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# **The impacts of grazing land management on the wind erodibility of the Mulga Lands of western Queensland, Australia**

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## **Abstract**

An estimated 110 Mt of dust is eroded by wind from the Australian land surface each year, mainly originating from the arid and semi-arid rangelands. Livestock production is thought to increase the susceptibility of the land surface to wind erosion by reducing vegetation cover and modifying surface soil stability. However, research is yet to quantify the impacts of grazing land management on the erodibility of rangelands, or determine how these impacts vary between land types. We present a simulation analysis that links a pasture growth and animal production model (GRASP) to the Australian Land Erodibility Model (AUSLEM) to evaluate the impacts of stocking rates and stocking strategies on the erodibility of the Mulga Lands in western Queensland, Australia. Our results show that adopting conservative and flexible stocking rates, that enable managers to maintain land in good condition can help reduce the susceptibility of the Mulga Lands to wind erosion.

Keywords: wind erosion, land degradation, management, GRASP, stocking rate, modelling

## 1. Introduction

Wind erosion is widespread across the World's drylands, including the arid and semi-arid rangelands of Australia (Shao et al.,2011). Human activities, including agriculture and livestock production, are known to intensify wind erosion processes through their impacts on vegetation cover and soil surface stability (Gillette, 1999). However, the sensitivity of spatial and temporal patterns of wind erosion to climate variability makes quantifying the impacts of land management on wind erosion rates an inherently challenging task (Belnap et al.,2009; Baddock et al.,2011; Xu,2006; Mahowald et al.,2002). Increasing pressures on dryland environments from land use change and climate change may affect the susceptibility of rangelands to wind erosion. Quantifying the impacts of grazing land management on the susceptibility of rangelands to wind erosion is therefore important for the ongoing management of rangeland resources.

We present an experimental study which couples a pasture growth and livestock production model (GRASP) with a land erodibility model (AUSLEM) to simulate the impacts of land management on the erodibility of the Mulga Lands. We address two objectives, which are to: 1) evaluate the effects of stocking rates on land erodibility; and 2) evaluate the effects of stocking strategies on land erodibility of the Soft Mulga. XX

## 2. Study area

The study area lies within the Mulga Lands bioregion (DEWR, 2007), and we focus our analysis on the Soft Mulga land type.

The Soft Mulga is characterised by a semi arid climate with annual rainfall varying from 300mm in the drier zones to 500mm in the wettest parts. To represent this rainfall gradient, we use two stations representing the extremity: Eulo (dry) and Charleville (wet). The mean maximum temperatures range from 20°C in winter (June, July, August) to 35°C in summer (December, January, February).

The light sandy clay to medium clay soils support shrublands and low woodlands mainly composed of mulga (*Acacia aneura*) and kangaroo grass (*Themeda triandra*). XX

## 3. Methods

### 3.1 GRASP

GRASP is an empirical point-based model that simulates a daily soil-water balance, grass growth and animal production in response to climate inputs and land management options (Day et al., 1997, Littleboy and McKeon,1997; McKeon et al.,2000).

The soil water balance for four layers depth is simulated by partitioning the rainfall into runoff and infiltration. The pasture growth is modelled as a dynamic system where senescence, detachment, decomposition and animal consumption degrade the green pools into dead biomass and surface litter in response to water, radiation and transpiration efficiencies. The influence of trees on pasture growth is modelled through their effects on water use and nitrogen uptake (McKeon et al., 2000). The subroutine for animal production simulates the interactions between plant and cattle. In addition to a decrease of grass cover due to daily animal intake, the consequences of grazing pressure on plant production are modelled by increasing the runoff and the sensitivity of plant growth to soil water deficit, and by reducing the potential nitrogen intake and the overall nitrogen use efficiency (McKeon et al.,2000). Changes in pasture composition induced by heavy grazing are modelled by relating the percentage of desirable perennial grasses to pasture utilisation

GRASP was parameterised for the Soft Mulga land type in order to its capture landform, pasture species and soil attributes (texture, fertility and drainages) as reported by Day et al. (1997) and used by Webb et al. (2012). Monthly rainfall data geographically related

to the study area are required and sourced from SILO (climate database hosted by Queensland Climate Change Centre of Excellence). Two stations (Charleville, Eulo) have been used to capture the rainfall gradient (wet/dry) within the land type.

### 3.2 AUSLEM

Land erodibility was modelled with the Australian Land Erodibility Model (AUSLEM) developed and validated by Webb et al. [2006, 2009] in western Queensland, which includes the study area. The model predicts land through the effects of soil moisture and vegetation cover on the susceptibility of the land surface to wind erosion. The model outputs and erodibility index on a continuous and dimensionless scale (from 0 not erodible to 1 highly erodible). The two dynamic components, the soil moisture (mm per top 10 cm of profile) and the grass cover (%) are sourced from GRASP and used in empirical functions to determine the interactions between vegetation cover, soil water content and land erodibility. The grass effect  $E_{gc}$  (gc) is expressed by the negative exponential relationship between the land erodibility and the percentage of grass cover (%gc).

$$E_{gc} = 55.873 \exp^{-0.0938 (\%gc)}$$

The water effect  $E_w$  (w) is based on relationship between soil water content of the source area (w) and local dust frequency events observed in western Queensland (Webb et al., 2009).

$$E_w = \exp^{-0.236w}$$

The land erodibility value ( $E_r$ ) is predicted by integrating these two subroutines through a multiple approach, following the logic of previous relationships (Shao, 2008), in the form:

$$E_r = E_{gc}(gc) * E_w(w)$$

AUSLEM only simulates situations where wind erosion can occur, therefore as trees shut down wind erosion their effect are not accounting for in the land erodibility model. However, the tree cover and distribution are indirectly described within the grass growth calculation of GRASP.

Soil moisture is the only parameters describing soil erodibility in AUSLEM. The model does not account for others factors such as soil texture, aggregation and crusting which can be affected by livestock and therefore modify the erodible fraction available for erosion (Baddock et al., 2011).

### 3.3 Model simulations

Two experiments were established to determine the response of land erodibility to land management practices. Each experiment is a simulation of monthly land erodibility over the period of 1900 to 2010.

#### 3.3.1. Stocking rate

The first experiment tests the sensitivity of land erodibility to grazing intensity. Land erodibility has been simulated at a constant intensity for a range of stocking rates from 1 adult equivalent per 100 hectares (1AE/100 ha) to 30 AE/100 ha. A stocking rate providing 5% utilisation of pasture has been used to represent a baseline condition accounting for the utilisation by native animals.

#### 3.3.2. Stocking strategy

The second experiment examines the responses of land erodibility to five different stocking strategies. These include:

1. A high fixed stocking rate at 22 AE/100 ha;
2. A safe fixed stocking rate that maintains a good pasture conditions represented by a perennial content of at least 70 % over the simulation period;
3. Low flexibility strategy which limits changes in stocking rates;

4. A high flexibility strategy which allow stocking rates to track rainfall variability;
5. A conservative strategy which restricts the increase of stocking rate during wet years but facilitates destocking during dry years, and
6. An aggressive strategy which supports higher increases, but is less flexible when decreasing stocking level.

## 4. Results

### 4.1. Stocking rate

Increasing stocking rate results in an increase in the susceptibility of the Soft Mulga land type to wind erosion (Fig.1). Simulations show an increase in the rate of change in erodibility in response to stocking rate. This occurs when the stocking rate exceeds the long-term safe stocking rate for the land type. The impact of increasing stocking rate on erodibility stabilises for both sites at 22 AE/100 ha, as grazing pressure reaches a maximum and grass cover reaches a minimum.

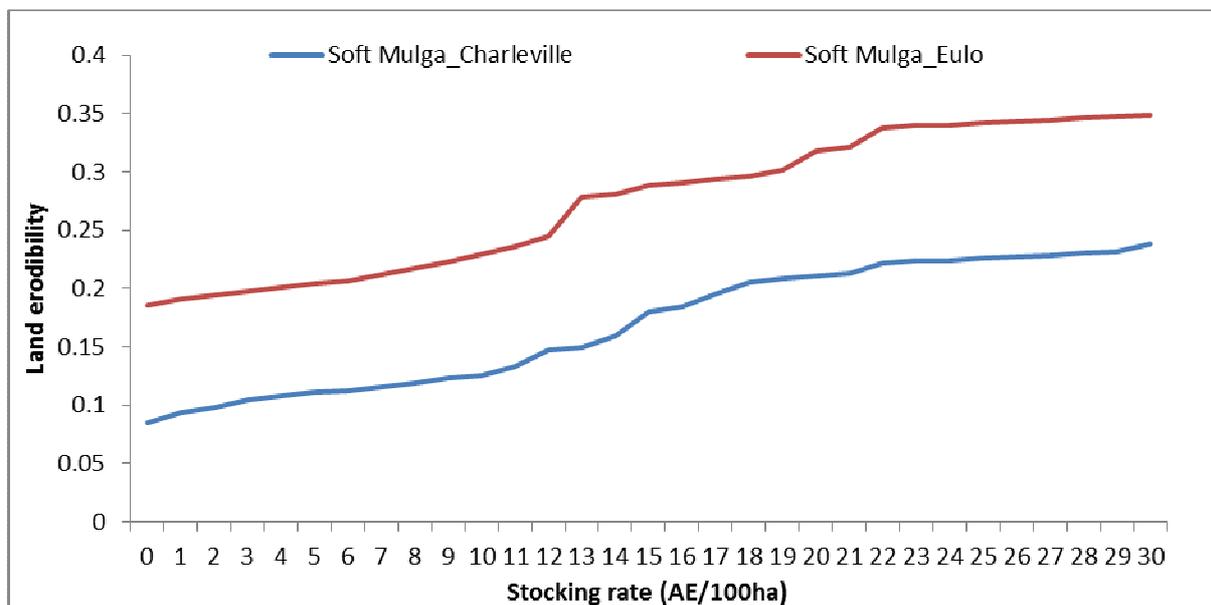


Figure 1- Long term average of land erodibility (1900-2010) modelled at each stocking rate (in Animal Equivalent/100 hectares)

### 4.2. Stocking strategy

The flexibility of stocking rates has a significant impact on the susceptibility of the Mulga Lands to wind erosion (Fig.2). This impact is realised through the capacity in drier periods to destock rapidly and limit overgrazing. The safe fixed stocking rate, the low flexibility strategy and the aggressive strategy result in a 10 % increase in erodibility relative to the fully flexible and conservative strategies. However, benefits for land erodibility of adjusting the flexibility of stocking rates around the long-term carrying capacity are less than that derived from moving from a high fixed stocking rate to the one around the long-term safe carrying capacity of the land

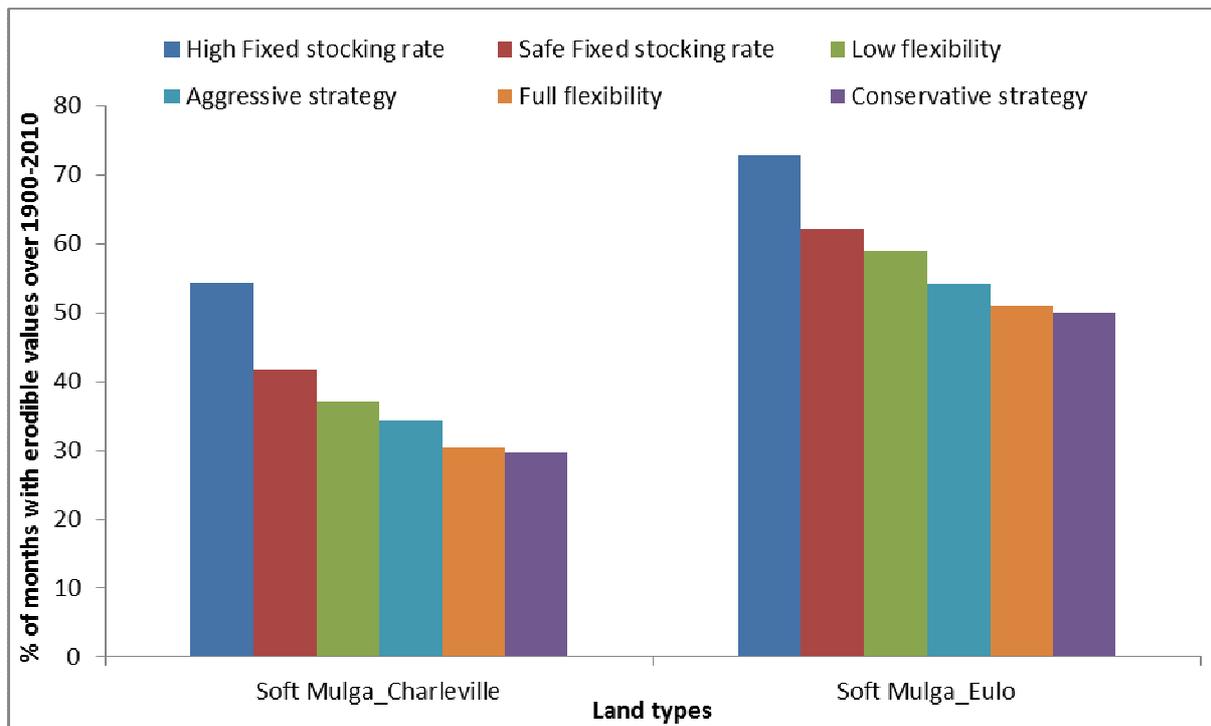


Figure 2- Proportional abundance of month with erodible **land (value >0.1)** for different stocking strategies.

## 5. Discussion

### 5.1 Stocking rates

Increasing the grazing pressure increases the susceptibility of rangelands to wind erosion. The grazing decreases vegetation and soil moisture. Our results show that pasture utilisation increases in accordance with increasing stocking rates, which results in a reduction in ground cover. Reduction of vegetation cover decreases physical protection of the soil surface, reducing the surface roughness and the wind shear stress required for erosion, and therefore increasing the area exposed to wind erosion. (Webb and Strong,2011). Constant defoliation impacts plant regrowth rates (Tefera et al.,2010), and pasture species composition with the increase dominance of annual species. Annual grass species are typically more sensitive to drought conditions than perennial species, and their dominance is likely to result in a greater sensitivity of pastures to climate and grazing stresses, and an increase in erodibility (Belnap et al.,2009). The increase of stocking rates also causes a slight decrease of soil moisture, leading to a reduction of cohesive forces between particles lowers the threshold wind velocity (Cornelis et al.,2003).

The responses of wind erosion to stocking rate increase are non linear containing breaking points and plateaus. Nonlinear responses to grazing impacts are a common feature reported notably in grazing gradients studies resulting from a sharp increase of annual species out competitively perennial species (Todd,2006). These changes in vegetation composition feedback on soil and vegetation responses, and ultimately on land erodibility (Peters et al.,2004). The final plateaus in the simulations correspond to a threshold where beyond no further degradation can occur.

### 5.2 Stocking strategies

Stocking strategies which allow a rapid destock in response to drought conditions have the lowest impact on land erodibility. Simulations under fully flexible or conservative strategies demonstrate that maintaining a moderate grazing pressure through time have less impact on the pasture and enable retention of sufficient ground cover to minimise the erodibility of the landscape (Hunt et al.,2008). As simulations used a safe stocking rate,

overgrazing is limited, and therefore the impact on land erodibility is reduced for most land types, even if it still higher than baseline condition. Conversely, our results show that fixed stocking rates, and stocking strategies that lack flexibility, can increase grazing pressure during drought as high stocking rates are maintained. This amplifies the decrease of vegetation cover caused by lower pasture production and higher mortality due to water stress and exposing larger areas of drying soils to wind erosion processes. As a result, land erodibility is the highest under fixed, low flexibility and aggressive strategies. Overgrazing of this nature contributed to the land degradation episode in the Mulga Lands in the 1940s, which led to significant wind erosion and high dust storm activity (McKeon et al.,2004).

Simulations also show that moving from high stocking rates under a fixed stocking to a more flexible strategy with a lower initial stocking rate is shown to have a greater effect on erodibility than differences between flexible stocking strategies based around the long term safe stocking rates. However, differences between strategies are expected to be greater if the simulation were based around a higher stocking rate as it is more detrimental for environment and land erodibility as seen in the previous simulation.

## 6. Conclusion

This experimental study shows promising results in order to understand the land management effects on land erodibility. However simulations are expected to be higher as data was averaged across wet and dry years, the soil moisture was modelled to a depth of 10 cm, and soil erodibility was partly accounted for. Our results show that land erodibility of the Soft Mulga increases with stocking rate, showing a nonlinear response and under stocking strategies that lack the capacity to rapidly destock in response to drought conditions. However, the use of high fixed stocking rates instead of safe fixed stocking rate is shown to have a greater effect on erodibility than differences between flexible stocking strategies based around the long term safe stocking rates.

We hypothesise that declining land condition due to overgrazing could result in increases in erodibility. Thus, adopting conservative and flexible stocking rates, and maintaining land in good condition could help to further reduce the susceptibility of the Soft Mulga to wind erosion. Further extension of this study to other land types is important to better understand the past and present impacts of land management and land condition on arid and semiarid rangelands in Queensland.

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