QUANTIFYING DEGRADATION RISK – INTEGRATING CLIMATE RISK INTO RANGELAND MANAGEMENT

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ABSTRACT
This paper describes a modelling approach to quantifying pasture degradation risk using a decision tree model in conjunction with information generated from the AussieGRASS Environmental Calculator. Model development, calibration and validation are presented, and the limitations of the approach discussed.

INTRODUCTION
Australia has one of the most variable climates in the world. Pastoral agriculture in Australia, as a climate-dependent industry, operates under highly variable climatic conditions. Pastures are often over-utilised in dry years due to low pasture growth and failure to match livestock numbers to available feed. Heavy pasture utilisation in dry growing seasons has been identified as the major driver of pasture degradation and has caused serious pasture degradation events in Australia over the last 100 years or more (McKeon *et al.* 2004). The social, economic and environmental impacts of pasture degradation have been well documented in Australian history (McKeon *et al.* 2004).

This paper describes the development of a modelling approach to quantifying degradation risk, some preliminary results and limitations of the approach.

JUSTIFICATION AND APPROACH
Results of grazing trials and grazier experience have indicated that the interaction of heavy pasture utilisation and drought is the major driver of pasture degradation (McKeon *et al.* 2004). The level of pasture degradation risk depends on the severity of drought, the level of overgrazing and the fragility/resilience of particular land types.

To match livestock numbers to available feed during drought, it would be beneficial to have reliable and relatively long lead climate forecasting information. However, current seasonal forecasts are inherently probabilistic and not always well adopted in grazing land management. In lieu of seasonal forecasting being adopted in grazing land management, a "safe" (*i.e.* conservative) pasture utilisation rate has been advocated (*e.g.* Johnston *et al.* 2000). Previous studies have indicated that the "safe" utilisation rate is closely related to pasture growth rate, which is a function of vegetation, soil and climatic factors (McKeon *et al.* 1990). In the GRASP model (McKeon *et al.* 1990) and the spatial version of this model – the AussieGRASS Environmental Calculator, solar radiation, available soil moisture and temperature are expressed by a growth index. The growth index ranges from 0 to 1, indicating the worst to the best growing conditions for pastures. The percentage of days in a year with the growth index >0.05 (%GiDays) has been shown to provide a useful indication of "safe" pasture utilisation rate and animal performance at land type scale (Hall *et al.* 1998). For example "safe" pasture utilisation rate was expressed by a relationship:

$$SU = -11.2 + 0.385 * \%GiDays \quad (n = 6, r^2 = 0.853) \qquad \text{equation (1)}$$

where SU is "safe" utilisation rate in percentage based on long-term average annual pasture growth, %GiDays is the percentage of days in a year with growth index >0.05 (Hall *et al.* 1998).

The severity of drought can be directly indicated by the deficit of rainfall. However, pastures may produce different amounts of dry matter for same amount of rainfall, depending on the soil type, ground cover, topography, species composition and rainfall distribution. Therefore, pasture growth ranked against historical values (*i.e.* as a percentile) is a better way to indicate the severity of drought for the purpose of this study.

A decision tree modelling approach (Zhang *et al.* 2005) was applied to quantify degradation risk. Initial input variables tested were actual utilisation rate (calculated from modelled annual pasture growth and estimated stocking rate), modelled "safe" utilisation rate, severity of drought (expressed as percentile pasture growth) and seasonal rainfall outlook based on Southern Oscillation Index (SOI). Other factors which we propose to test in future include ground cover, land type and pasture condition. Logical decision rules in this decision tree model were subjectively derived from past studies (*e.g.* Scanlan *et al.* 1994; Johnston *et al.* 1996; Day *et al.* 1997; Hall *et al.* 1998; McKeon *et al.* 2004) and were refined through model calibration by selecting different subsets of input variables and splitting points.

Model calibration was carried out using the outputs generated by the AussieGRASS Environmental Calculator. A long-term (30 year: 1977–2007) median %GiDays spatial layer for Australia was calculated which was used to derive a spatial layer of "safe" utilisation rate based on equation (1). Time series (1880–2007) of stocking rate (beef equivalent [BE], 400kg live weight per 100ha), annual pasture growth (kg DM/ha), 24 month percentile pasture growth and forecast rainfall probability were generated across Australia on a 5km × 5km grid for each year ending September. These time series were then input to a decision tree model to predict degradation risk for each year from 1890 to 2007. Model calibration was conducted through iteratively refining the logical decision rules by comparing model predictions against eight well documented historical degradation episodes in six regions across Australia (Fig. 1) as described by McKeon *et al.* (2004). When the logical decision rules were constructed, an independent validation of the decision tree model was conducted. As all well-documented degradation episodes were incorporated in the model calibration, four areas located in Northern Territory, Queensland and New South Wales where pastures were considered to have never been subjected to severe degradation episodes (Fig. 1) were selected to conduct an initial model validation.

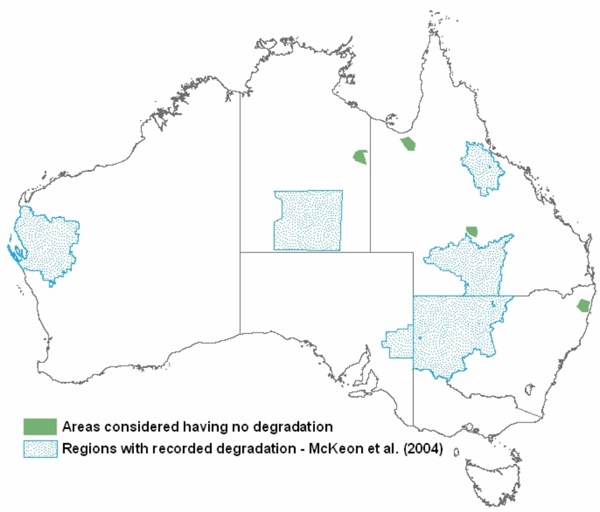

Figure 1. Areas and regions used in model validation.

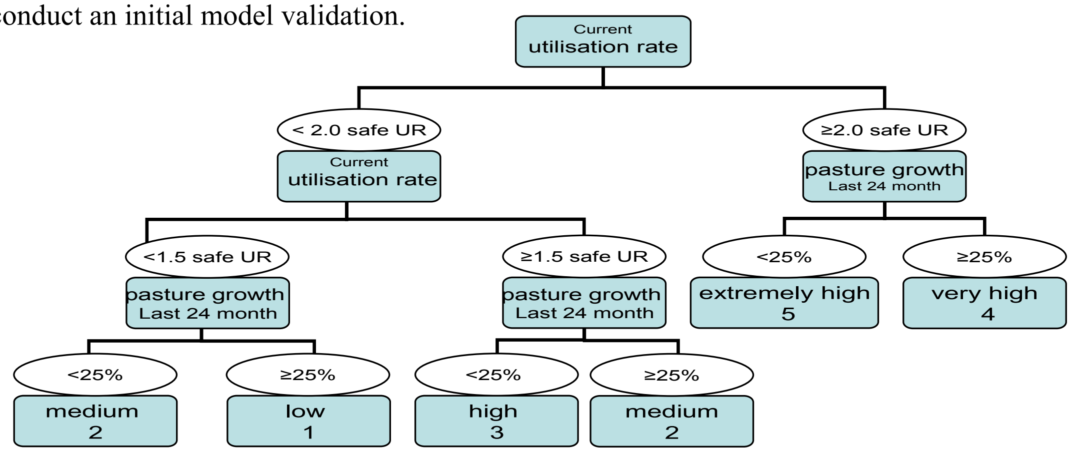

Figure 2. A prototype of the decision tree model used to quantify potential degradation risk. Degradation risk is classified into five levels from 1 – 5 (low to extremely high) by different decision rules. For example, if current utilisation rate is < 2.0 times "safe" utilisation rate (safe UR) but ≥ 1.5 times "safe" utilisation rate, and pasture growth in last 24 month is lower than the 25th percentile of its long-term record, then the potential degradation risk is predicted as level 3 (high). Whether degradation occurs depends on individual property management in terms of stock numbers.

PRELIMINARY RESULTS

A prototype decision tree model for quantifying potential degradation risk is shown in Fig. 2. When comparing model predictions against the eight episodes described by McKeon *et al.* (2004), the predicted high degradation risk periods (average risk level > 2) were in agreement with the time periods when the eight episodes occurred. Fig. 3 presents the predictions for South West Queensland where one major degradation episode was well documented. It can be seen in Fig. 3 that more high degradation risk periods were predicted than the one degradation episode described by McKeon *et al.* (2004). McKeon *et al.* (2004, page 34) identified eight well documented episodes as well as another nine episodes that were less well described or may not have had a strong episodic component. This analysis will allow further investigation of other episodes.

Results of the model validation for the four areas considered as having never been subjected to a degradation episode showed low degradation risk (maximum risk level ≤ 2) except for one area (located in the high rainfall zone of the Clarence Valley in NSW) where there was a predicted high degradation risk period in the early 1990s.

DISCUSSION

The reasonable performance of this modelling approach (as indicated by the results of initial model validation) suggests that this decision support tool could be used to quantify potential degradation risk at a broad spatial scale, although further development is warranted to improve spatial and temporal accuracy.

Of the factors tested, seasonal rainfall outlook based on the SOI was the least indicative of degradation risk. Previous analysis indicated that the majority of years (75%) in the drought sequences of the degradation episodes were: (a) neutral ENSO year-types; and (b) when inter-decadal Pacific Ocean indices were in neutral or in cool phases (McKeon *et al.* 2004, p.55). Thus this finding confirms the importance of developing better seasonal climate risk assessment such as SPOTA-1 (Day *et. al.* 2001, http://www.longpaddock.qld.gov.au/) and systems that also capture quasi-decadal and inter-decadal features of climatic (rainfall) variability. Nevertheless, reduced stocking rates during El Nino years can reduce the risk of damage to perennial grass basal area (McKeon *et al.* 1990) with subsequent benefits in later years.

Previous criteria for assessing degradation risk have been mainly based on qualitative analyses of pasture utilisation and drought situation (*e.g.* Day *et al.* 1997; Johnston *et al.* 2000). This new approach allows quantitative testing of a variety of plausible criteria and the derivation of more sophisticated rules within the decision tree. This approach also has the potential to derive different rules for different regions which might be expected given the wide range of pasture types, land types and climatic zones across Australia. For example, Hall *et al.* (1998) demonstrated that “safe” utilisation rate varies across northern Australia. In addition, this decision tree tool could provide one means of further developing and exploring important criteria for grazing land management and for improving monitoring tools such as the AussieGRASS Environmental Calculator.

There are some limitations to this modelling approach. For example, the equation used to calculate “safe” pasture utilisation rate was developed from estimates at a land type scale in northern Australia. Extrapolation across Australia may introduce extra uncertainty in the results. Also, the variable “%GiDays” in this equation is likely to be very sensitive to soil parameters (*e.g.* available water range) and representation of potential evapotranspiration. An analysis in this study indicated that %GiDays only accounts for a small proportion (15%) of the variation in the calculated pasture utilisation at a shire scale in Queensland. Hence more research is required to develop more robust models of %GiDays that are less sensitive to parameterisation, and to improve estimates of the area actually used for livestock grazing. As livestock numbers for this analysis were sourced from the ABS census and survey for Statistical Local Areas (*i.e.* on a shire basis) and apportioned across land types in the AussieGRASS Environmental Calculator, there will be uncertainty in the estimated stocking rate at a local (*i.e.* sub-shire or property) scale. Due to these uncertainties and the coarse scale of other information (*e.g.* rainfall), the predictions from this modelling approach are only relevant at a regional scale (*i.e.* shire or broader scale) and are not recommended for property scale applications.

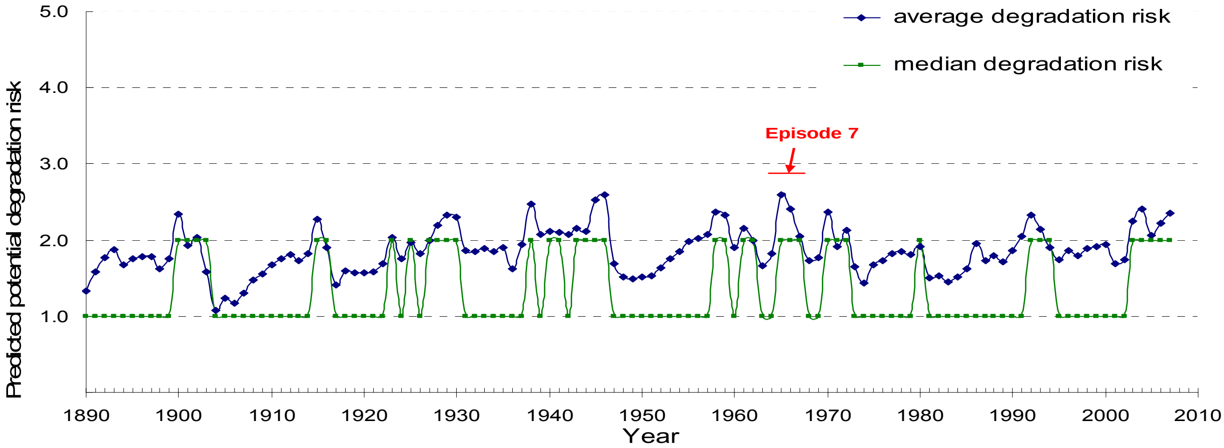

Figure 3. Predicted median and average potential degradation risk for all grid-cells within the South-west QLD region from 1890 – 2007. The Episode 7 indicated above is that described in McKeon *et al.* (2004).

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