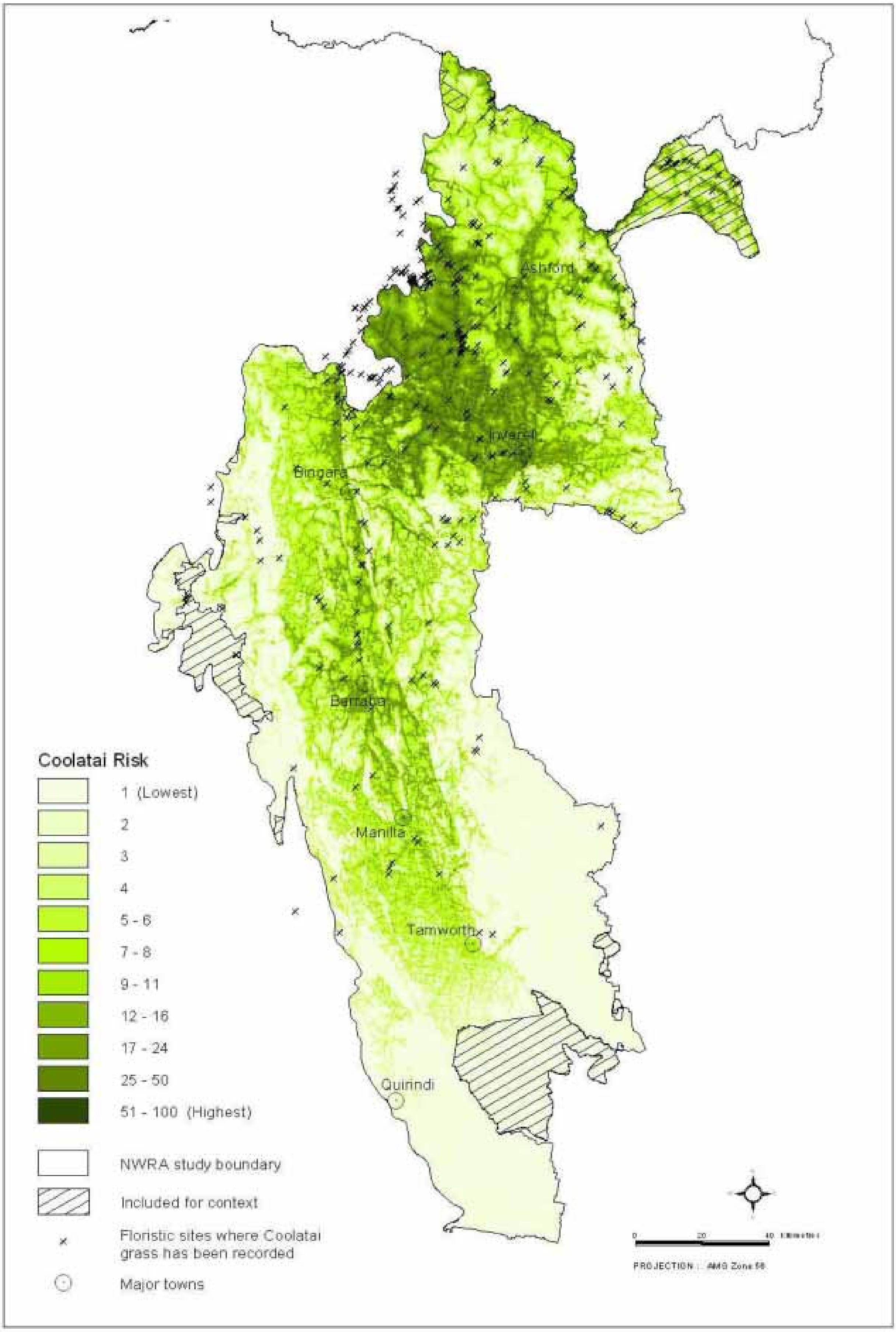


FIGURE 3-I

Coolatai grass invasion risk

3.5 TECHNICAL WORKING GROUP

A technical working group (TWG) comprised of agency representatives was established to oversee technical aspects of the project in progress. An initial TWG meeting was convened in July 2003, with a further meeting in February 2004 and a final meeting in June 2004.

The landscape conservation modelling framework, methods used in derivation of key data sets and their limitations were discussed in some detail. The TWG provided valuable insight and constructive comment on development of the data layers. Particular interest was shown in the modelling parameters and the difficulties associated with remote mapping of vegetation condition.

The TWG expressed some reservation with the level of reliance on API mapping in derivation of the current condition layer, specifically concern for the potential of assigning poor condition values to:

- native vegetation of open woodland structure due to a naturally low crown cover percentage score (**Table 3-A**), and
- multi-aged forests due to a significant regrowth percentage score (**Table 3-D**).

Further consultation with the key API mappers confirmed that intact vegetation across Nandewar typically has a crown cover percentage of >50 and areas assigned ccp of <50 have usually been subjected to some level of structural modification (eg thinning). Most of the original indigenous vegetation of Nandewar is considered to be of open forest or woodland structure with true open woodlands being of relatively limited extent. However, areas of intact open woodland may erroneously be assigned low condition due to low reliability in distinguishing native from introduced ground layers by API.

Regrowth RCCP coding of *s* (10-30%) and particularly *e* (>30%) were typically applied in API mapping in association with disturbance (such as logging, clearing, ringbarking, fire and dieback) and are likely to represent reduced vegetation condition rather than representing multi-aged forest structure (a positive condition attribute).

A further issue was raised in relation to dense regeneration of cypress pine exhibiting a seral stage referred to as “lock-up” where understorey vegetation is very sparse and presumably of lower biodiversity value. Concern was expressed regarding the potential for such stands to be incorrectly assigned high condition based on full canopy cover (ccp). Experienced aerial photographic interpretation readily recognises the distinctive canopy signature (texture) of dense cypress regrowth and in conjunction with contextual information (adjacent land use, patch/polygon size) such areas are likely to be distinguished from mature vegetation and assigned a regrowth coding and lower condition score as appropriate.

4 Outputs and Applications

The Nandewar Landscape Conservation project has progressed the development of interactive conservation assessment tools. A framework has been established by which landscape-scale analysis of biodiversity information can be undertaken to inform conservation planning.

Maps presented in this section demonstrate the <u>type</u> of outputs that the assessment tools can deliver. These maps should be treated as <u>example outputs only</u> and not as a definitive or static result.

The maps represent a certain scenario associated with a particular set of input layers and parameters that were intended to have a dynamic capability. This project utilised one type of biodiversity surrogate (vegetation units) and preliminary subjective modelling parameters. Outputs would necessarily vary as inputs and parameters are modified or altered. The modelling framework allows a conservation assessment analysis to be reiterated with additional, updated or enhanced biodiversity information (eg. species models) and/or revised objective modelling parameters set through a more formal consultative process or more thorough investigation of relevant studies.

4.1 SPATIAL OUTPUTS

The landscape assessment across the Nandewar WRA study area has generated a number of key outputs (refer to Figure 2-B).

The key input layers of **land use**, **current condition**, **threatening processes** and **vegetation communities** are described and presented in Section 3.

The derivation of predicted **future condition** of vegetation is described in Section 2.2.1 and the final coverage is shown in **Figure 4-A**. Future condition is an output of Sub-model 1 which predicts the future condition of vegetation as a function of current condition, existing or proposed land use and the likelihood of exposure to threats.

In Sub-model 2, the effects of habitat fragmentation on species diversity are factored in by converting the area of vegetation predicted to remain in each community to an ‘effective habitat area’. In this process the contribution to biodiversity persistence of small isolated remnants is downgraded relative to large well-connected blocks of vegetation (see Section 2.2.2).

Current effective habitat area represents a habitat spatial configuration measure based on the proportion of original connectivity to surrounding habitat that remains. The current effective habitat area coverage is shown in **Figure 4-B**. The **future effective habitat area** – the spatial configuration of predicted future habitat – is shown in **Figure 4-C**.

Conservation status is based on the relative representation of each vegetation unit (biodiversity surrogate). Representation refers to the proportion that remains (i.e. extant) of the predicted (i.e. pre-clearing) extent of each vegetation unit. **Figure 4-D** displays conservation status across the entire study area while **Figure 4-E** is masked to extant vegetation. The maps clearly indicate the relatively poor representation and conservation status of vegetation units across the intensive agricultural areas of the Inverell Basalts and central Peel Provinces. By contrast less modified areas associated with the granitic western edge of the New England Tablelands and the Kaputar region have comparatively much better conservation status.

The predicted pre-clearing extent of each vegetation unit (biodiversity surrogate) and the current and predicted future effective habitat areas are presented diagrammatically in **Appendix 4.1** (in order of increasing area) and **Appendix 4.2** (arranged according to relationships between vegetation units).

Priorities for retention. In this output the land use is altered in the model to a *cleared or developed state*. With each step the biodiversity index of the status quo is compared to the biodiversity index if a cluster is cleared. The priority grid provides an estimate of the current contribution of each grid cell to the regional biodiversity outcome index of the status quo. The outputs, displayed over the entire study area (**Figure 4-F**) and masked to extant vegetation (**Figure 4-G**), highlight the significance of large intact areas.

These outputs display the current relative contribution (of individual grid cells) to regional biodiversity (calculated as a biodiversity index). They may be viewed in terms of a relative measure of overall biodiversity that would be lost if an area were to be cleared.

Priorities for conservation action. In this output the land use is altered in the model to a *conservation land use*. When the conservation land use is applied most modelled threats (except Coolatai grass invasion) are removed allowing natural regeneration to occur. With each step the regional biodiversity outcome index of the status quo is compared to the index if a cluster is reserved or managed for conservation. The output grid provides an estimate of the potential improvement provided by each grid cell to the regional biodiversity outcome index if it were to be managed for conservation. **Figure 4-H** shows the entire study area and **Figure 4-I** is masked to extant vegetation

These outputs display one possible output showing priority areas for conservation action including rehabilitation / revegetation, application of incentive funds, and protection / reservation. The figures illustrate the varying effectiveness of hypothetical conservation action in terms of potential gains to the overall biodiversity index. That is, conservation efforts carried out across the darker mapped areas are expected to be more effective in promoting persistence of regional biodiversity (compared to lighter mapped areas). Large intact areas and poorly represented areas (see above) retain high priority for conservation action where they are subject to projected threats. Such areas however are apportioned lower priority where some degree of security against modelled threats in conferred, for instance, by tenure (eg. State forests are not subject to the risk of clearing).

4.1.1 Limitations

The methods applied here can be readily refined with improved and extended input information and can be interfaced with tools that deal with non-biodiversity issues. These conservation priority grids (priorities for retention and priorities for conservation action) presented here have specific and limited application and must be used cautiously. More specifically:

- The parameters underlying the current outputs are preliminary and subjective. In particular, the outputs are sensitive to the clearing threat information which cannot be conclusively defined until the consequences of recent vegetation clearing reforms in New South Wales are known.
- The priority grids presented here are based on vegetation communities acting as a surrogate for biodiversity. The resulting priorities do not necessarily reflect the priorities for individual species (particularly fauna species) or within-species variation.
- Each grid provides an insight into only one possible land use change at a time, not combinations.
- These priority grids should not be viewed as static. Grid cells will not retain the level of priority indicated by the priority grids once significant changes are made in other parts of the region. During scenario development or during a planning process priorities need to be updated.
- The priority grids presented here include relatively near neighbour spatial configuration calculations only (in the order of several kilometres). They do not include regional and coarser scale connectivity considerations (see Scotts & Drielsma 2003).
- The priority grids presented here include no socio-economic considerations; they attempt to portray priorities only from a biophysical viewpoint but do not include, for example, the economic cost or the desirability of making land use changes at specific locations.

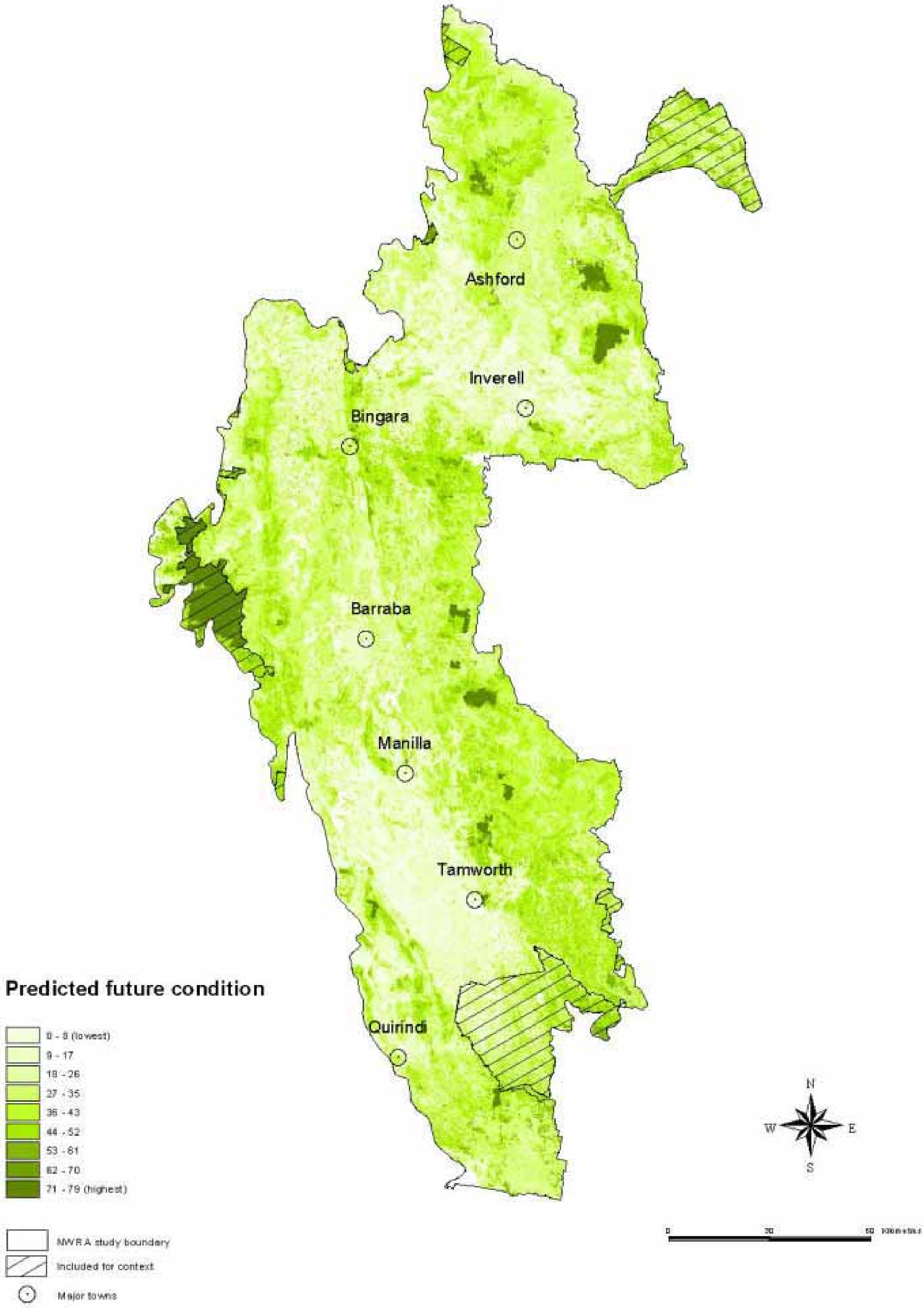


FIGURE 4-A

Predicted future condition

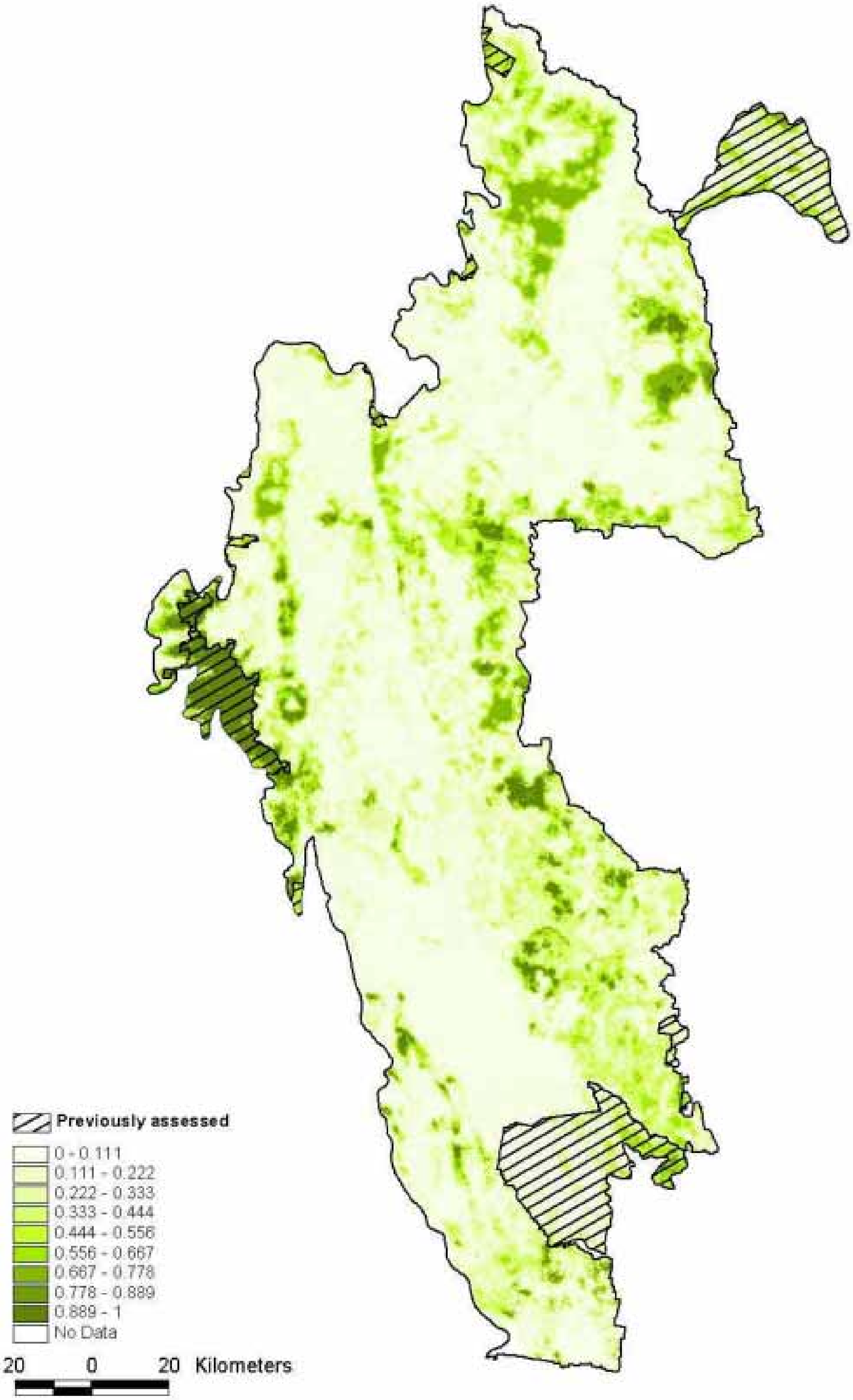


FIGURE 4-B

Current effective habitat area

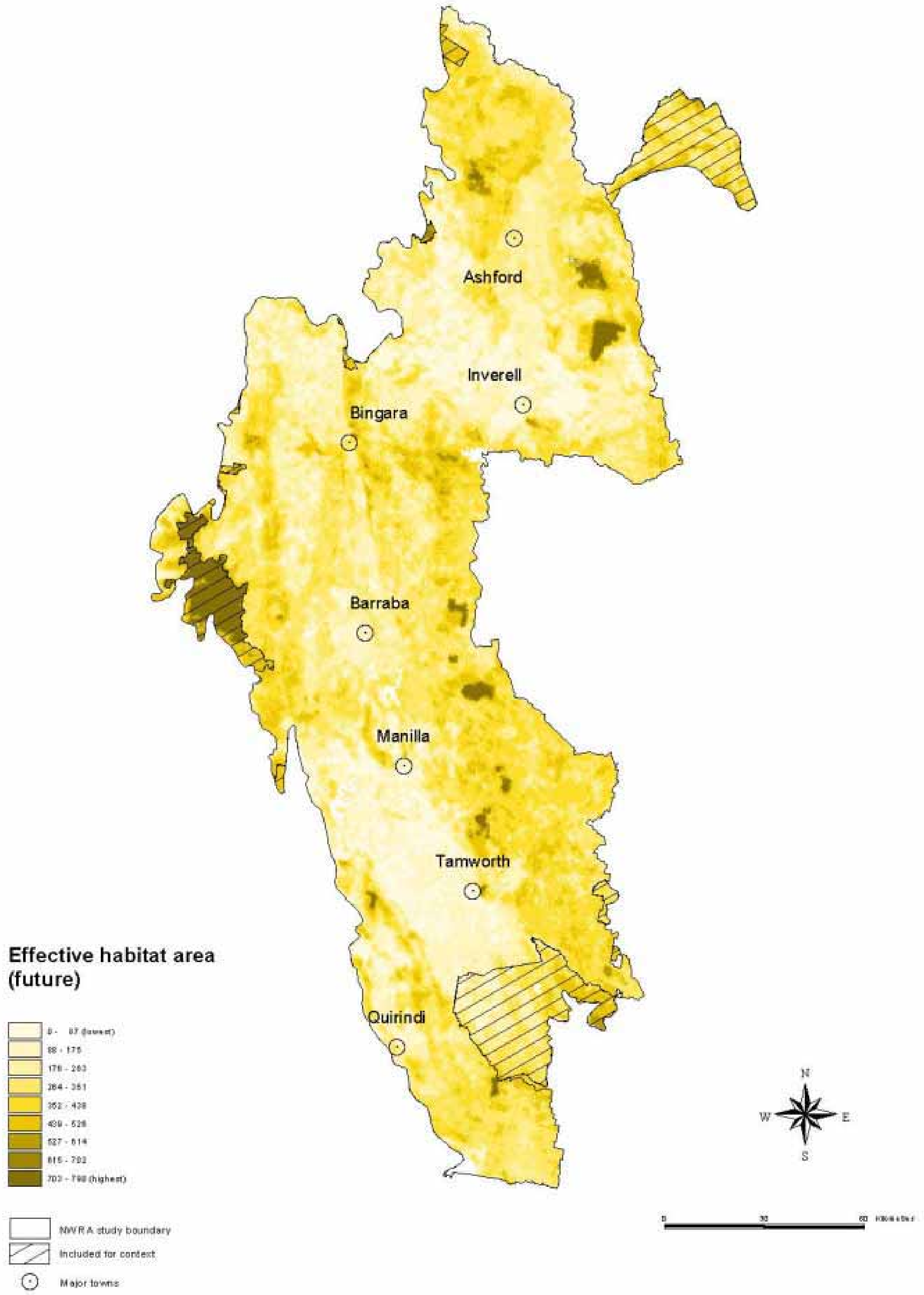


FIGURE 4-C

Future effective habitat area

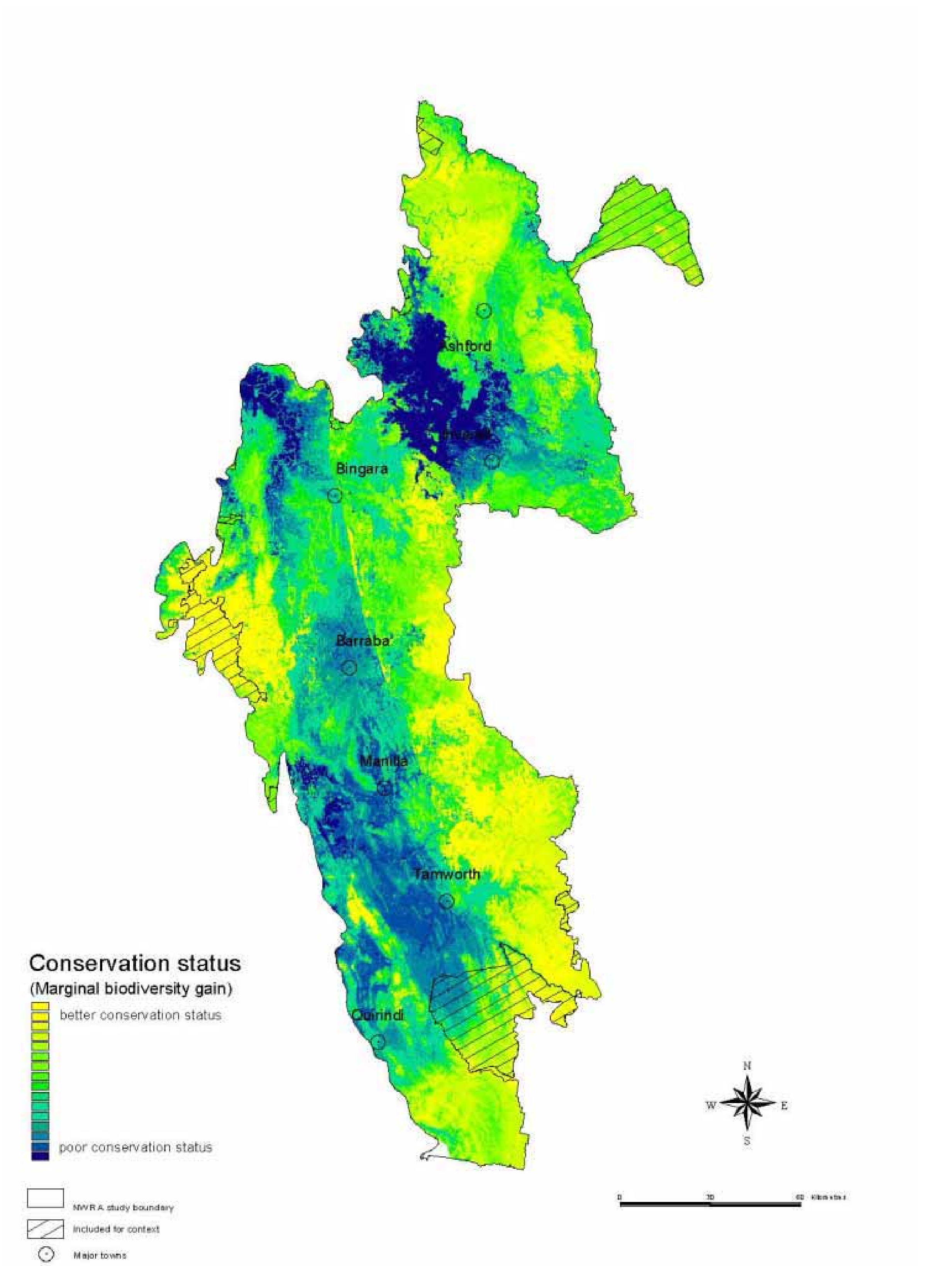


FIGURE 4-D

Conservation status

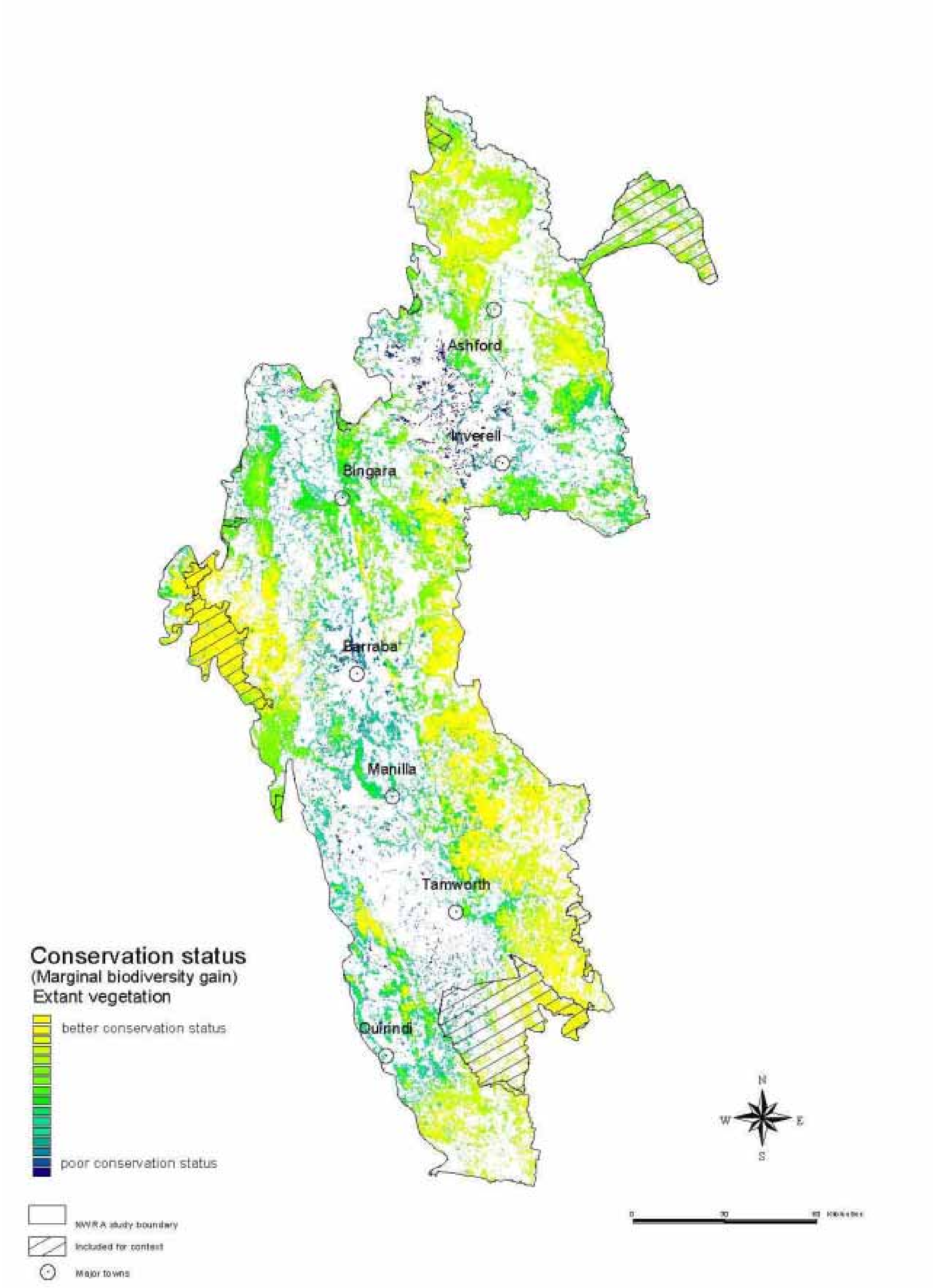


FIGURE 4-E

Conservation status (existing vegetation)

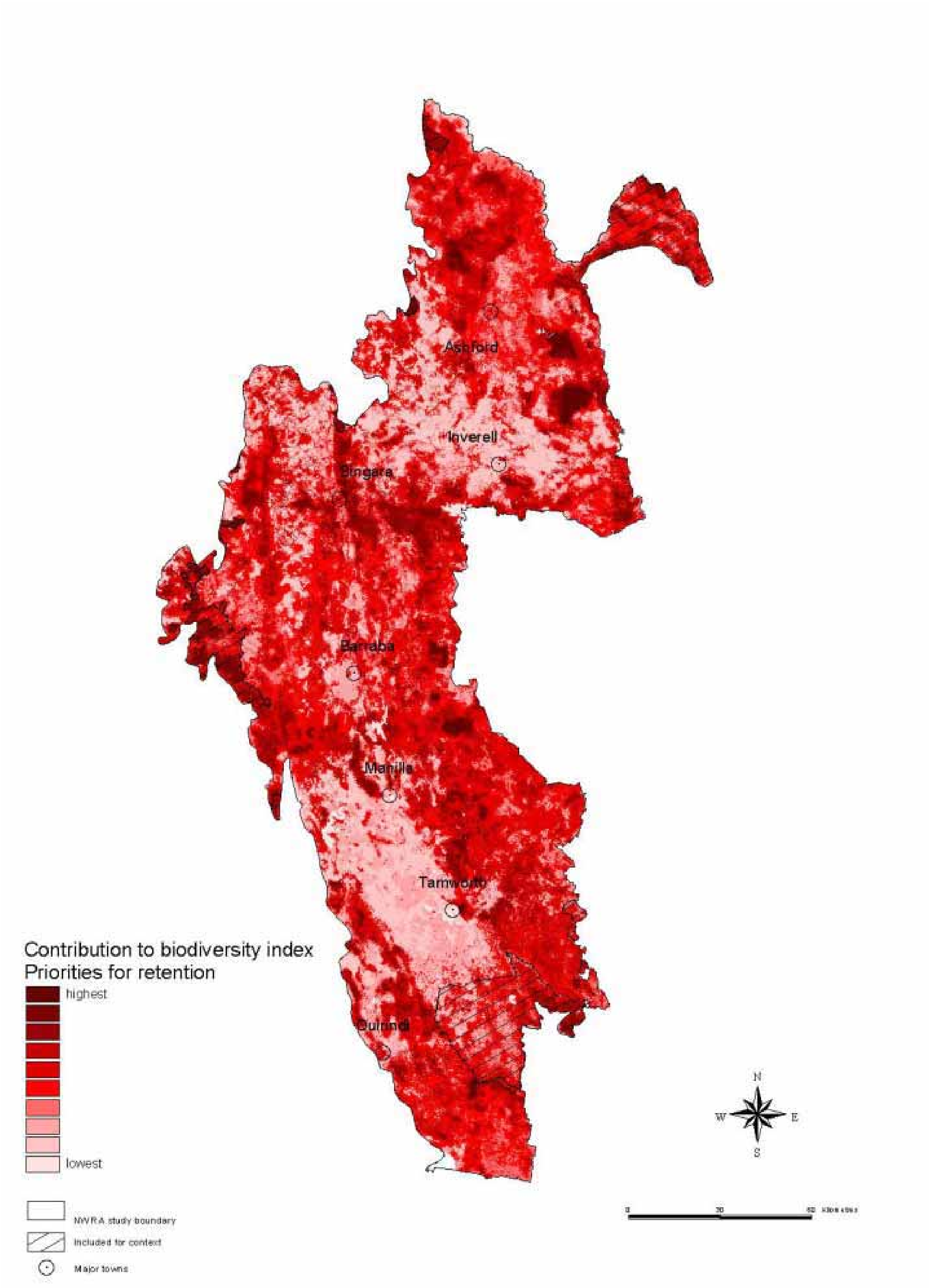


FIGURE 4-F

Current contribution to biodiversity – priorities for retention

Note: Maps presented in this section demonstrate the type of outputs that the assessment tools can deliver. These maps should be treated as example outputs only and not as a definitive or static result.

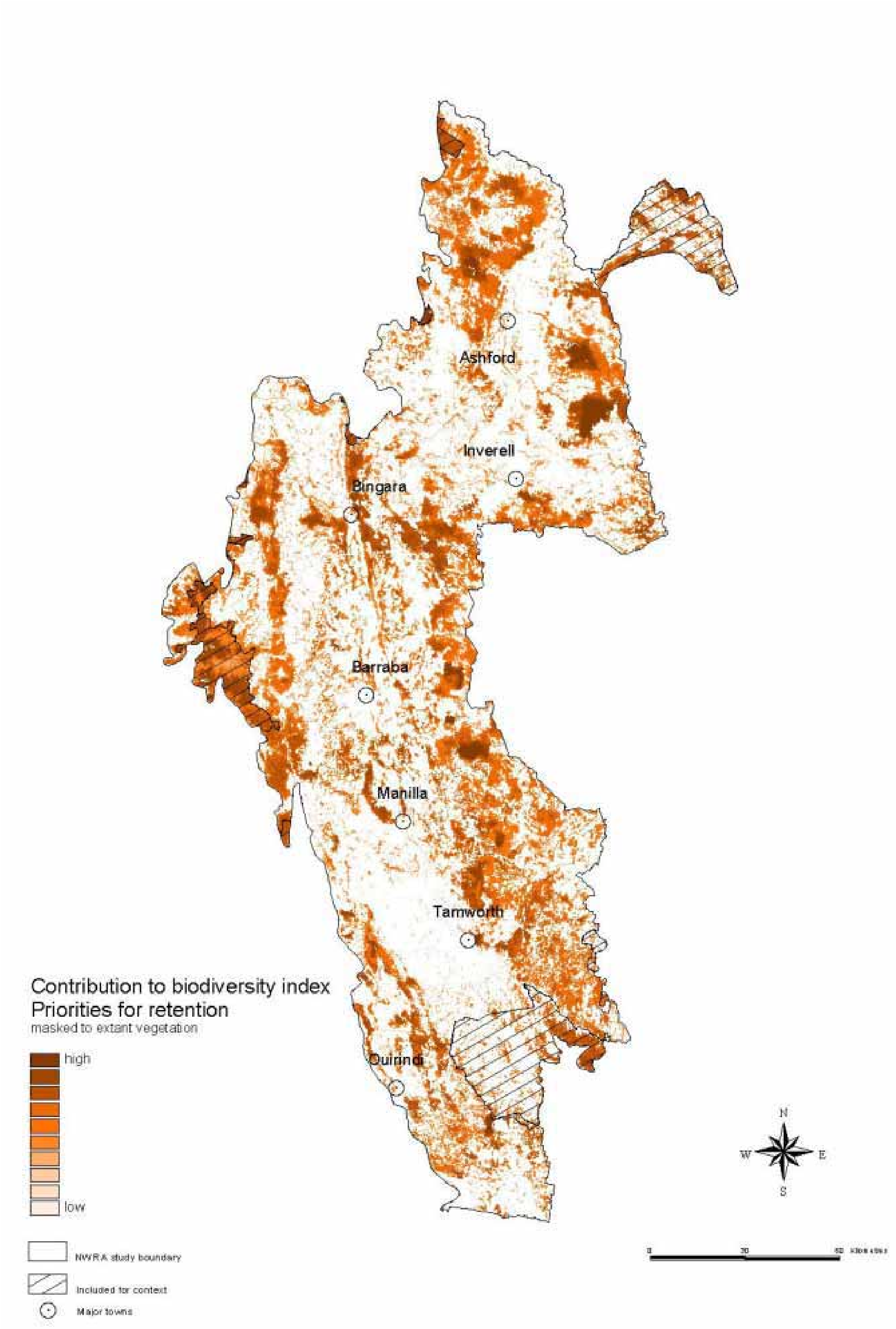


FIGURE 4-G

Current contribution to biodiversity – priorities for retention (existing vegetation)

Note: Maps presented in this section demonstrate the type of outputs that the assessment tools can deliver. These maps should be treated as example outputs only and not as a definitive or static result.

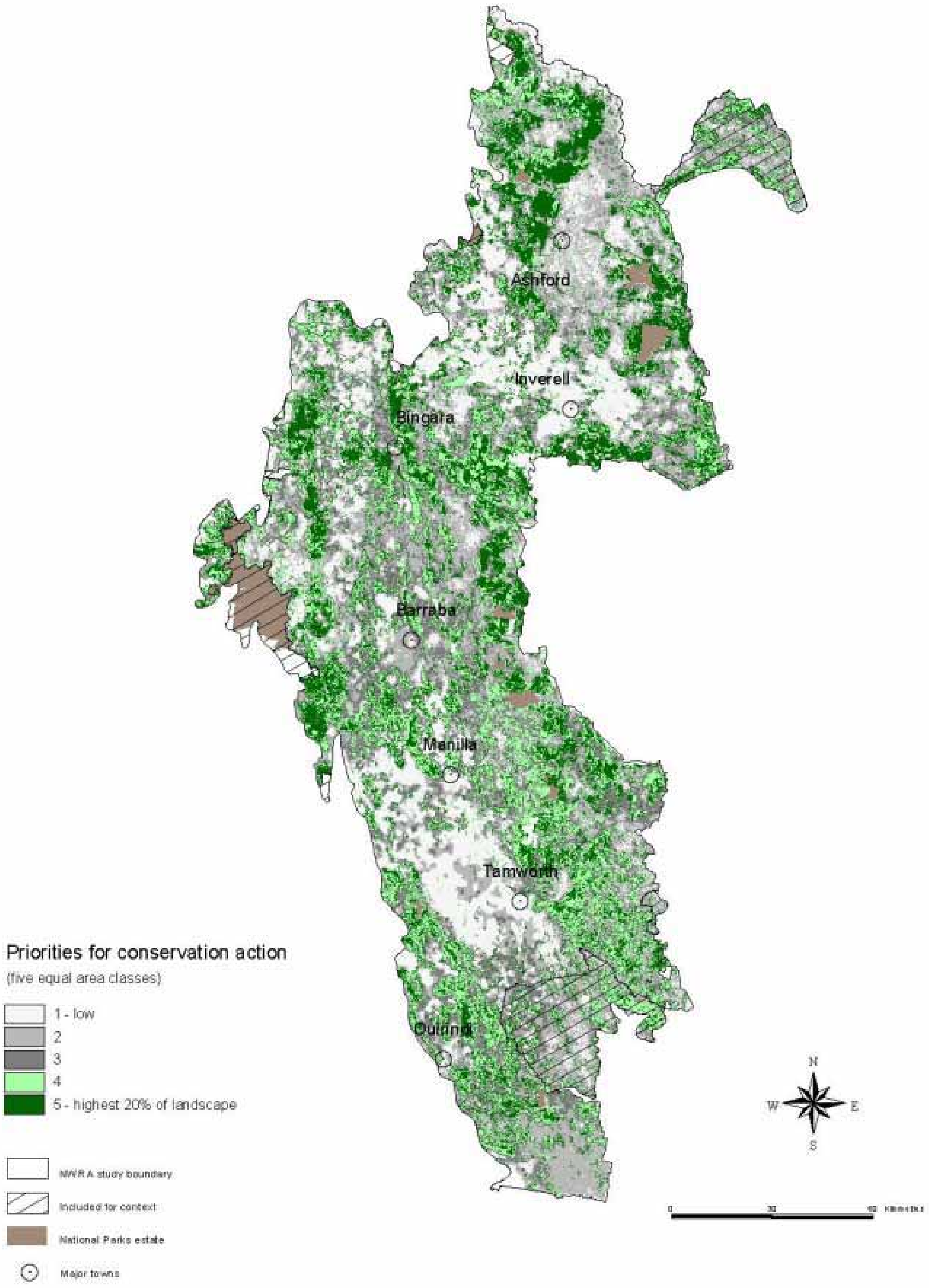


FIGURE 4-H

Priorities for conservation action

Note: Maps presented in this section demonstrate the type of outputs that the assessment tools can deliver. These maps should be treated as example outputs only and not as a definitive or static result.

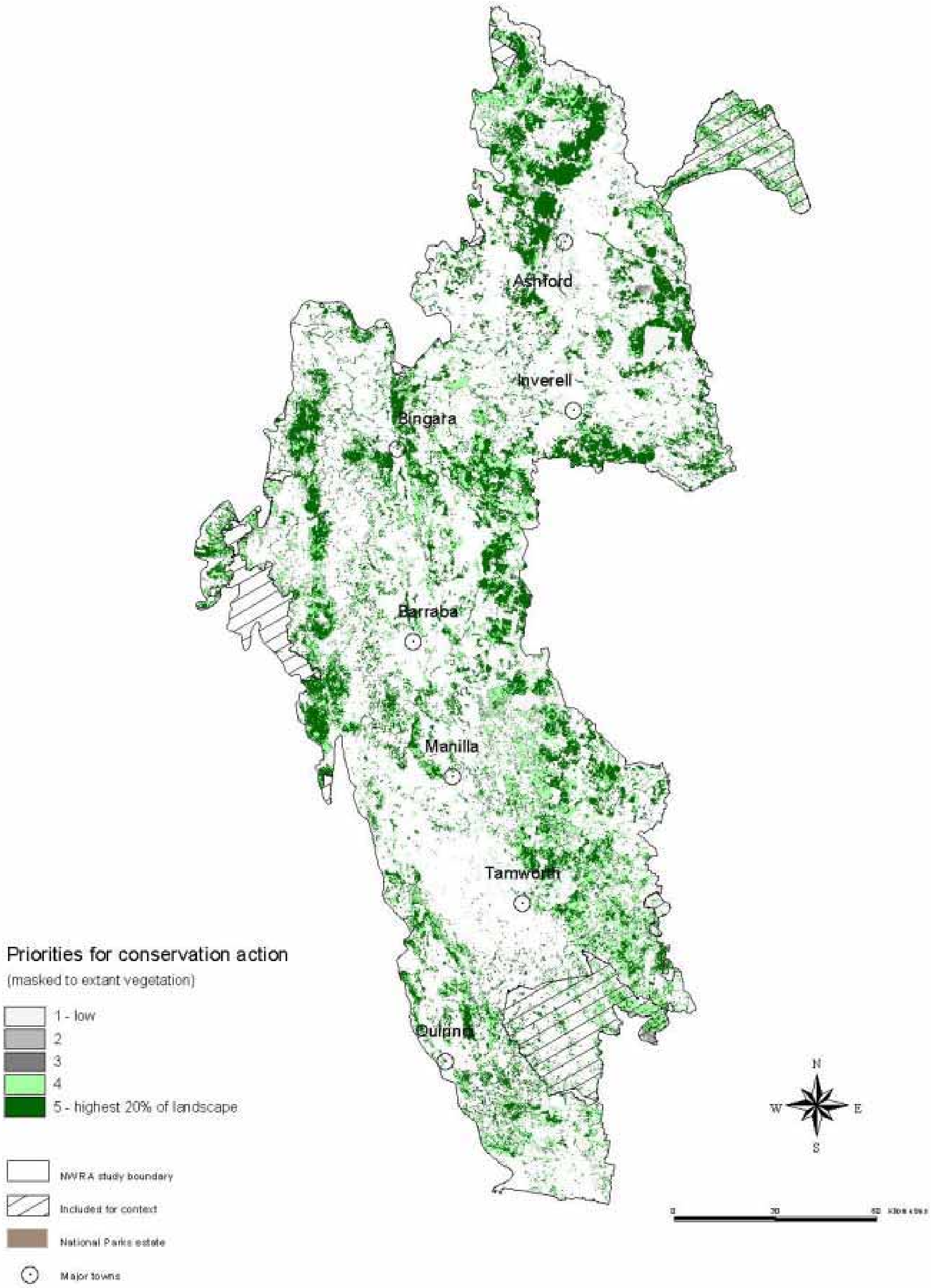


FIGURE 4-I

Priorities for conservation action (existing vegetation)

Note: Maps presented in this section demonstrate the type of outputs that the assessment tools can deliver. These maps should be treated as example outputs only and not as a definitive or static result.

4.2 POTENTIAL ROLE IN DEVELOPING AND EVALUATING LAND USE SCENARIOS FOR THE NANDEWAR WRA

As indicated in Section 2 the current project has focussed mainly on setting up the underlying biodiversity model for Nandewar, with particular emphasis on establishing the necessary spatial data-sets to support this model. The model has then been used to trial the mapping of conservation priorities within Nandewar, thereby demonstrating the potential applicability of such mapping to conservation assessment and planning within the region. However, it should be noted that many of the parameters used in these preliminary trials are subjective approximations based largely on expert knowledge (within the Department of Environment and Conservation) in lieu of relevant supporting data. There is considerable potential for these parameters to be refined in the future through further consultation with external experts, and accompanying endorsement by other agencies and stakeholders. Such refinement and endorsement is an essential precursor to any application of the other capabilities of the modelling tools, ie to developing and/or assessing real land use scenarios for the region.

The scenario development and evaluation capabilities of the tools are currently being refined and extended for broader application in Natural Resource Management Reform throughout New South Wales. This refinement will directly benefit any future application of the software to scenario development and evaluation in Nandewar. Alternative land use scenarios translate to modification of future vegetation condition, and ultimately to changes in biodiversity outcomes. These can be presented as both single metrics for the region (the regional biodiversity index) or as individual outcomes for each vegetation community (see **Appendices 4.1, 4.2**).

The modelling framework developed here can be integrated with tools developed by DEC which allow users to interactively edit a polygon land use map using priority maps and contextual information, such as cadastre, to delineate proposed land use boundaries (see example in **Figure 4-J**). Land use changes are automatically translated into changes to vegetation condition and ultimately to changed biodiversity forecasts and updated priorities. In this way alternative land use scenarios can be compared (see example in **Figure 4-K**).

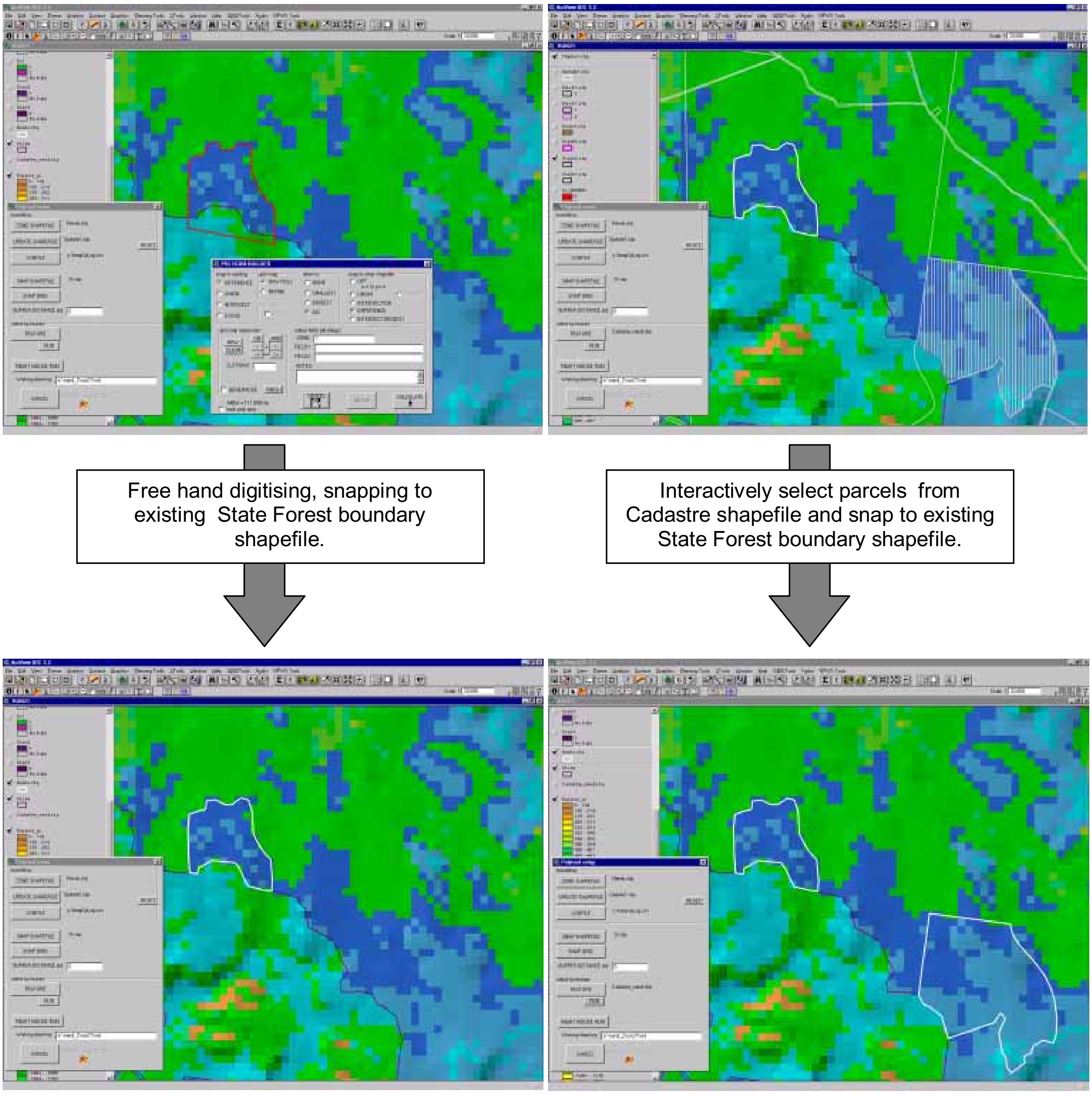
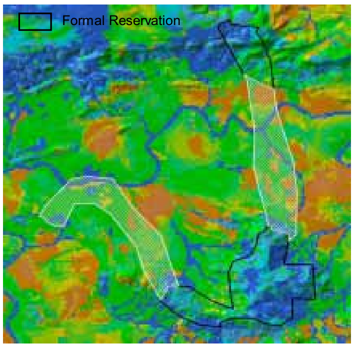
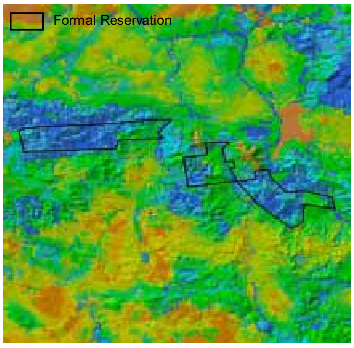
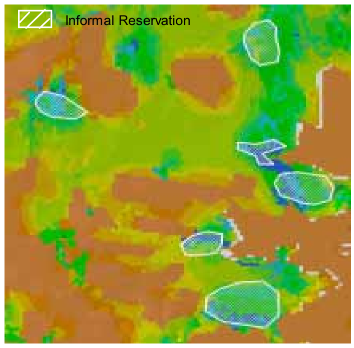
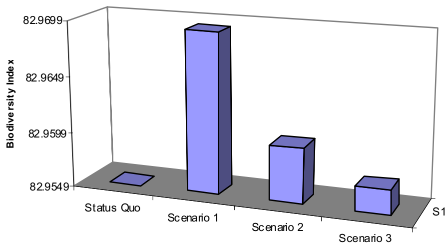


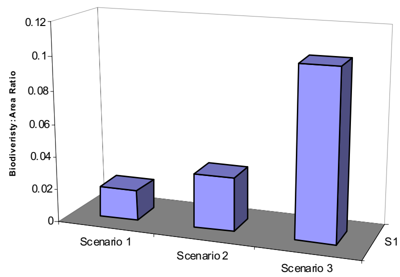
FIGURE 4-J

Examples of the application of "Polytool" to the interactive editing of land use boundaries in the development of land use scenarios

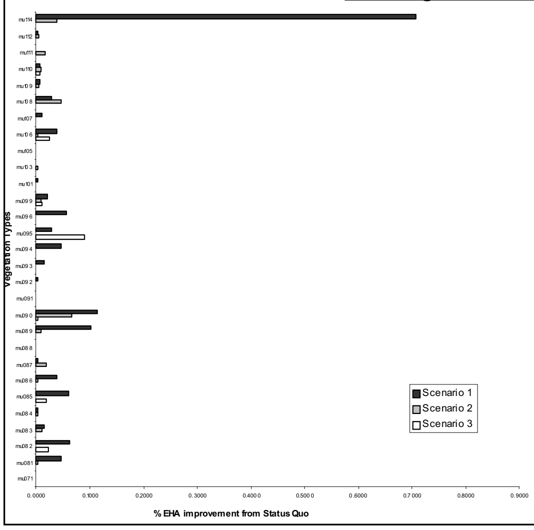
		
SCENARIO 1	**SCENARIO 2**	**SCENARIO 3**
Formal Reservation adjoining State Forest with informal reservation corridors connecting formal reservation areas.	Formal Reservation adjoining and connecting State Forest	Isolated individual informal reserves
Formal Reservation Area = 2253ha Informal Reservation Area = 2328ha	Formal Reservation Area = 2565ha	Informal Reservation Area = 2328ha

Scenario Evaluation





Scenario evaluation of EHA's and contribution to overall BDI of Vegetation Types



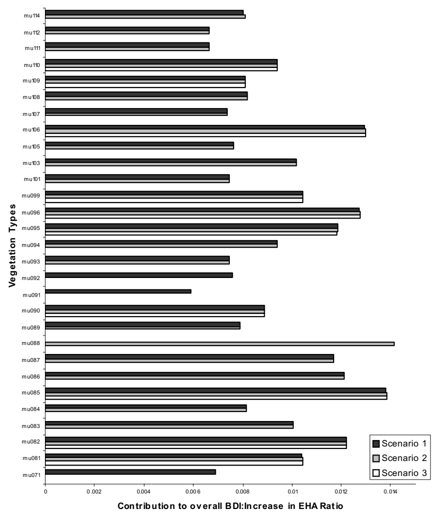


FIGURE 4-K

Example evaluation of land use scenarios

4.3 POTENTIAL ROLE IN OTHER PLANNING PROCESSES

The conservation assessment tools used in this project have considerable potential to contribute to other natural resource planning processes, including planning for catchment management authorities. The tools enable conservation priorities to be mapped across all tenures, indicating both priorities for protecting remaining vegetation remnants and priorities for revegetating areas of cleared or degraded land. The tools can also facilitate development and evaluation of land use or management scenarios across all tenures.

4.3.1 Limitations

The following caveats should, however, be noted when considering any potential application of the tools to other planning processes within the region:

- The main product of this project was not intended to be a static map of conservation priorities, but rather a dynamic mechanism for conservation prioritisation and evaluation that can best be applied through interactive collaboration with other planning processes.
- The assessment tools can provide guidance as to "where" best to direct conservation effort within the region, but do nothing to solve the problem of "how" to fund and facilitate such action. For the assessment tools to contribute to any real conservation outcomes outside of public land they will need to be linked to processes that address the "how" issue, eg. incentive schemes.
- Although they have the potential to do so, the assessment tools do not currently consider any environmental values other than biodiversity (eg. other ecosystem functions and services), nor do they address social or economic values. Further effort needs to be directed towards incorporating these other values into the prioritisation of conservation action. Of particular importance is the need to factor implementation costs into the estimation and mapping of biodiversity conservation priorities – i.e. enabling priorities to be expressed in terms of the predicted gain in conservation effectiveness achieved per unit cost.
- As noted earlier, many of the data-sets employed in the assessment of biodiversity are relatively coarse-scaled and likely to contain inaccuracies. Further effort needs to be directed towards refining these data layers, particularly those relating to condition and threat. Effort also needs to be directed to refining the analytical techniques used to model persistence of biodiversity.
- While the assessment tools described here can help to provide a "big picture" context for local planning decisions, the identification of priority areas from remotely mapped information should, wherever possible, be validated and augmented by direct field observation.

- The use of vegetation communities as a general surrogate for biodiversity should ideally be supplemented by consideration of the needs of individual species of particular conservation concern (eg. threatened species including fauna).

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Appendix 2.1

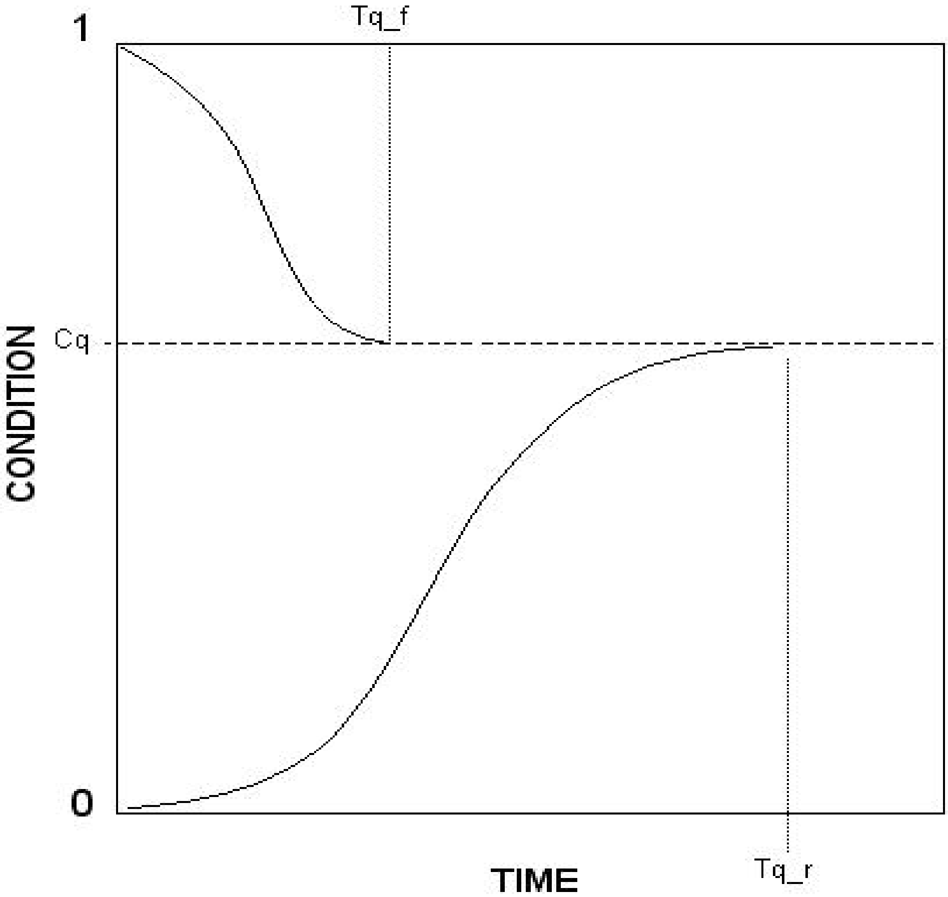
<u>Decision tree for the calculation of future condition based on multiple threats</u>

Rows in the table represent all the possible combinations of outcomes. Each of the first five columns represents the probability of a threat either eventuating (eg p(cl_1)) or not (eg p(cl_0)) as the case may be. Probabilities can be calculated over any timeframe. Columns 6-8 show the consequences of the combination of threats represented by each row, for each condition component. For each cell in the region the product of the probabilities and Q are calculated then summed over all the rows to give the expected condition outcome. The overall condition for a site is then the sum of the conditions for the individual components. In each case the condition is unaffected when the current condition is below Q.

CLEAR-ING	DEGRAD-ATION	LOGG-ING	COOL-ATAI	FIRE-WOOD	Q			PRODUCT		
					Can.	U/S	CWD	Can.	U/S	CWD
p(cl_1)	p(dg_1)	p(lg_1)	p(co_1)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_1)	p(lg_1)	p(co_1)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_1)	p(lg_1)	p(co_0)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_1)	p(lg_1)	p(co_0)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_1)	p(lg_0)	p(co_1)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_1)	p(lg_0)	p(co_1)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_1)	p(lg_0)	p(co_0)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_1)	p(lg_0)	p(co_0)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_0)	p(lg_1)	p(co_1)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_0)	p(lg_1)	p(co_1)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_0)	p(lg_1)	p(co_0)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_0)	p(lg_1)	p(co_0)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_0)	p(lg_0)	p(co_1)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_0)	p(lg_0)	p(co_1)	p(fw_0)	2.25	9	10			
p(cl_1)	p(dg_0)	p(lg_0)	p(co_0)	p(fw_1)	2.25	2.25	5			
p(cl_1)	p(dg_0)	p(lg_0)	p(co_0)	p(fw_0)	2.25	9	10			
p(cl_0)	p(dg_1)	p(lg_1)	p(co_1)	p(fw_1)	27	2.25	5			
p(cl_0)	p(dg_1)	p(lg_1)	p(co_1)	p(fw_0)	27	2.25	10			
p(cl_0)	p(dg_1)	p(lg_1)	p(co_0)	p(fw_1)	27	15.75	5			
p(cl_0)	p(dg_1)	p(lg_1)	p(co_0)	p(fw_0)	27	15.75	10			
p(cl_0)	p(dg_1)	p(lg_0)	p(co_1)	p(fw_1)	29.25	2.25	5			
p(cl_0)	p(dg_1)	p(lg_0)	p(co_1)	p(fw_0)	29.25	2.25	10			
p(cl_0)	p(dg_1)	p(lg_0)	p(co_0)	p(fw_1)	29.25	15.75	5			
p(cl_0)	p(dg_1)	p(lg_0)	p(co_0)	p(fw_0)	29.25	15.75	10			
p(cl_0)	p(dg_0)	p(lg_1)	p(co_1)	p(fw_1)	27	2.25	5			
p(cl_0)	p(dg_0)	p(lg_1)	p(co_1)	p(fw_0)	27	2.25	10			
p(cl_0)	p(dg_0)	p(lg_1)	p(co_0)	p(fw_1)	27	36	5			
p(cl_0)	p(dg_0)	p(lg_1)	p(co_0)	p(fw_0)	27	36	10			
p(cl_0)	p(dg_0)	p(lg_0)	p(co_1)	p(fw_1)	40.5	2.25	5			
p(cl_0)	p(dg_0)	p(lg_0)	p(co_1)	p(fw_0)	40.5	2.25	10			
p(cl_0)	p(dg_0)	p(lg_0)	p(co_0)	p(fw_1)	45	45	5			
p(cl_0)	p(dg_0)	p(lg_0)	p(co_0)	p(fw_0)	45	45	10			
							SUM			
									TOTAL	

Appendix 2.2

The model used to define vegetation condition dynamics. The shape of the function relies on three parameters: the equilibrium condition Cq as well as rising and falling transition times Tq_r and Tq_f (the latter usually being much more rapid).



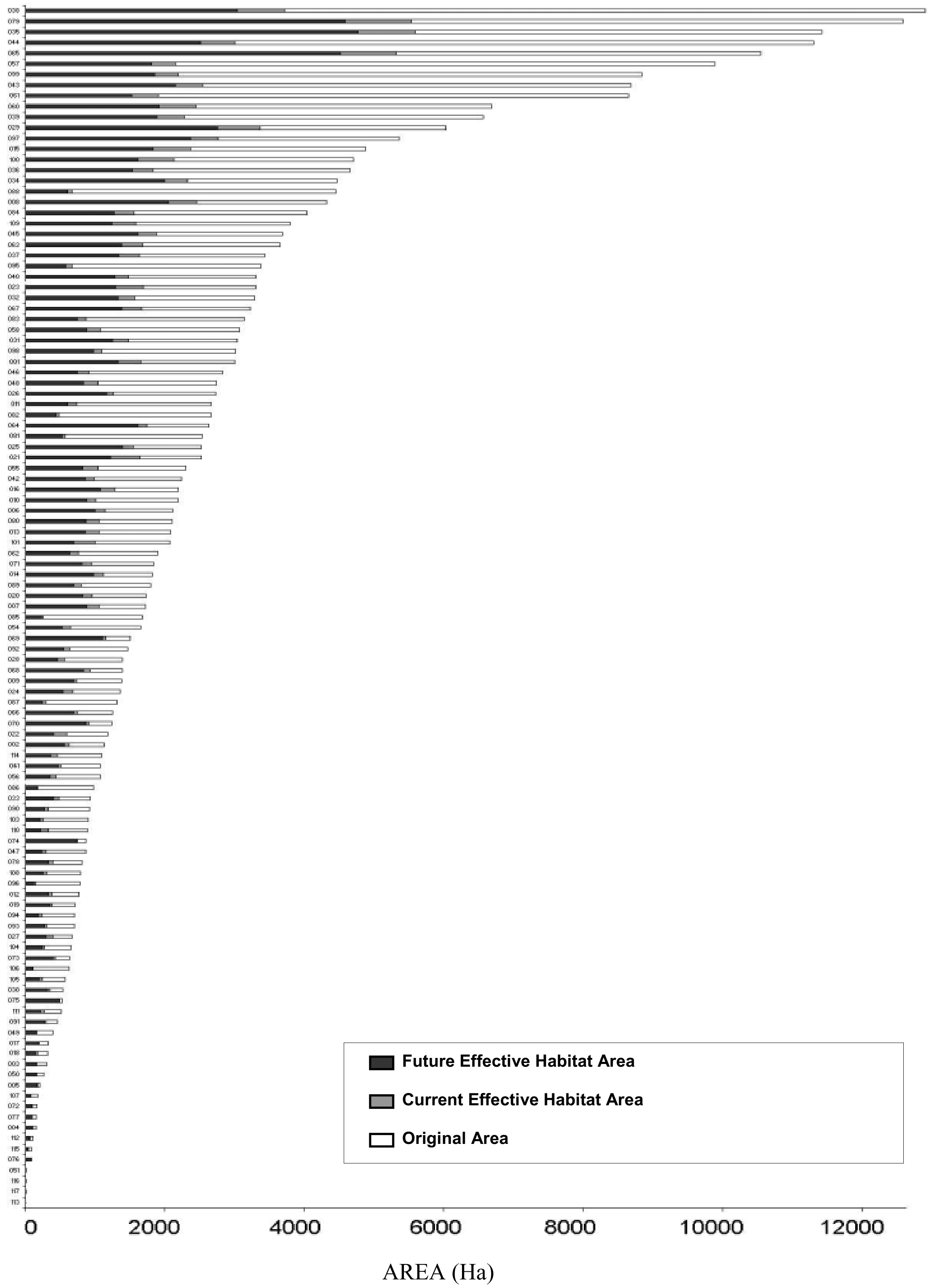
Appendix 3.1

Broad Land use (management) categories derived for the Nandewar WRA study area

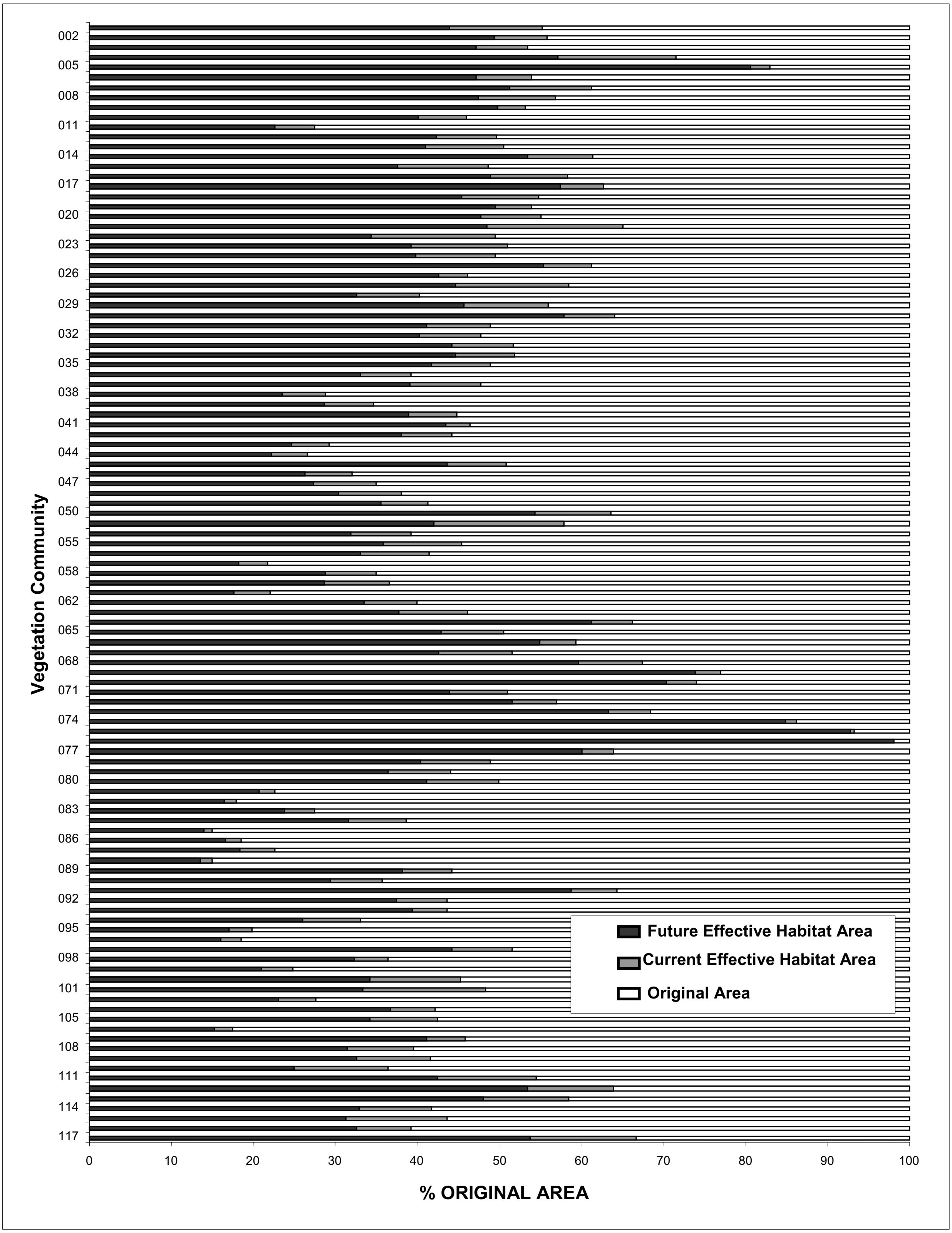
(based principally on API canopy cover, landsat classification (landcover), tenure and existing land capability mapping)

Land use code	Land use category	criteria	details
1	conservation	Tenure: NPWS; SF Flora reserves	confined to formal statutory reserves
2	informal reservation	Tenure: VCA's; SF-PMI 2 & 3; special crown reserves	Voluntary conservation areas; special management zones in State forests; special crown reserves (Horton Falls, Goonoowigal, Oxley Park); few small National Estate areas
3	low intensity use	API canopy cover; Land Capability	areas with land capability not consistent with high intensity use (6-8) and API canopy cover >50%
4	moderate intensity use (in native ecosystems)	API canopy cover (exclude land use 1-3,5)	API ccp 20%-50% or ccp > 50% if land capability high (1-5)
5	logging	Tenure	State Forest PMI 4 only
6	grazing (rangelands)	API canopy cover	All areas of land with API canopy <20% not allocated to land use categories 7 & 8 by landsat
7	intermittent/prior cropping; +/- intensive grazing of introduced pastures	API canopy cover; landsat classification; land capability	API cover <20%; landsat classified as 'past cropping/intensive grazing'; land capability consistent with intense use (1-5)
8	intensive cropping	API canopy cover; landsat classification; land capability	API cover <20%; landsat classified as 'cropped land'; land capability consistent with intense use (1-5)
0	non-natural	API canopy cover; landsat classification; land capability	Land classified as urban, mining or dams

Appendix 4.1


Future Effective Habitat Area
Current Effective Habitat Area
Original Area
0
2000
4000
6000
8000
10000
12000
AREA (Ha)

Appendix 4.2


Vegetation Community
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095
098
101
105
108
111
114
117
0
10
20
30
40
50
60
70
80
90
100
% ORIGINAL AREA
Future Effective Habitat Area
Current Effective Habitat Area
Original Area