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Impact of mulga thinning on forage and livestock productivity

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Abstract

Savannas, woodland and forests are utilised for grazing domestic stock around the world. In most systems a higher density of woody plants leads to reduced herbaceous forage productivity. Graziers often reduce woody biomass through clearing or thinning, which has implications for carbon stocks, biodiversity and ecosystem function.

In Australia's semi-arid regions, *Acacia aneura* (mulga) woodlands are widespread, with mulga often either cut/felled to provide a maintenance livestock diet and drought fodder reserve or cleared to improve forage productivity. Three replicated experiments were established in mulga woodland with initial density of 1900 to 5600 trees/ha in the 1960s to study the impact of thinning to 40, 160 and 640 trees/ha. Individual trees were tagged at two sites. These experiments were reassessed 50-60 years later to investigate long-term woodland recovery, differences in individual tree growth and health, and woodland basal area and carbon stocks. This paper reports on individual tree growth and survival, and models the impact of thinning on forage productivity.

All thinning treatments demonstrated substantial regrowth post-thinning, with all treatments having similar woodland basal area after 50-60 years, but with forage productivity having been much higher for the first ~25 years after thinning. Detailed economic assessment and property design considerations are recommended to determine the best combination of management strategies across a property, with any contemplated changes in vegetation management considered in the context of regulatory guidelines. Insights gathered from these experiments demonstrate the value of long-term trials and datasets to provide clear evidence of multidecadal responses to management impacts such as woodland recovery after thinning on environmental and economic goals.

Introduction

Rangelands, including savannas, shrublands, woodlands and forests, are utilised around the world for grazing domestic livestock. These systems contain a woody vegetation stratum (or strata) and a grass or herbaceous ground layer. Woody vegetation (trees and shrubs) often competes with the herbaceous layer for limited resources of soil water, nutrients and light. In many land types, the grass and herbaceous layer are the primary forage for domestic livestock, having a key role in grazing productivity and the livelihoods of millions of people. In some regions, edible or partially edible trees and shrubs are also browsed, but often contain chemical compounds or physical defences to deter grazing or restrict digestion, minimising their contribution to the diet of productive domestic livestock. Therefore, it is intuitive (perhaps inevitable) that graziers would endeavour to increase the abundance of the grass and herbaceous layer, by reducing the density of woody vegetation.

In Australia, graziers have invested significant resources to manage woody vegetation through broadscale tree clearing or partial tree clearing (e.g. thinning), using a range of mechanical and chemical techniques over many decades. In Queensland, tree clearing has occurred on over 30 Mha of rangelands to benefit domestic livestock production. This tree clearing has had other local and global consequences including loss of woody foliage available for grazing in some systems, loss of biodiversity, soil erosion (where the herbaceous layer has not been managed sustainably), changes to hydrology cycles, impact on landscape aesthetics, increased carbon (C) emissions and loss of non-atmospheric C storage.

In the Mulga Lands bioregion of south-west Queensland and western New South Wales, woody vegetation management is a key consideration in balancing goals of livestock production and maintaining or increasing C stocks. Management decisions are complicated by the fact that mulga (*Acacia aneura*), although high in tannin, is relatively palatable and grazed by livestock to provide a

diet that generally meets livestock maintenance requirements. The retention of mulga provides both drought fodder in a highly climate variable region, while also maintaining landscape function (e.g. reduced wind erosion and maintaining litter cover for rainfall infiltration). Therefore, from a grazing business perspective, mulga is an important component of the forage system that, in times of drought can complement the higher nutrition, but often sparse, grass and herbaceous forage.

Three replicated mulga thinning experiments were established in the late 1960s to assess the impact of thinning on ecological processes (woodland recovery, hydrology cycle, C stocks) and forage production. Historical site data on tree basal area and tree/grass relationships were located. For two sites, Boatman and Monamby, ~336 trees had been individually tagged as part of the experiments. Fifty to 60 years after the experiments were established, the sites were re-sampled for current tree size, tree health and biomass, debris and soil C stocks. In this paper, we analyse the tagged tree data to report tree survival and growth trajectory over 50 years. C stock differences are reported in England *et al.* (2026; this conference). In addition, we model the impact of thinning treatment on forage productivity.

Methods

Comprehensive experimental methods for the Boatman and Monamby sites are described in Beale (1973) and for the Charleville Reserve site in Pressland (1976). In summary, the sites were located in the region around Charleville (-26.42°, 146.28°) in south-west Queensland, Australia, with an initial mulga woodland density of 1900 to 5600 trees/ha. The Boatman and Monamby sites were established in 1963 and 1965, respectively, with a randomised block design of three treatments; 40, 160 and 640 trees per ha post thinning, and 7 replications (21 plots of ~0.4 ha). After thinning, 15-16 individual mulga trees per plot were randomly selected and tagged with a wire loop and numbered metal tag (total 335 or 336 tagged trees per site). The circumference of each tagged tree was measured at 30 cm height a number of times until 1973. In 1970, the Charleville Reserve site was established with six treatments; 40, 160 and 640 trees per ha, completely cleared with and without fire, and uncleared, and 3 replications (18 plots).

In 2022, at Boatman and Monamby, each plot was searched and all tagged trees found were re-measured for circumference at 30 cm height and assigned a health score (Piper *et al.* 2026). Tag retention to 2022, percentage of live or dead trees in 2022 and circumference growth to 2022 were analysed. Further, at each site in 2022-2023, in a subset area within each plot (1600-6400 m²), all trees and shrubs were assessed, recording; Diameter at Breast Height (DBH), tree health score and species (England *et al.* 2026, this conference). At Boatman and Monamby, an uncleared area adjacent to the experiment was identified (using visual inspection and historical satellite imagery) and sampled as per the experimental plots. DBH data were used to calculate woodland basal area (BA, m²/ha) at 30 cm height (assuming circular stems and multiplying by 1.5294 to convert from 130 cm to 30cm height) for the forage productivity analysis. Initial woodland BA pre-thinning was extracted from historical records.

Forage productivity modelling utilised annual BA generated for each treatment for each year for four treatments; 40, 160 and 640 trees/ha and unthinned. Annual BA estimates between measurements including between the last historical measurement and the modern measurement, a gap of ~50 years, was assumed to be linear. Annual herbaceous forage biomass was calculated by applying the composite relationship of Beale (1973), developed from data at Boatman and Monamby.

Statistical analysis

The effect of thinning treatment on the percentage of trees that retained tags was assessed using analysis of variance. Replicate was included as the blocking structure and the fixed treatment was the thinning treatment.

For the Boatman and Monamby sites, the trend in tree circumference over time was analysed using exponential regression. The model was of the form $Y=A+B \cdot R^X$, where the response (Y) was the circumference averaged over all available trees for each replicate and treatment combination and the explanatory variate, (X), was Year. The analysis determined whether the parameters (A, B, R) differed between the treatments.

Results

Tag retention and percentage of tagged trees Live or Dead

Tag retention rates after ~57 years were 50.4% at Boatman and 77.5% at Monamby. There was a significant effect of thinning treatment for both the Boatman ($p<0.001$) and Monamby ($p=0.023$) sites, with more tags being retained for the 640 trees/ha treatment compared to the 40 trees/ha treatment.

All tagged trees were classified for tree health and whether Live or Dead in 2022. There was no significant effect of treatment on the percentage of Live trees that retained tags for the Boatman site ($p=0.860$), with an average of 71% of tagged trees Live. At Monamby, there was a significant effect of treatment on the percentage of Live trees ($p=0.017$), with 71% Live tagged trees in the 640 trees/ha treatment and only 41% Live trees in the 40 trees/ha treatment.

Tree circumference of Live trees 1966 to 2022

Fitted exponential regressions of circumference (or ln circumference) at 30 cm were significantly different, with trees in the 40 trees/ha treatment larger than in the 640 trees/ha treatment, which was maintained throughout the trial (Fig. 1).

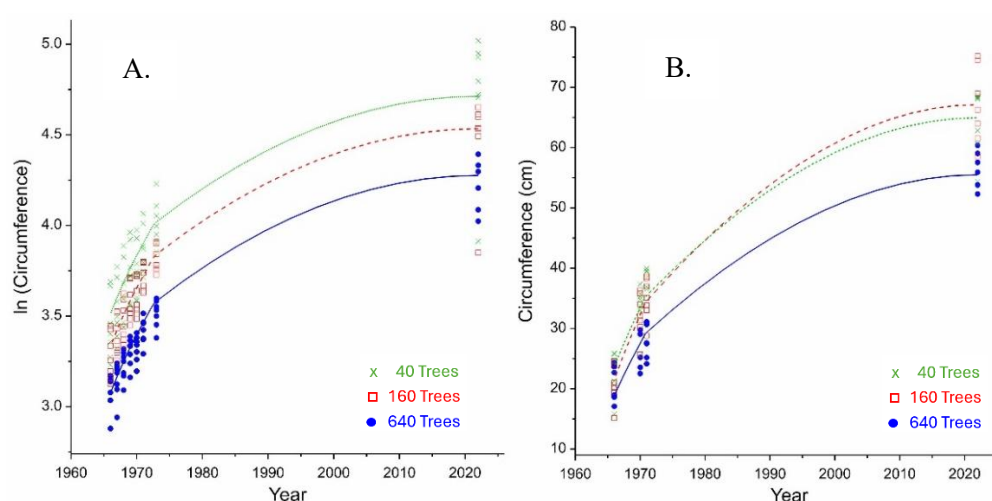


Figure 1. Circumference of tagged Live trees at 30 cm height for the Boatman (ln circumference) (A.) and Monamby (B.) sites over time.

Woodland basal area and modelled pasture biomass

Thinning had a substantial impact on woodland BA (m^2/ha), but over the following 50-60 years, BA (Fig. 2A, C, E) and C stocks (England *et al.* 2026, this conference) recovered to be similar between treatments. Modelled pasture biomass remained very low in unthinned woodland but increased substantially following thinning. Forage biomass improved by approximately 60 times during the first 10 years after thinning in the 160 trees/ha treatment (Fig. 2B, D, F), with livestock productivity (carrying capacity) expected to more than double. Over 50 years, forage biomass was approximately 20 times higher on average, although forage biomass was relatively low after 25 years.

Discussion

Thinning mulga woodland to 40, 160 and 640 trees/ha substantially altered the woodland basal area, retained tree size, retained tree growth and forage productivity. However, after 50-60 years, the thinning treatments through improved individual retained tree growth and establishment of new trees, particularly at Monamby, had a similar woodland basal area and carbon stock (England *et al.* 2026, this conference) to the initial woodland and nearby unthinned areas, demonstrating substantial recovery from the thinning treatments.

In the ~25-year period following thinning, forage biomass was substantially enhanced, and this would have supported increased grazing productivity. Given the demonstrated woodland recovery from thinning at three sites, thinning appears to have minimal long-term impact on woodland structure over a 50-year time scale and may support development of large mature trees, as opposed to stands of smaller 'whip-stick' trees. From this work, it is recommended that thinning be considered as part of the suite of

options to manage mulga woodlands in the Mulga Lands Bioregion for multiple outcomes including pastoral productivity, carbon storage, biodiversity and drought resilience. However, detailed economic assessment and property design considerations will be required to determine the best combination of management strategies across a property, with any contemplated management changes in vegetation management considered in the context of regulatory guidelines.

Insights gathered from these trials demonstrate the value of long-term trials and datasets to provide clear evidence of multidecadal responses to management impacts such as woodland recovery after thinning on environmental and economic goals, including emerging carbon and biodiversity markets and livestock production.

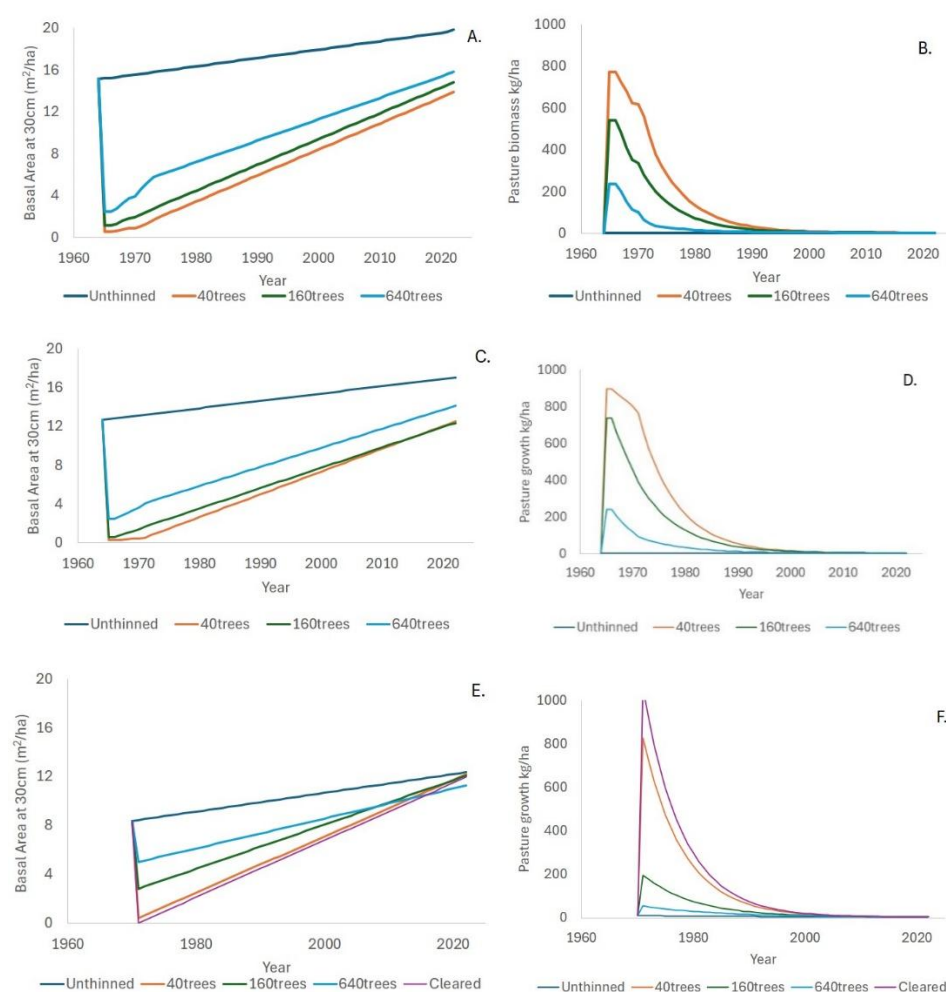


Figure 2. Mulga woodland tree basal area at 30 cm and modelled pasture biomass in response to thinning treatments compared to unthinned over time at Boatman (A. and B.), Monamby (C. and D.) and Charleville Reserve (E. and F.).

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