PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY

19th BIENNIAL CONFERENCE

Official publication of The Australian Rangeland Society

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The reference for this article should be in this general form:

Author family name, initials (year). Title. In: Proceedings of the 19th Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).

For example:

Bastin, G., Sparrow, A., Scarth, P., Gill, T., Barnetson, J. and Staben, G. (2015). Are we there yet? Tracking state and change in Australia's rangelands. In: 'Innovation in the Rangelands. Proceedings of the 18th Australian Rangeland Society Biennial Conference, Alice Springs'. (Ed. M.H. Friedel) 5 pages. (Australian Rangeland Society: Parkside, SA).

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Assessing the impacts and opportunities from carbon farming in western NSW

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Key words: soil carbon, erosion, biodiversity

Abstract

Emissions Reduction Fund (ERF) carbon sequestration projects aim to store carbon in woody vegetation for up to 100 years by avoiding deforestation or managing natural regeneration. This project addresses a lack of data around the carbon (C) storage potential of rangelands vegetation and soils. Initial results show high density Mulga (~2000 stems ha^{-1}) to have the lowest C pool (~5 t C ha^{-1}) but at densities <500 stems ha^{-1} additional benefit from *Eucalyptus* spp. can allow six- fold increases in the vegetation C pool. Conversely, high density Box communities represent the most valuable positions within the landscape for carbon (vegetation and soil) as well as biodiversity. Soil erosion modelling suggests that soil is removed by wind erosion (0.1-10 t ha^{-1} y^{-1}) and where the C stock is small (3 t C ha^{-1}) up to 1 t C ha^{-1} y^{-1} may have been removed. Increasing the C pools in vegetation would need to exceed this rate to have a net sequestration benefit. Economic analyses reveal carbon farming to have a 25-30 year benefit but in the long-term opportunity costs will require offsetting through livestock productivity gains.

Introduction

Transformative land-use change from livestock production to carbon farming is underway in some parts of south-eastern Australian rangelands. ERF projects now occupy over 2.7 M ha of the Cobar Peneplain and Mulga Lands Bioregions (Figure 1). These projects aim to sequester or store carbon in woody vegetation by encouraging natural regeneration or avoiding deforestation for 100 years. Areas of natural grassland or open woodland are expected to change to a more uniform vegetation structure at the landscape level which may negatively impact on biodiversity and pastoral production through irreversible establishment of invasive native scrub. While the investment value in carbon farming is considerable ($590M), there are questions over the sequestration potential of rangeland vegetation communities, the capacity of biomass to store carbon as well as the risk of losses of soil organic carbon (SOC) through erosion and losses in livestock production due to reduced grazing opportunities. These question place uncertainty over existing and future carbon farming investment.

Methods

Carbon in Vegetation

Above ground biomass (AGB, t ha^{-1}) was measured in 50 plots (100 x 20m) within the Cobar Peneplain Bioregion. Plots comprised five randomly placed replicates of three densities (High, Medium and Low) for Pine (*Callitris glaucophylla*), Box (*Eucalyptus populnea*) and Mulga (*Acacia aneura*) communities. Medium density Mulga included with (+shrubs) and without (-shrubs) understorey. AGB was estimated for all woody vegetation within each plot by measuring diameters at either breast (130cm) or basal (10cm) height and applying allometric equations of Paul *et al.* (2016).

Soil carbon

Three soil cores to 30cm depth were sampled to measure SOC stock (t ha^{-1}) at four depths (0-5, 5-10, 10-20, 20-30cm) at approximately 30, 60 and 90m along a 100m transect running through the centre of the AGB plots using methods outlined in Waters *et al.* (2016). Mean SOC stock was calculated for the 0-30cm soil depth and reported here.

Soil Erosion

To quantify the spatial loss of SOC by wind erosion we calculated the horizontal sediment flux (2000-2016) following the methods outlined in Chappell and Webb (2016) for three Bioregions (Cobar Peneplain, Darling Riverine Floodplain and the Mulga Lands). For further details on methods see Orgill *et al.* (2017).

Economic impacts

Project scenarios were created with data from ERF auction results, costs and revenues for a range of enterprises (sheep meat and wool; goat harvesting and managed goats) and carrying capacity over a range of seasons using rainfall records and GRASP modelling. Incomes with and without sequestration projects were estimated and a range of sensitivity analyses (discount rate, meat prices, carbon prices, sequestration rate) were considered and the net present values up to 30 years were calculated, further details provided in Cockfield *et al.* (2017).

Results

AGB estimates were highest for Box (37.2 to 51.4 t ha^{-}1) followed by Pine (20.6 to 35.9) then Mulga (5.9 to 18.7) (Figure 2a). High density Mulga (~2000 stems ha^{-1}, Figure 2a) had the lowest values with an understorey of other shrubby species (~5 t C ha^{-1}). SOC stocks were also less under high density Mulga compared with low density Mulga: 23.8 (1.0 se) *vs* 31.7 (1.2 se) t C ha^{-1}(Figure 2b). With lower Mulga stem densities (<500 stems ha^{-1}) AGB and SOC stock were highest for this vegetation community due to the additional biomass from other species e.g. *Eucalyptus* spp. (Figure 3). Unlike Mulga, increasing stem densities of Pine (up to 10,000 stems ha^{-1}) and Box (up to 500 stems ha^{-1}) incrementally increased AGB as well as SOC stock. SOC stocks were highest under high density Box compared with low density Box: 45.3 (5.6 se) *vs* 29.4 (2.5 se) t C ha^{-1} and high density Pine compared with low density Pine; 33.4 (2.8) *vs* 28.5 (2.3) t C ha^{-1}.

Between 2000 and 2016, the highest SOC stocks (23.2 t ha^{-1}) were in the Cobar Peneplain (Figure 4a). The western part of the study region (Mulga Lands and southern Darling Riverine Floodplain) had the lowest SOC stocks and experienced the greatest loss of SOC through wind erosion during 2000-2016 (Figure 4b).

Participating in ERF, with carbon prices of $10-13/tonne, meat prices ~$100+ per lamb or goat and sacrificing an area to carbon farming is generally financially beneficial up to 25-30 years. With commitments of 100 years though, opportunity costs will accumulate. Outcomes are highly sensitive to the agreed sequestration potential; commodity prices and stocking rates (see Cockfield *et al.* these proceedings).

Discussion

Based on AGB estimates, the Cobar Peneplain has a C pool in vegetation between 2.9 to 25 t C ha^{-1}. This range represents differences between vegetation communities and indicates that field estimates of C sink in vegetation will require stratification based on vegetation type. Differences between vegetation types and AGB estimates reflect the position in the landscape; e.g. drainage lines support high density box communities which yield the highest above ground biomass. These areas also provide favourable habitat and food resources (representing important biodiversity refugia) and therefore are the most valuable positions within the landscape for both existing carbon stocks and biodiversity. The importance of these areas may be further increased as the climate becomes hotter and drier.

Variation in AGB within vegetation communities was largely dependent on the presence/absence of large trees/shrubs (DBH > 20 cm). From our results, management which promotes regeneration and increased stem density in Mulga communities may not lead to significant carbon sequestration, may result in long-term (>100 years) reduction in livestock production following the completion of carbon projects and is likely to have negative impacts on biodiversity, particularly where large-scale regeneration homogenises habitat within the landscape. We suggest that management to increase the occurrence of *Eucalyptus* or *Callitris* in low density Mulga (<500 stems ha^{-1}), may provide a carbon sink comparable to higher densities of Mulga; provide a biodiversity advantage through enhanced structural diversity of vegetation which will provide greater habitat value; greater livestock productivity through increased perennial grass cover. Livestock grazing to suppress regrowth of palatable Mulga shrub seedlings but enhance tree (*Eucalyptus spp.*) recruitment (also palatable) may be difficult to manage and contingent on vegetation condition (foliage cover and the presence of mature trees). However, strategic grazing and/or the control of grazing pressure to allow tree seedling recruitment under favourable seasonal conditions may play a role.

Ways of offsetting long- term, opportunity costs could include occasional grazing of project areas and using sequestration income to reinvest in productivity gains, perhaps through total grazing pressure management.

Conclusion

The increased AGB and soil C we found in high density Pine and Box communities suggests management for increased regeneration within these vegetation communities will sequester carbon in both vegetation and soil. Both *Callitris* (Pine) and *Eucalyptus* (Box) species are capable of tolerating high levels of intra-specific competition for long periods and it is likely that regeneration of these species will continue to sequester carbon over the long-term. However, our multi-disciplinary approach quantifies the importance of considering resource condition and livestock production when achieving climate change mitigation efforts. Given the relationships between the density of vegetation, AGB and SOC stocks, failing to recognise and account for soil erosion represents a risk to the carbon sink capacity in this region.

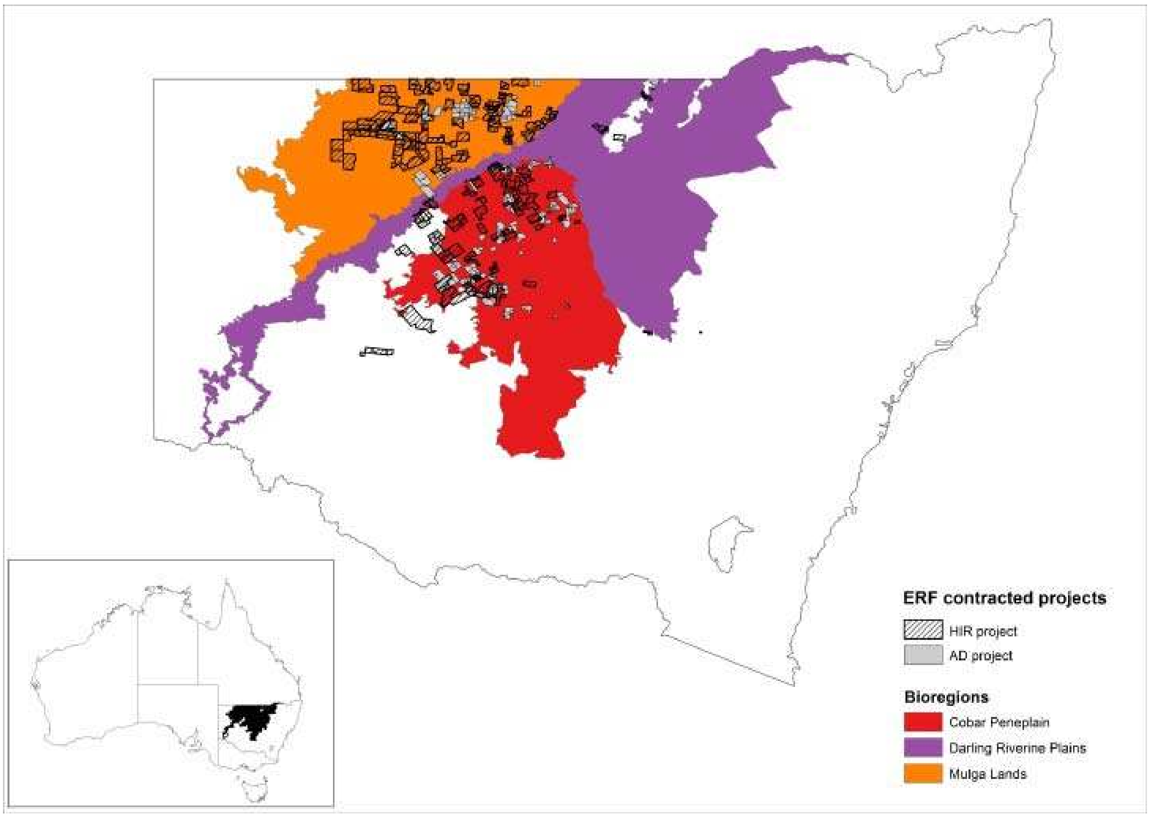


Figure 1. Spatial distribution of Emission Reduction Fund (ERF) projects in western NSW are largely contained within the Cobar Peneplain and Mulga Lands Bioregions.

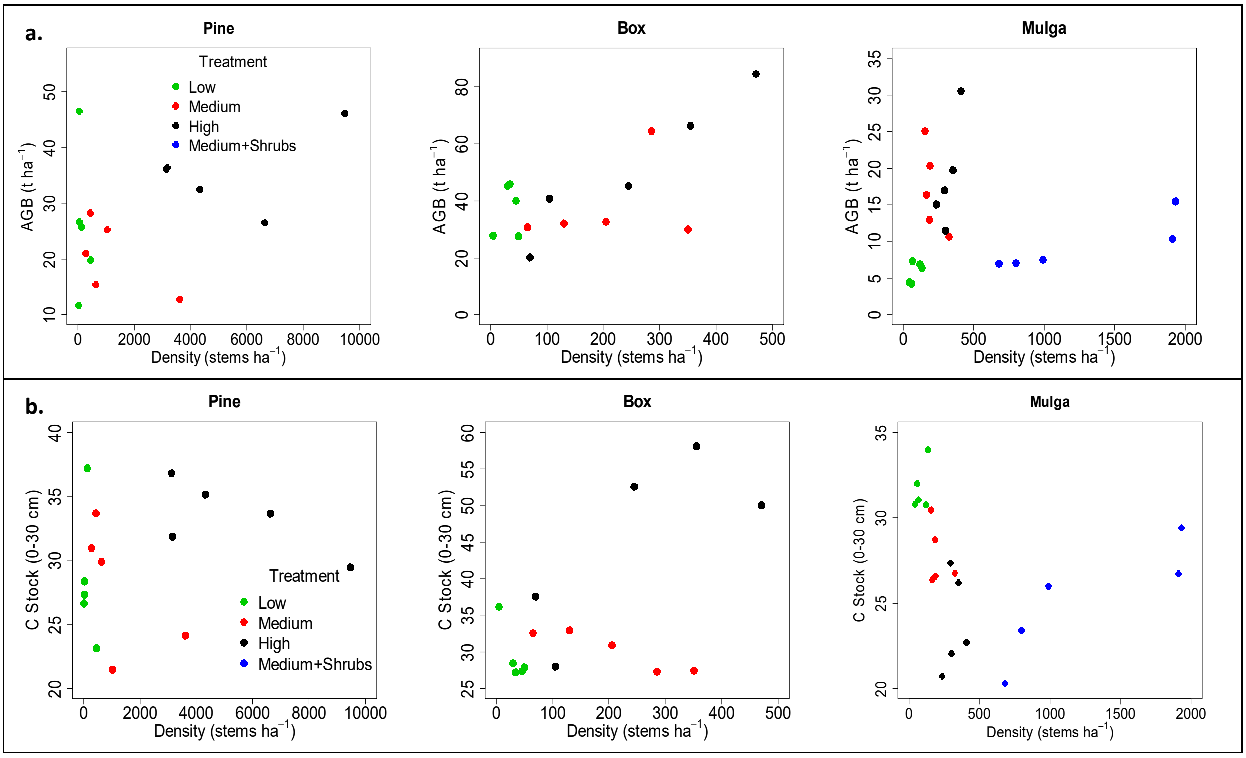
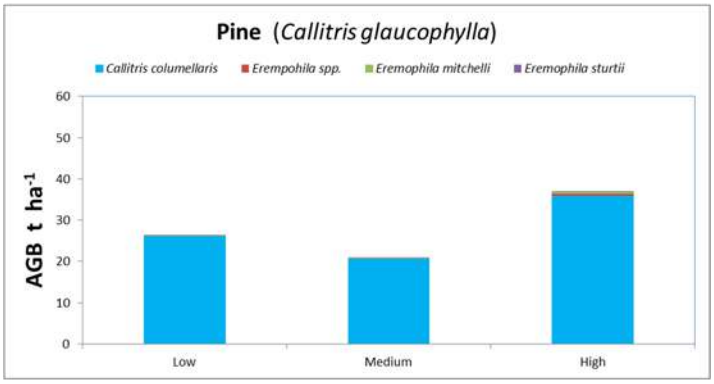
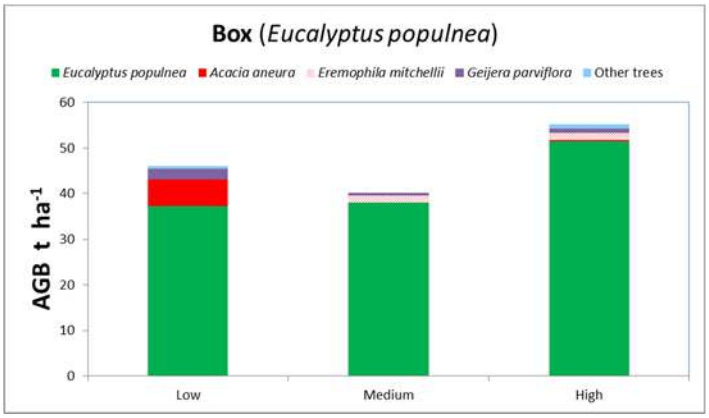


Figure 2. a above ground biomass (AGB, t ha^{-1}) for Pine (*Callitris glaucophylla*), Box (*Eucalyptus populnea*) and Mulga (*Acacia aneura*) species at different densities and **b** mean soil carbon stock, (C-stock, t C ha^{-1}) of Pine, Box and Mulga communities at different densities (Low, Medium, High) (stems ha^{-1}).





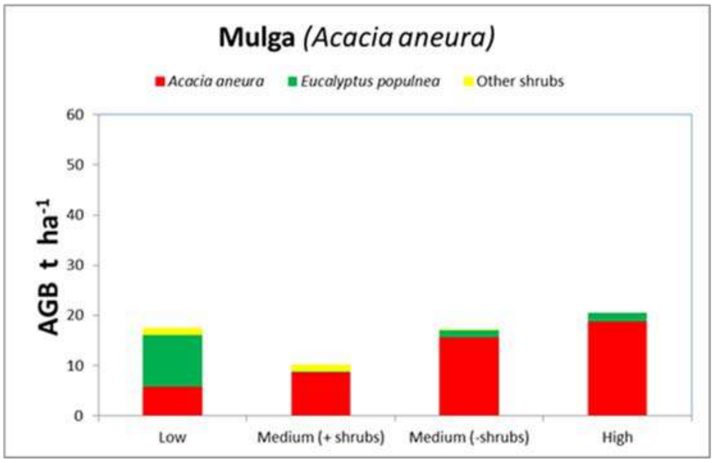


Figure 3. Proportion of above ground biomass (AGB, t ha^{-1}) for major species found in three vegetation communities (Pine, Box and Mulga) at different densities, H (high), M (medium) and L (low).

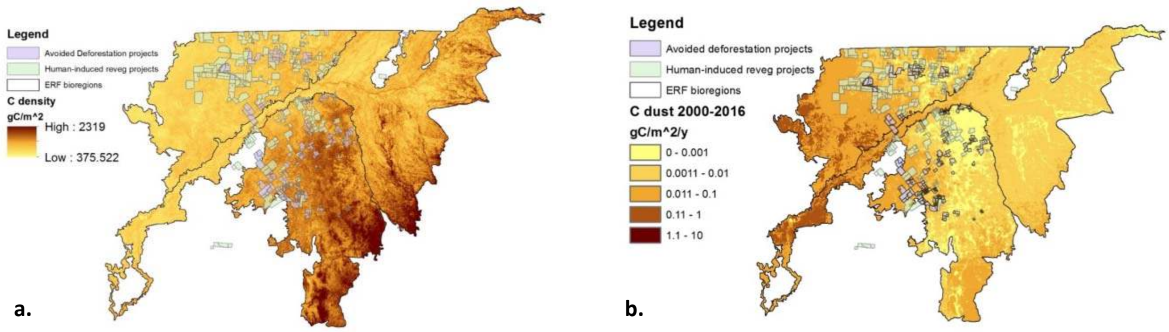


Figure 4. a. SOC stock (C density in g C m^2), and **b.** carbon loss via dust emission (C dust in g C m^2 y^{-1} from 2000 to 2016) for the major Bioregions effected by carbon farming in western NSW.

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