**Submission
No 486**

INQUIRY INTO MANAGEMENT OF PUBLIC LAND IN NEW SOUTH WALES

Organisation:	Frontier Optimisation
Name:	Dr Ernst Kemmerer
Date received:	28/09/2012

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Management of public land in New South Wales (Inquiry)

Towards evidence-based management of public land, using multi-criteria decision making systems

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1. INTRODUCTION

1.1 Scope of this submission

This submission only relates to part 3 of the terms of reference, that is:

> Examination of models for the management of public land, including models that provide for conservation outcomes which utilise the principles of "sustainable use".

To fully explore models for 'conservation outcomes', this submission discusses the use of decision support systems (DSS) for improved public land management and better landuse planning to achieve landscape-wide outcomes.

1.2 Disclaimer

The examples given in this submission are for illustration purposes only and do not represent a complete solution for a given landscape or situation, as not all factors have been described or included in the models. The reader should also note the section on data limitations which highlight the need for quality information to support the modeling and decision making process to avoid the 'garbage-in garbage-out' effect. The section also highlights gaps in data for landuse planning in New South Wales.

1.3 Single versus multiple objectives

In New South Wales, models for conservation outcomes have primarily focused on assessing land suitability for the purpose of identifying high conservation value areas or designing a permanent reserve system. For example, C-Plan software was designed to predict the irreplaceability value of forested lands to determine suitable conservation areas (Ferrier et al, 2000) as part of the Comprehensive Regional Assessments. In addition, the Biodiversity Forecaster Tool was developed by the Department of Environment and Conservation (DEC, 2006) for assessing the value of land parcels for their intrinsic flora and fauna values. In another example from Queensland, Marxan software was developed for designing new reserve systems, reporting on performance of existing reserves, or developing zoning plans within reserves (Ball et al, 2009).

The key limitations of these tools are that they are built for a single objective (assessing land units for their biological or conservation value) and they are static models (giving a snapshot in time, rather than being dynamic). These tools have very specific uses and do not consider a wider range of landuse activities (eg forestry, beekeeping, grazing) or events (eg fire, storms, disease, feral animals), or how the activities relate to wider landuse (eg forestry, agriculture, mining and urban development) issues within a catchment or landscape.

In contrast, the global trend is to assess lands not only for their suitability but evaluate land units with multiple objectives and over time. These are referred to as 'multiple-criteria decision making' (MCDM) or 'multiple-criteria decision analysis' (MCDA) tools. These DSS were developed as a sub-discipline of operations research, which encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency (see IJORIS). A brief overview of MCDM DSS and optimisation methods are given in Appendix 1.

The use of MCDM tools enable land to be assessed at a landscape level across a range of tenures, with multiple objectives and over long planning horizons. This enables planners to evaluate landuse outcomes in the long-term against social, economic and environmental criteria. In this way, MCDM tools can fully utilise the principles of sustainable development. For example, ensuring intergenerational equity in the use of non-renewable resources and using longer-term planning cycles; rather than relying on short-term financial or political cycles.

MCDM tools are most useful when the number of decision variables, constraints and goals exceeds that of human capability to determine an optimal solution. For example, in managing 1000ha of land divided into 100ha parcels (10 units), with 3 different activities or events, and a planning horizon of 50 years, then we have 1500 possible combinations or decisions to make over the planning cycle (10x3x50=1500). In practice, a decision matrix is much larger than this to cater numerous decision variables, longer planning horizons, multiple objectives and thousands of hectares. In these complex situations, planning without a MCDM will most likely be sub-optimal.

This submission outlines the use of MCDM in the areas of biodiversity conservation, fire management and landuse planning to achieve optimal outcomes for public land management.

2. EXAMPLES SHOWING POTENTIAL USE OF MCDM

2.1 Fire management – a landscape approach

Fire management in New South Wales has conventionally been carried along tenure lines, with each agency conducting its fire management activities to meet the purposes of the agency. Currently it appears that two competing fire management philosophies exist, firstly the 'no-burn' or 'let-burn' approach for naturally started fires[1], and the second is for active fuel management and suppression. This submission argues that where multiple management goals

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[1] For example, the McLeod inquiry into the Canberra fires of 2003 concluded that the fires, started by lightning strikes (*in NSW*), might have been contained, had they been attacked more aggressively in the 24 hours after they broke out (McLeod, 2003 pg iii). In addition, both the forests and parks authorities should have dedicated access during the bushfire season to a small number of light graders and bulldozers, capable of speedy transport to fire sites. This equipment could be strategically placed to assist rapid deployment (McLeod, 2003 pg vii).

exist, an evidence-based approach needs to be taken for managing fuel levels across the landscape.

To achieve this, agencies need ***area*** information about vegetation, a geographic information system to record fire history (***current state***), and fire-response information (***yields***) for the decision variables. A key component is developing post-fire yield curves, for example the rate of fuel load accumulation for each vegetation type over time. Typically, these response curves can be described as first-order dynamic equations as shown in Figure 1. There is a lag phase (red), a response phase (brown), and an equilibrium or steady state phase (green). The fuel accumulation rate will vary for each vegetation type and with intensity of burns (or ***events***). Each vegetation type also requires fundamentally different fire management regimes that can be treated as model ***constraints*** across the landunits (operational sub-divisions of the land into fuel management units).

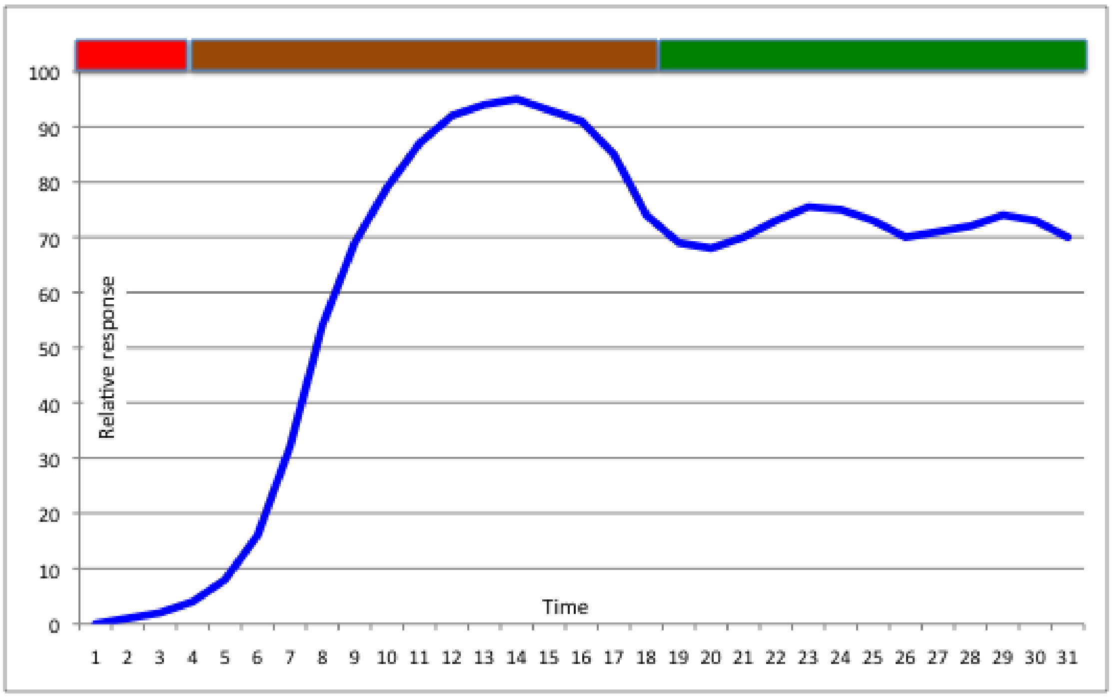


Figure 1 Sketch of a dynamic response to a disturbance event

Having described the ***area***, current ***state***, and ***yields*** for each ***event*** type, it is now possible to describe a management objective (or ***objective function***). In a simple example, the objective function may be to minimise the fuel load across the landscape over a 120-year cycle while not burning any vegetation type beyond its specified fire frequency regime or limit. Using a Linear Programming (LP) solution, the optimal fire regime will result in a spatial display showing the sequence of burn events to be carried out annually across the landscape for the pre-defined land units (termed ***landscape units*** or development types).

Objective functions are not fixed and can be modified to suit the question at hand. LP models can be constructed as templates that can be modified by planners for scenario analysis, optimisation or operational scheduling. Also, in the event of a wildfire the current state can be updated and the model re-run to provide the adjustments in the fuel reduction schedule. This is the beginning of evidence based fuel management using MCDM tools. Variations to the model for achieving biodiversity conservation aims are described below.

2.2 Biodiversity conservation – evidence based management

Fire is an important part of Australia's landscape, and the adaptive response of fauna to a fire event varies between species. The key question is what should the frequency and intensity of burning be, to cater for the diversity of fauna across the landscape? This problem can be solved by converting the LP solution as described in section 2.1 to a Goal Programming (GP) solution by adding fire-response yield-curves for each species and having multiple objectives or targets (ie for both fauna and fuel reduction targets).

Species recover at different rates ranging from short-term responses from opportunistic ground mammal species, to long-term recovery for arboreal mammals. Indicator species can be used to evaluate short, medium and long-term responses and the proliferation of research on species response to fire, now makes this possible (for example, Watson et al 2012). By simulating various fire regimes, a better appreciation of the ecology and balance in nature can be obtained (see Kelly et al, 2012). Figure 2 provides and example of the yield curves for ground mammals on the north coast of New South Wales (adapted from Fox and McKay, 1981).

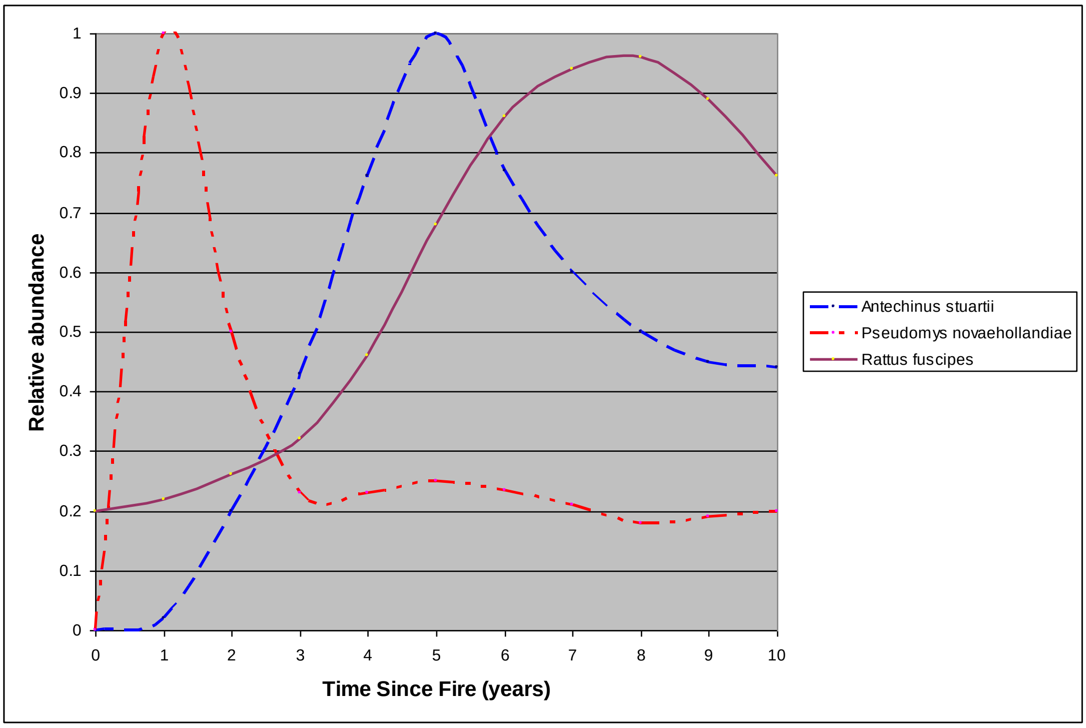


Figure 2 Post-fire population response for three small ground-mammals (adopted from Fox and McKay, 1981)

By using GP it is now possible to have multiple objectives or criteria such as minimising fuel loads, or achieving fuel reduction burning area targets, while at the same time maximising species diversity or abundance. Again, the solution or output is a spatial map of the required fuel reduction patterns or fuel management schedule required to achieve the various goals. The advantage of this approach is that more certainty about the environmental impacts is achieved, and fuel reduction burns can be readily modified to suit the local flora and vegetation structure, or immediately adjusted with any given wildfire event. Therefore the GP approach can provide natural resource managers with a tool to schedule the ideal fire regime for a particular region while considering a range of values or targets to be achieved. This is an example of how evidence based fuel management could be applied to public lands in NSW.

2.3 Landuse planning and policy evaluation

With increasing landuse pressure from urbanisation, forestry, agriculture and mining, the emergence of landuse conflict in New South Wales is likely to increase as the population increases. The coal-seam-gas debate is one example of the emerging complexity of the socio-economic and environmental issues being faced by rural communities.

As part of the landuse conflict is the increasing demand for environmental services (clean water, recreation, accessibility) from public land, as well as increasing demand for forest products and uses (timber, beekeeping, grazing, hunting). As public lands often constitute a large proportion of the landscape, there is a need for government agencies to assist in achieving balanced outcomes and understanding long-term cumulative impacts of development activities within a landscape context (ie both public and private lands). MCDM tools can play a central role in a complex decision making environment. These DSS tools can also assist the NSW Government in testing and formulating policy before implementation. A case example from the Hunter Valley is given below for the study area shown in Figure 3.

LP is conventionally used to solve landuse allocation problems (see Riveira and Maseda 2006 for a review of uses). However, in the case of the coal mining in the Hunter Valley, economic benefits are highly skewed towards coal production compared to other sectors such as agriculture or forestry. In this decision making environment, it is possible to switch to GP to enable community values and goals to be included in the decision making process. For example, the Hunter Valley Coal Chain (HVCC) has projected an expansion of coal mining from 90 megatonnes per annum (Mtpa) to over 250 Mtpa over the next decade (Boyle, 2010). In this situation GP can be used to forecast the cumulative impacts across the landscape under this scenario. Figure 4 shows the impact for one part of the valley over the next 10 years.

The majority (60%) of mining in the HVCC is open-cut mining, which may require clearing of native vegetation. The regulatory requirement for developers is to seek to offset the impact of vegetation clearing by obtaining additional land parcels of similar vegetation type to the zone of impact. However, there is no requirement to strategically locate offsets to meet conservation goals such as linked corridors within the landscape. The key issue is how to achieve this in a free market?

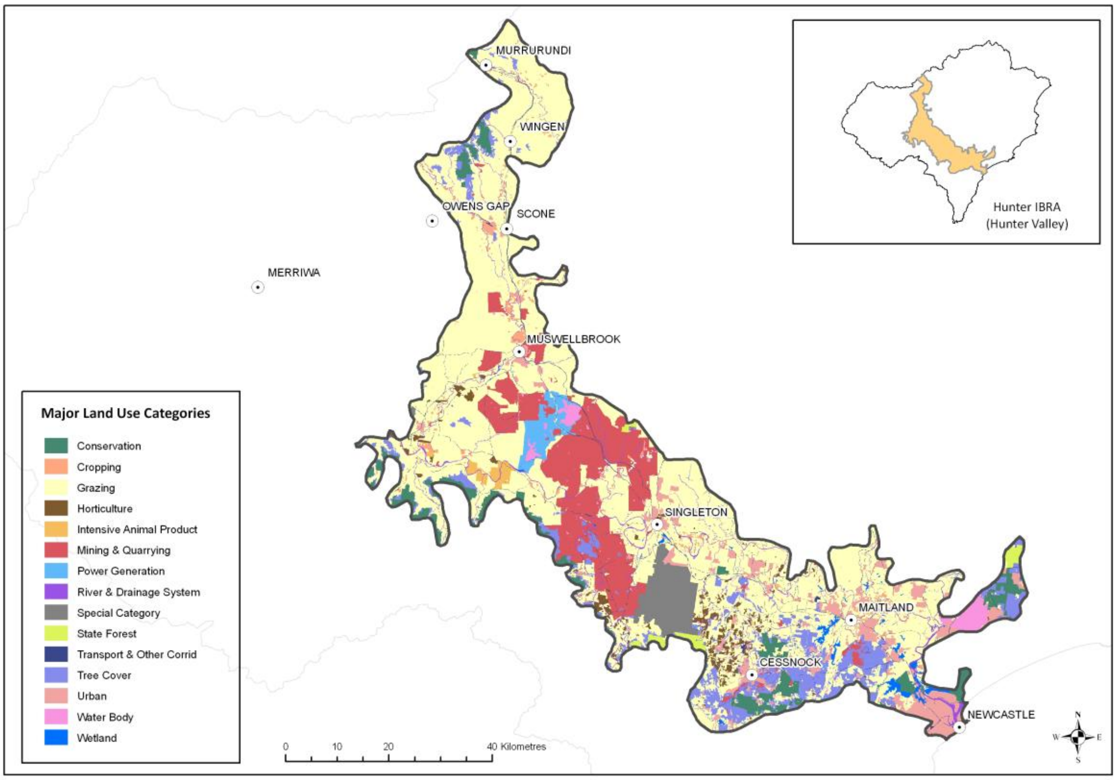
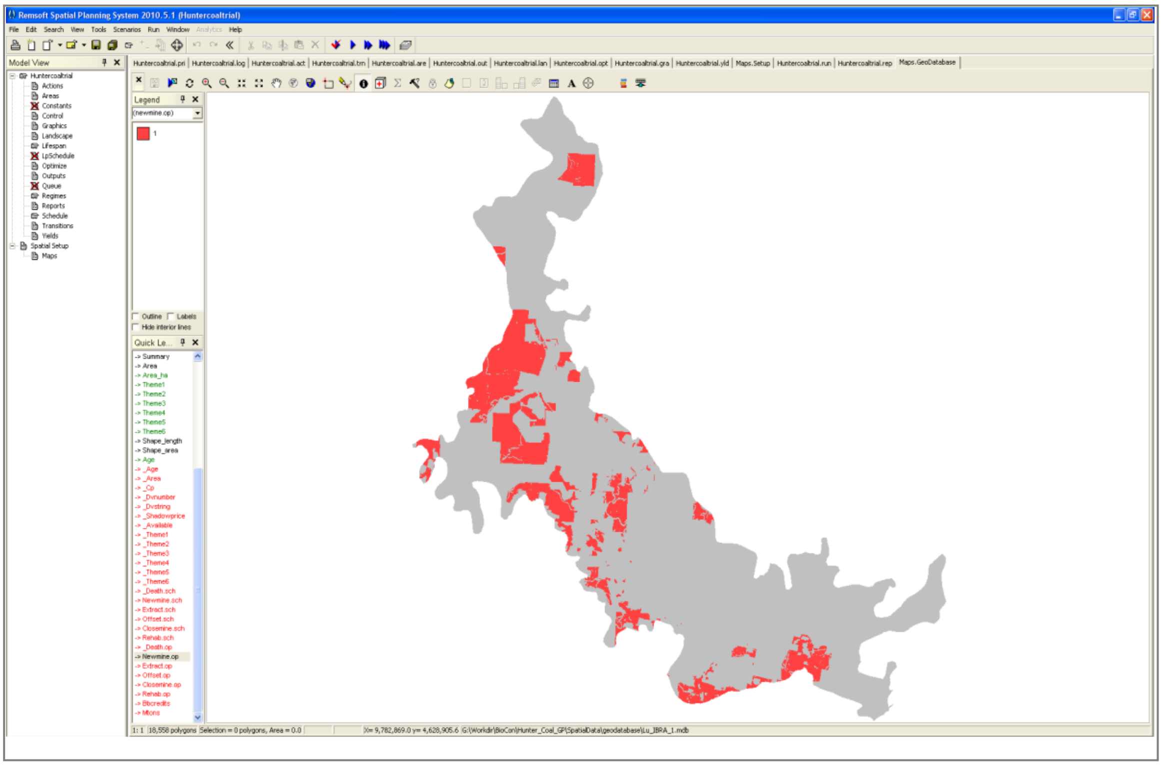


Figure 3 Current state of landuse for part of the Hunter Valley, NSW



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1: 1 | 18,558 polygons | Selection = 0 polygons, Area = 0.0 | | | X= 9,782,869.0 y= 4,628,905.6 | G:\Workdir\BioCon\Hunter_Coal_GP\SpatialData\geodatabase\Lu_IBRA_1.mdb
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Figure 4 Illustration of potential future coal extraction areas under a scenario of increased coal production targets (example only)

Using GP it is possible to test various offset policies under the 250 Mtpa scenario using a prototype data model (ie one built using coal production statistics by DPI, 2009). Two policy settings could be applied; 1) a fixed 1:3 offset ratio and 2) a variable offset ratio with increasing discounts for adjacency and connectivity. The result of the fixed offset ratio indicates that offset lands are exhausted within 20 years and the majority of offsets occur in large freehold areas well away from the valley floor. An observable trend from the prototype model was that the rate of rehabilitation could not keep up with the rate of mining due to the number of new mines and mine extensions created.

A variable offset ratio with discounts given to adjacency does result in improved connectivity, but not sufficient to link valley floor remnants unless further constrained by proximity to the zone of impact. However, this option was not able to be properly tested due to the absence of land-price information in the prototype model. Nevertheless, it is expected that developer behaviour would change significantly if the offset discounts were sufficient to offset the increase in land price in the Hunter Valley floor, resulting in connectivity in the landscape. Furthermore, it may facilitate increasing effort into mine rehabilitation to be of sufficient standard for biodiversity credits.

This example demonstrates that GP can be used to test policy settings and basic assumptions of a policy in a free market situation before attempting to implement policy. Furthermore, it shows that with MCDM tools, government policies can shift their focus away from the regulatory mode to the development of appropriate incentives to achieve the desired outcomes at a landscape level.

3. DATA LIMITATIONS

To build DSS for public land management requires a hierarchy of data as follows:

1. A land information database to record the historical ***events***, ***actions*** and ***current state(s)***of the values for the decision making criteria

2. A spatial information system to record the ***area*** and attribute information for the ***current state(s)***, and

3. ***Yield*** information or response-curves for each of the actions or events described.

DSS require quality information for input into the models in order to correctly inform the decision making process and for the planners and stakeholders to have confidence in the outputs. For example, to build a DDS for evaluating fuel management scenarios, the underlying vegetation maps need to be of appropriate resolution, the fire history data needs to be up-to-date and the fuel sampling program needs to be effective for landscape wide management.
The input data also needs to be commensurate with the scale of decision making where fine scale mapping and sampling is required for local planning, and regional scale information for regional planning. While most areas of NSW do

not have fine scale vegetation mapping to built a DSS for fire management, there are some local government areas that have been mapped using high resolution ADS40 imagery (supplied by NSW Land and Property Information).

To improve the models to include management for biodiversity requires more detailed fire-response models for a range of species within different habitat types. Furthermore, the varying response to low, medium and high intensity burns needs to be understood as well as the varying size or scale of fires. Where information is incomplete, it is possible to use expert opinion, heuristics or fuzzy logic, or to use sensitivity analysis to explore a range of possible outcomes.

The likely level of information held by each agency for levels one to three is listed in Table 1.

	DoP	CMA	NPWS	FNSW	RFS	Comments
Land Information Database	×	✓	×	✓	✓	A historical record of actions and events
Spatial Information System	×	✓	✓	✓	✓	Area and attribute information for the decision criteria
Optimisation Software	×	×	×	✓	×	MCDM software for simulation, forecasting, and optimisation

Table 1 Example of a high level information audit required for implementing MCDM

There are likely to be major data gaps in NSW which would need addressing before implementing MCDM applications. For example, the Rural Fire Service generally has a range of sophisticated information to support suppression activities and is continually improving its decision support systems, but relies on broad vegetation mapping at the class level, which may be inappropriate for coastal areas of NSW. Furthermore, the only agency that uses optimisation software is Forests NSW, but it is only used for a single purpose objective of maximising returns from wood production in plantation forests. However, the potential exists for a much wider improvement program to support decision making for public land management in NSW.

4. RECOMMENDATIONS

1. That a continuous improvement program commence within NSW Government for the using MCDM to support public land management

2. That research and development activities focus on applied science to support MCDM systems

3. That quality vegetation mapping programs underpin information systems to support improvements in public land management

4. That an integrated and whole of government approach be taken to the collection and sharing of baseline data (such as vegetation mapping) to improve public land management and decision making.

5. SUMMARY

The submission demonstrates the potential role of MCDM tools to support government policy development, decision making in a complex environment, and evidence based management of public land.

Information systems and research activities need to underpin MCDM tools to ensure outputs can be reliable to inform the decision making process.

A topic not explored in this submission is the potential role of MCDM to engage stakeholders in the planning process. This is now achievable because of the fast processing speeds and output of results using visual spatial displays, graphics and reports.

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APPENDIX 1. Types of decision support systems and mathematical methods

For simplicity, mathematical descriptions are not included in this overview.

The three main uses of systems are:

i) Simulation – can be used for scenario analysis and adjusting the parameters of a model to test 'what if' situations (eg fire spread simulation with given temperature, humidity and rainfall measurements).

ii) Prediction – is used to forecast or estimate a future state given a series of current inputs, which are known to be related to or assist in predicting a future state. Reliability of the prediction generally decreases when trying to predict too far in the future (eg weather predictions).

iii) Optimisation – is used to maximise or minimise the performance of a system relative as measured by the objective function. Principles of optimisation have been developed in the fields of operations research, mathematics and engineering, and can be equally applied to natural resource management issues (eg maximising timber revenue while maintaining sustained yields and biological values or targets).

Mathematical methods for optimisation are:

i) Linear programming (LP) – can be used for allocation problems, planning, scheduling, and routing. LP solutions can be applied to various fields of study such as business, economics, engineering, transportation, energy, telecommunications, and manufacturing. LP solutions only work with a single objective function, for example maximising revenue.

ii) Goal programming (GP) – is the same as an LP solution except that multiple objective functions can be specified (with different weightings) and the solution shows how well the targets are met for each decision criteria.

iii) Dynamic programming (DP) – is a specific implementation of Bellman's principle of optimality (Bellman, 1957) and can be used in a variety of scheduling problems.

iv) Stochastic programming (SP) – is a variation of the above (deterministic models) by introducing randomness into the model, and evaluating expected across a range of expected outcomes. The solution is one that maximizes (or minimises) the expected cost over all possible realisations.

v) Optimal control (OC) – used in control systems to maximise or minimise the outputs by finding (or solving for) the optimal sequence of inputs.

LP and GP are most commonly applied to natural resource management issues, landuse planning, agriculture and forestry. GP solutions are also the most common solution for MCDM and perhaps the easiest to implement (ie a solution is rarely infeasible, but not necessarily optimal in order to achieve the desired targets for each decision criterion).