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Using local knowledge to identify drivers of historic native vegetation change

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Abstract: Research underway with three Catchment Management Authorities in Victoria (Goulburn Broken, North Central and North East) is examining the impacts these bodies have had, and could potentially have, on native vegetation extent and quality (condition) on private land. This paper outlines how local knowledge together with spatial data and ecological information is being used to develop Bayesian Networks (BNs) that show historic changes in native vegetation quality and extent in three regions of northern Victoria since the 1880's. The research is being focused on three case study areas, one located in each partner CMA (Figure 1).

Comparison of aerial photography from 1946/7 with contemporary modelled tree canopy cover identified that native vegetation extent has increased or decreased to varying degrees over time and space in each case study areas.

Local knowledge elicited from the regional workshops has identified the catalysts of change over time as including episodic events, the viability of the farming industry, demand for 'lifestyle' properties, rabbit control, NRM and Landcare initiatives and policy instruments. Changes in extent and quality of native vegetation varied spatially and temporally across the landscape depending on the presence of remnant native vegetation, land tenure, agronomic potential of the land, historic events (e.g. bushfires), characteristics of the local population and targeted policy instruments. Expansion and intensification of farming between the mid-1950s and the late 1970s was matched by a general decline in the extent of woody native vegetation on private land. A decline in farm profitability from the 1980s to 2006 was associated with declines in farm employment, the number of farmers, population, and businesses and services in small rural towns dependent on agriculture and increases in 'lifestyle' farming around rural towns and regional centres. A general increase in the extent of woody native vegetation on private land was noted over this period by workshop participants.

BNs are being used to integrate local knowledge on historic land cover and vegetation change, and its drivers, with analysis of spatial data to capture changes in condition over time (60+ years). The regional workshops have been crucial in developing conceptual understanding of the relationships between external drivers (e.g. climate, market forces), actions (e.g. land clearing, de-stocking, revegetation) and outcomes (e.g. vegetation change). The knowledge and understanding of changes in land use and management and their drivers that was gained from the workshops have been used to refine the influence diagram for the historic vegetation extent and quality BNs, define the details of each variable (e.g. states, key assumptions) and identify key decades to represent in the models.

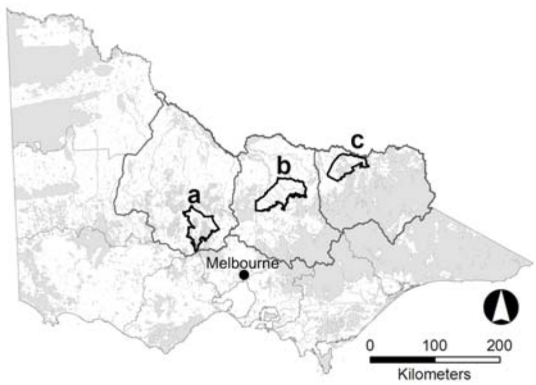

Figure 1. Partner CMA and case study areas (CSA): (a) Muckleford CSA in the North-Central CMA, (b) Longwood CSA in the Goulburn-Broken CMA, and (c) Chiltern-Springhurst CSA in the North-East CMA. Public lands are shown in grey.

Keywords: *local knowledge, consultation, Bayesian Networks, model development, native vegetation*

1. INTRODUCTION

Understanding how past human activities and environmental events have altered native vegetation extent and quality is critical for managing native vegetation into the future. A retrospective analysis of native vegetation change in three NRM regions in northern Victoria, being undertaken as part of the federally funded Landscape Logic research hub (www.landscapelogic.org.au), aims to identify changes in native vegetation over time and relate these changes to land use and management practices. This knowledge, together with social research aimed at identifying why past and present management practices were adopted, will be used to support future decision-making by the NRM regions.

Relating historic changes in vegetation to land use and management is problematic given that documentation of land use and, in particular, land management over time is very rarely available, complete or consistent. Analyses of aerial photographs and other data can provide an assessment of the amount of change that has occurred although causality can be difficult to ascertain. Local knowledge (e.g. oral histories) is often a crucial part of retrospective analyses as it can help researchers identify leads and contacts to follow up in future data analyses and can contribute to conceptual understanding of relationships between external drivers (e.g. climate, market forces), actions (e.g. land clearing, de-stocking) and outcomes (e.g. vegetation change).

We are developing Bayesian Network (BN) models to examine the likely impact of intervention activities across a region on vegetation condition, and potentially, where to invest in the region to get the best return(s). This paper outlines BNs that are being designed to show changes in native vegetation quality and extent since the 1880's in three regions of northern Victoria. The recollections of, and information provided by, participants in local workshops has been critical in refining the structure of the BN (e.g. key drivers, causal relationships) and identifying potential sources of data that will be used to parameterise the model.

2. BAYESIAN NETWORKS

Bayesian Networks (BNs) are the main approach being used for integration of research outcomes in Landscape Logic. They are a technique that has been used increasingly over the last decade to model environmental systems, including the biophysical, social, and/or economic impacts of implementing NRM strategies or technologies (e.g. Cain et al., 1999; Bromley et al. 2005). Influence diagrams are used to show causal relationships between variables which are described using probability distributions that can be derived from data of varying sources and forms including monitoring data, model simulations, surveys, expert elicitation and/or stakeholder beliefs. The development process for BNs (Table 1) and the advantages and limitations of the technique have been discussed widely in the literature (e.g. Ticehurst, 2008).

Table 1. Typical steps to develop BNs.

Step	Description
1	Define focus issue and scale
2	Develop influence diagram (e.g. Figure 5a)
3	Review influence diagram (link back to step 2)
4	Define states for framework variables
5	Populate BN with data
6	Review and test BN (link back to step 3)
7	Use BN for scenario analysis
8	Monitor and observe (link back to step 5)

The increased popularity of BNs has partly been due to perceived limitations in other statistical analyses or modelling frameworks in supporting environmental decision-making. For example, Ghazoul and McAllister (2003) stated that by failing to (a) integrate social needs and perceptions into analytical frameworks applied to biophysical data and (b) communicate predictions to stakeholders and decision makers in a form readily interpretable by non-scientists, forestry scientists have generally lacked the ability to gain the support of all relevant stakeholders in the implementation of proposed solutions. The authors identified the need for an analytical framework that clearly identifies actions that have the greatest likelihood of meeting management objectives and contended that the Bayesian approach was a powerful and intuitive tool in environmental decision-making contexts where decisions are based on a wide variety of information sources.

3. METHODOLOGY

3.1. The Victorian Retrospective Study

To understand contemporary native vegetation change due to natural resource management investment, the degree of change brought about through investment can be compared with the degree of change attributable to other sources of change, including those associated with land use change over longer periods. In this study, a combination of mapping, modelling and social research are being employed to identify periods where extensive vegetation change occurred and provide context for key government policies, and environmental and socio-economic conditions during the periods of change. This process was primarily designed to provide leads for subsequent and more detailed ecological and social research. Three case study areas (CSAs) are being used to focus the spatial analysis and social research: one in each of the Victorian partner NRM regions (see Figure 1).

Maps of wooded native vegetation cover change

To aid the elicitation of drivers of vegetation cover change, maps and interactive GIS displays were produced that compared wooded native vegetation cover as evident in aerial photography from 1946/47 against contemporary modelled tree canopy cover. For each sub-region, digitised 1946/47 aerial photograph mosaics, were geo-rectified in 2D by warping the digitised image ("rubber-sheeting") against a base map by Photomapping Services P/L (Abbotsford, Victoria). The rectification process used nine control points per photo mosaic, and the georectified images were then joined to provide a seamless meta-mosaic image.

Woody cover from the 1946/47 imagery was compared against a layer of mature tree canopy modelled from (*circa* 2005) spectral data (DSE, 2006) within 1.5 km diameter sample windows, distributed as a lattice at 3 km intervals across each CSA. Approximately 15% of the total area of the CSAs was directly mapped using this sampling approach. Operators drew polygons delimiting zones of vegetation change (described in Table 2) using ArcView3.2 (ESRI). As the base material was manually prepared photo-mosaics, any inaccuracies in the original data were carried forward into the meta-mosaic product. Road and stream features were used to help guide the observers to correctly compare the historical data with contemporary data.

Table 2. Categories of wooded vegetation cover change comparing the 1946/47 moasaic with *circa* 2005 modelled canopy cover.

Category	1946/47 cover	2005 cover
Cleared – solid	Solid native canopy evident	Cleared land
Cleared – scattered	Scattered native trees evident	Cleared land
Major thinning	Solid native canopy	Scattered tree canopy
Recolonisation	Cleared land evident	Scattered or solid canopy, or scrub
Major Thickening	Scattered native trees	Substantially denser canopy

Regional native vegetation change workshops

Regional workshops involving local stakeholders were used to gain landholder perspectives on broad landscape change in native vegetation cover, and identified leads and contacts to follow up with further interviews, image analysis and modelling. The 'rapid appraisal' process involved field visits and a three hour workshop with a diverse mix of people, including agency staff and landholders with a long family history in the local area. For example, the families of at least four of the Muckleford workshop participants had been in the local area since the 1850s. In the workshops, facilitated discussions about major changes over the study period together with discussion of the provisional maps of vegetation change were used to develop timelines of key activities or events that participants related to changes in native vegetation in the area. Emphasis was placed on eliciting information from the 1940s to the present, in order to correspond with the availability of spatial data sets, although knowledge about earlier influences was recorded.

3.2. BN Development

The four Bayesian Networks outlined in Table 3 are being developed for each case study area using the process outlined in Table 1. They will be based on Ecological Vegetation Classes (EVCs) – the basic mapping units used for biodiversity planning and conservation assessment at landscape, regional and broader scales in Victoria.

The 'Historic' BNs will reflect the major influences on native vegetation since the 1880s. These influences are being defined from the oral histories constructed from research described above in addition to more detailed landholder surveys currently being undertaken in the CSAs and, where available, review of published literature.

Table 3. Bayesian networks being developed for each case study area

	Extent	Quality
Historic	BN that show effects of past government policies, land use market forces, and environmental events and conditions on vegetation extent.	BN that show effects of past government policies, land use and management, market forces, and environmental events and conditions on vegetation quality.
Landscape Drivers	BN that predict • Likely adoption of selected management actions • Impact of likely adoption of selected management actions on vegetation extent.	BN that predict • Likely adoption of selected management actions • Impact of likely adoption of selected management actions on vegetation condition.

The 'Landscape Drivers' BNs are being developed to predict the effect of different environmental, social and management factors on vegetation extent and quality. They focus on a discrete set of management actions identified by the partner CMAs and/or considered critical to achieving desirable outcomes like increased native vegetation extent and improved native vegetation quality. These actions include fencing native vegetation, fencing to manage stock access to riparian areas, tree and shrub plantings, and grazing and/or weed management.

4. DRIVERS OF HISTORIC NATIVE VEGETATION CHANGE

4.1. Local Knowledge

Facilitated discussions about the major changes in native vegetation conducted in the workshops were used to develop timelines of key activities or events that participants related to changes in native vegetation in the area. The timeline developed for the Chiltern-Springhurst CSA is shown in Figure 2. A number of common key influences on and trends in native vegetation change were identified by the participants in each of the three workshops. However, there were differences between the workshops in terms of the perceived significance and timing of different factors.

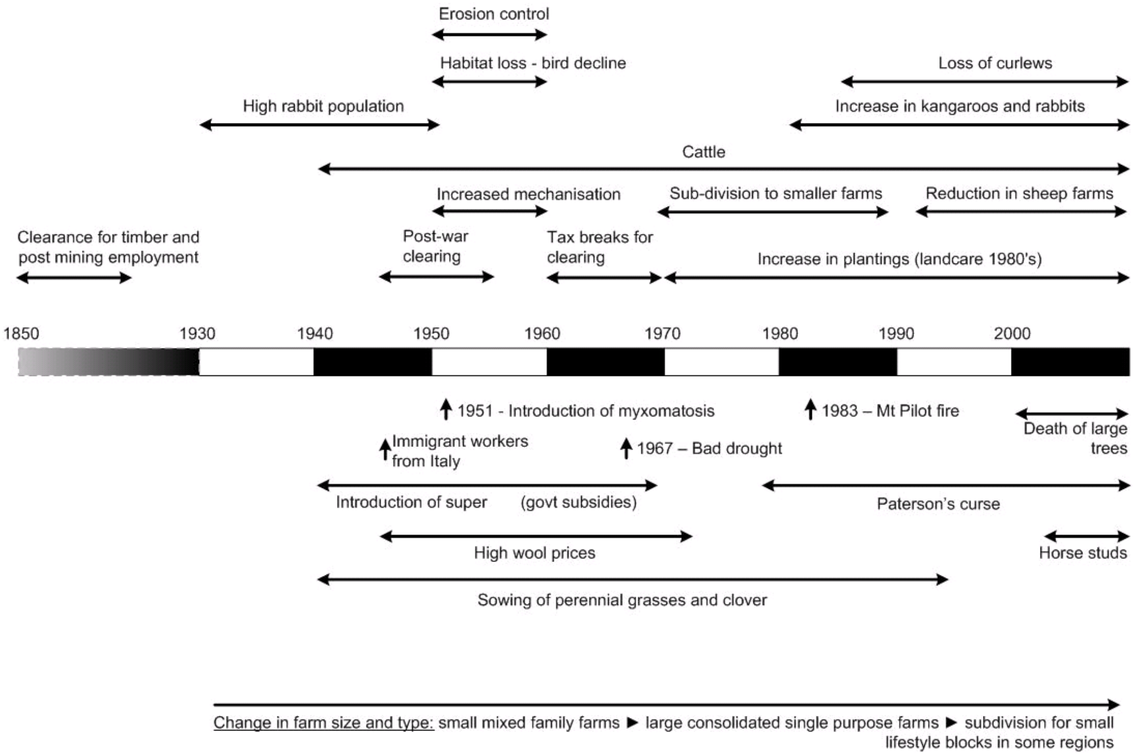

Figure 2. Timeline of key activities, events and changes in the Chiltern-Springhurst case study area developed from the rapid appraisal process.

Broad trends

Farming expanded and intensified between 1946 and the late 1970s and there was a general decline in the extent of woody native vegetation on private land. All CSAs saw a steady expansion of farmland area until mid-1970s, then decline in area in the late 1970s. Peak wool prices during early-1950s led to 'improved' pastures, application of fertiliser, and increased mechanisation. Farm machinery allowed larger areas to be cropped. A trend toward beef cattle production occurred during the late-1960s to mid-1970s. Landcare or NRM programs started in the 1970s with a focus on erosion control. Plantings tended to be overstorey species that were not necessarily indigenous to the area.

The 1980s to 2006 saw a decline in farm profitability which was associated with declines in farm employment, the number of farmers, population, and businesses and services in small rural towns dependent on agriculture. Livestock numbers fell and management practices that favoured exotic pasture species over native species (e.g. fertilising, sowing) declined. 'Lifestyle' farming increased around rural towns and regional centres like Castlemaine and Wodonga. Revegetation works focused more on the establishment of both understorey and overstorey components with local native species. These activities, together with the contraction of farming area, led to a general increase in the extent of woody native vegetation on private land.

The catalysts identified for changes in native vegetation on private land included the fluctuating viability of commercial farming, episodic events (e.g. fire, flood and drought), an increasing desire for and affordability of 'lifestyle' farms; control of rabbits, the aggregate impact of a variety of programs and initiatives under the Landcare umbrella, and policy instruments (e.g. fertiliser subsidies in the 1940s, tax incentives to clear in the 1960s, and clearing regulations under the Victorian Government *Planning and Environment Act 1987*).

The type of change in native vegetation – such as loss or gain in area and deterioration or improvement in quality – varied both spatially and temporally across the landscape. Landscape heterogeneity has been shaped by the presence of remnant native vegetation, land tenure, agronomic potential, historic environmental events like bushfires and floods, social and demographic characteristics of the local population and targeted policy instruments (e.g. protection of roadside vegetation, planting along fence lines or riparian areas).

Reliability

A number of studies have investigated the value of local knowledge as an information source for environmental management (e.g. Tibby et al. 2008) and for developing understanding of the causes and timing of changes in land cover or woody vegetation (e.g. Wezel and Lykke, 2006; Chalmers and Fabricius, 2007). While the potential value of local knowledge is acknowledged, it is also widely recognised that there are a number of potential limitations including failure or deterioration of memory, re-interpretation of events, personal bias, and/or difficulties in determining causality for observed or perceived changes over time.

Some factors were raised by the participants in only one of the three workshops. In some cases this is plausible: for example, episodic events such as fire or flood may be localised in extent. Other factors such as state-wide clearing regulations should be relevant to all three CSAs yet were only raised in the Muckleford regional workshop.

The precision of the timing of key events or activities identified by workshop participants also has to be critically assessed. The Victorian Retrospective Study is focusing on the last 60 years, due to the availability of aerial photography in the CSAs, although recognises that land use and management prior to 1946 will have influenced native vegetation extent and quality in later time periods. Issues of memory and/or re-intepretation of events could be expected to be significant over this lengthy timeframe. Many common factors were identified in the three workshops although over different time periods. For example, increasing kangaroo numbers were noted from the 1970s in the Longwood workshop compared with the 1980s in both the Chiltern-Springhurst and Muckleford workshops.

While participants in the workshops were able to identify historic events and activities that could affect native vegetation condition, identifying causal relationships between those drivers and change was more difficult. In the Muckleford workshop, participants identified broad trends in the loss or gain of woody and herbaceous vegetation that corresponded to the timeline of events and activities. In the other workshops, causal links between drivers and change were less defined. Periods of increased weediness were identified in the Chiltern-Springhurst workshop and related back to land use or management in the landscape. Factors influencing land use or management over time were identified in both the Chiltern-Springhurst and Longwood workshops. However, how these factors related to perceived or actual trends in vegetation change over time was not as well articulated as at the Muckleford workshop.

The timelines and factors identified in the workshops will be checked for errors (omission, commission and timing) and for plausibility in terms of any perceived impact on native vegetation. The reliability of the information gained from the workshops will be verified using historical records, published literature and image analysis.

4.2. Refining the structure of the 'Historic' BNs using local knowledge

The process for developing BNs in Landscape Logic firstly involved capacity building within research teams and the NRM regions to understand and contribute to the development of BNs. Complex influence diagrams were then developed which represented the biophysical and social systems that impact native vegetation condition. The current phase of development is the construction of 'integrated' BNs which include only the key biophysical, ecological and social factors that influence native vegetation condition. Simple influence diagrams have been developed for all four BNs listed in Table 3.

The 'historic extent' BN developed is shown in Figure 3a. Government policies, market forces, kangaroo and rabbit populations and climate influence native vegetation through impacts on active clearing, dieback, revegetation and recolonisation (e.g. due to removal of stock and/or non-stock grazing pressure). Outcomes from the rapid appraisal workshops are being used to refine the influence diagram shown in Figure 3a, define drivers of the changes in the extent and condition of native vegetation over time, and to start defining the details of each variable (e.g. states and key assumptions).

The timelines referred to in Section 4.1 were used to identify key activities or events identified by workshop participants that were consistent across the three study areas (i.e. identified in two or more CSAs for a given decade). For example, government policies identified by workshop participants as impacting the extent of native vegetation over time include clearing requirements (1880s to 1930s), clearing regulations introduced in 1989, superphosphate subsidies in the 1950s and 1960s, and promotion of Phalaris (*Phalaris tuberosa*) from the 1950s. The rise and fall of wool prices over time was identified as determining land use as well as a farmers' financial capacity to invest in infrastructure which in turn affected land management and the level of active clearing (Figure 3b).

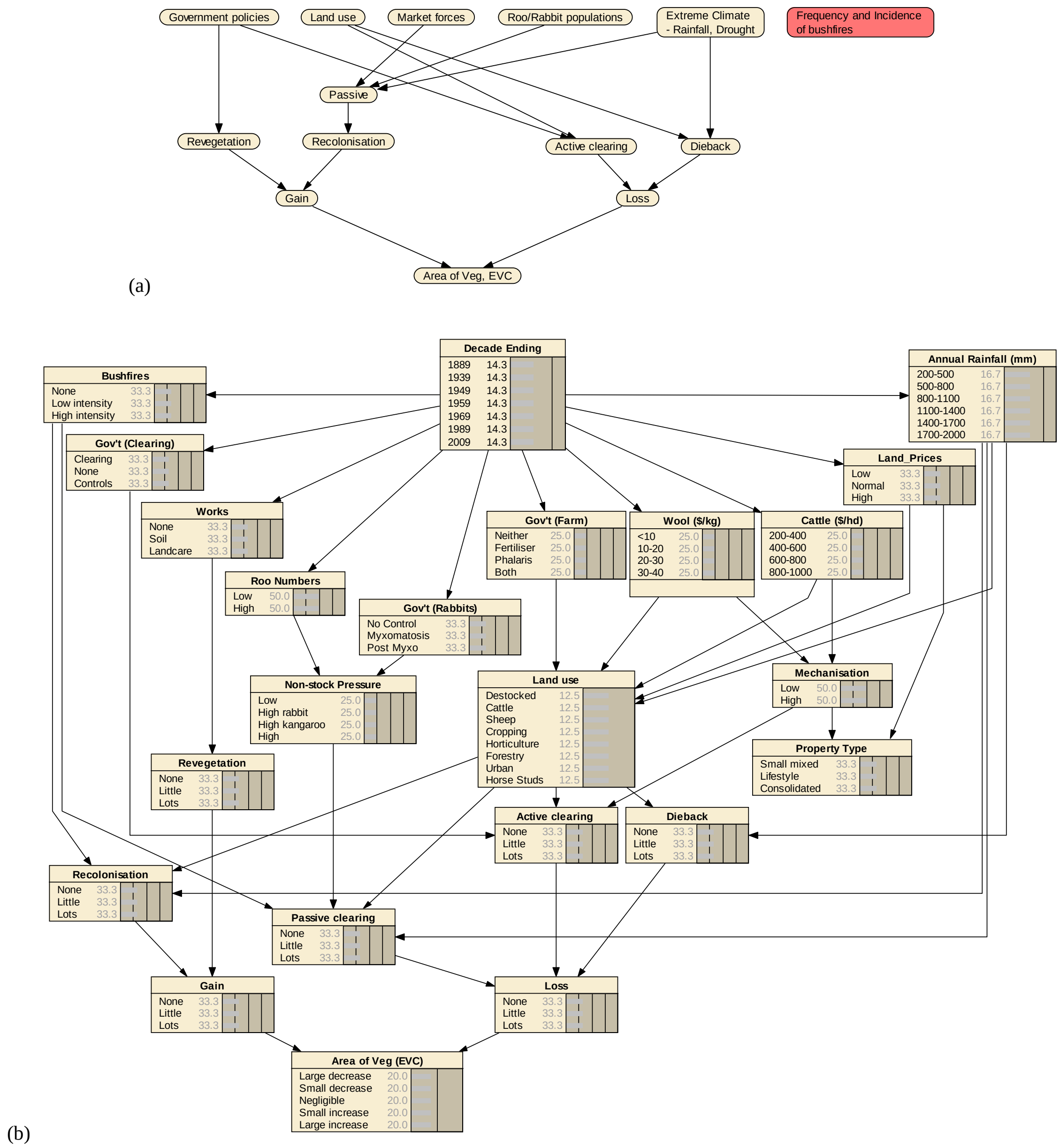

Figure 3. Structure of the BN for historic drivers of vegetation area: (a) network developed prior to rapid appraisal process, (b) revised network developed using outputs from rapid appraisal process.

Key time periods to represent in the BNs are the decades ending in 1889, 1939 to 1969, 1989, as well as the 2000s. The influence diagram in Figure 3b will continue to be refined as the model development moves into the data population and review phases (steps 5 and 6 in Table 1). Further analysis of aerial photography during the key time periods will provide a data set with which to test the plausibility of the BN structure. Aerial photographs for the three CSAs are only available since the 1940s and any representation of earlier time periods will be more speculative and have less certainty or reliability attached to any modelled change in native vegetation than for post-1940s time periods.

5. DISCUSSION AND CONCLUSIONS

How land has been used and managed over time has shaped the current extent and quality of native vegetation on private land in the north of Victoria. Government policies, markets, climatic conditions and demographics have all influenced land use and management, either through direct (e.g. clearing, revegetation) or indirect (e.g. control of rabbits, changes in demographic) actions. Native vegetation condition varies spatially and temporally across the landscape depending on the presence of remnant native vegetation, past and present land tenure, agronomic potential of the land, historic events (e.g. bushfires), characteristics of the local population and targeted policy instruments.

BNs are being used to integrate local knowledge on historic land cover or vegetation change, and its drivers, with analysis of spatial data to capture changes in condition over time. The regional workshops have been crucial in developing our conceptual understanding of relationships between external drivers (e.g. climate, market forces), actions (e.g. land clearing, de-stocking, revegetation) and outcomes (e.g. vegetation change). The knowledge and understanding of changes in land use and management and their drivers gained from the process has been used to refine the influence diagram for the historic vegetation extent and quality BNs, and define the details of variables (e.g. states, key assumptions) and key decades to represent in the models.

Comprehensive landholder surveys and analysis of imagery for key periods of change over the last 60 years are underway for each of the case study areas. This will further develop understanding of how native vegetation has been shaped by drivers of land use and land management in these landscapes.

ACKNOWLEDGMENTS

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REFERENCES

Bromley, J, N.A. Jackson, O.J. Clymer, A.M. Giacomello, and F.V. Jensen, (2005). The use of Hugin® to develop Bayesian networks as an aid to integrated water resource planning. *Environmental Modelling and Software*, 20, 231-242.

Cain, J, C. Batchelor, and D. Waughray, (1999). Belief networks: a framework for the participatory development of natural resource management strategies. *Environment, Development and Sustainability*, 1, 123-133.

Chalmers, N, and C. Fabricius, (2007). Expert and generalist local knowledge about land-cover change on South Africa’s Wild Coast: can local ecological knowledge add value to science? *Ecology and Society*, 12(1), 10 [on-line].

Department of Sustainability and Environment, (2006). MetaData Report: Tree Density 1:25,000—Vicmap Vegetation ANZVI0803003127. Department of Sustainability and Environment, Melbourne.

Ghazoul, J. and M. McAllister, (2003). Communicating complexity and uncertainty in decision making contexts: Bayesian approaches to forest research. *International Forestry Review*, 5(1), 9-19.

Tibby, J, M.B. Lane, and P.A. Gell, (2008). Local knowledge and environmental management: a cautionary tale from Lake Ainsworth, New South Wales, Australia. *Environmental Conservation*, 34 (4), 334-341.

Ticehurst, J, (2008). Evolution of an approach to integrated adaptive management: the Coastal Lake Assessment and Management (CLAM) tool. *Ocean and Coastal Management*, 51, 645-658.

Wezel, A. A.M. Lykke, (2006). Woody vegetation change in Sahelian West Africa: evidence from local knowledge. *Environmental Development and Sustainability*, 8, 553-567.