Trade-offs and Optimisation of Land-Use for Pastoralism and Carbon in Southeastern Australia

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Presenter Information

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Abstract

Globally, pressure to ensure future food security is being challenged by competing needs for multiple land-uses in agricultural systems. Rangelands are both a source of greenhouse gas emissions as well as providing opportunities for emissions reduction. Carbon farming is a new land-use option that sequesters carbon in vegetation and soils. National incentive programs in Australia for this option have resulted in significant recent land-use change across Australian rangelands.

Beyond the mitigation benefits, the potential for carbon farming income to enhance socio-ecological resilience in rangelands has been identified. However, there are major uncertainties about the impacts of climate change on sequestration rates and trade-offs between land-use for carbon and pastoral production. The AUD$2.45 billion Commonwealth Emissions Reduction Fund has driven recent land-use change and a further AUD$2 billion over the next 10 years, coupled with a fast-growing secondary carbon market is continuing to drive demand for carbon credits. The ability to supply these carbon credits and meet international emissions reduction obligations but limit the trade-offs with pastoral production can be supported through an identification of spatial prioritisation and optimisation at a landscape scale.

We use a case study of New South Wales where ~3 million ha of traditional rangeland pastoralism is currently delivering ~27% of the national land sector abatement. Priority areas and optimisation of land-use for carbon farming and production under current and future climates were determined by developing a Carbon Optimisation Model (COM). This high-resolution integrated environmental-economic model provides predictions of spatiotemporal dynamics of land-use options for variations of incentive payment levels and policy settings. Regional downscaling of an ensemble of global circulation models (GCMs) were used to predict the climate impacts on future sequestration rates derived from 3PG forest growth model to quantify carbon supply under future climates. The COM can be used to produce spatial maps to underpin strategic prioritisation abatement activities and allow abatement opportunities to be incorporated into regional NRM planning.

Introduction

Natural climate solutions such as regeneration of native vegetation are recognised globally as providing some of the most cost-effective climate mitigation pathways. Between 2015 and 2020, the southern Australian rangelands have seen a change in land-use which now incorporates carbon farming activities driven primarily by the Australian government purchasing Australian Carbon Credit Units (ACCUs) under the AUD$2.5 billion Emissions Reduction Fund (ERF). Approximately 23% of all land sector ACCUs issued to-date have been achieved through regeneration under the method 'Human-induced regeneration' (HIR) (Fig.1). Abatement achieved in these areas is therefore central for the delivery of Australia's commitment to emissions reduction under the 2015 Paris agreement.

In western NSW, approximately 3 million ha is being managed for the long-term (100 years) under HIR incentivised by payment worth approximately AUD$373 million. Management practices under HIR must lead to recruitment or resprouting (regrowth) on previously cleared, regrowth suppressed areas. This can be achieved through grazing management where livestock are excluded, or changes in the timing and extent of grazing (Baumber et al 2020). The management of grazing intensity consistent with HIR objectives can be achieved using exclusion fencing (Waters et al. 2020), however this comes at an increased cost to the land manager. Under the HIR method grazing is permitted on revegetated areas resulting in partial forgone livestock production but the amount of lost income will increase over time as trees competitively interact with pasture production.

The concentration of abatement activities such as HIR in the low and highly variable rainfall, semi-arid rangelands of NSW means that this abatement activity is geographically exposed to regional climatic risks. Any expansion of activities outside these vulnerable rangelands areas to higher rainfall areas will reduce the risk of this exposure. Understanding spatial changes in carbon supply and the changes in costs and returns likely under future conditions is central to reducing risks to abatement delivery. It is also key to understanding the costs and returns facing land managers when making decisions around land-use change which incorporates carbon farming.

Methods and Study Site

A high-resolution (1km grid cell) integrated environmental-economic model (Carbon Optimisation Model, COM) was developed for NSW following an approach similar to Bryan et al. (2014). The COM examined future spatiotemporal dynamics of land-use change from a livestock enterprise to vegetation regrowth for carbon sequestration under the HIR method (natural regeneration of native vegetation). The COM was founded on a HIR land-use suitability spatial layer (Baumber et al. 2020) and integrated the tree growth model 3PG to determine carbon accumulation with different economic and climate scenarios. Within the 33,385 km^2 suitable for HIR in NSW, changes were determined within the 1km grid for 100 years, starting in 2020. Here, we present the changes in carbon supply at 2030 and 2050 under current and future climates.

Economic scenarios

The net present value (NPV) for land-use change was calculated using $NPV = \sum_{t=1,100}(R_t - TC_t)/(1+i)^t$ where R= revenue from carbon in each year (t), calculated as the above ground carbon dioxide equivalent (CO_2e) from vegetation regeneration multiplied by the carbon price; TC = total costs associated with the change ($TC_t = FC + BC_t + MC_t - OC_t$) including: fencing costs (FC) to exclude all herbivores (native and feral), establishment and brokerage costs (BC_t) associated with ERF contracts and ERF contract maintenance costs (MC_t). Foregone income from the land-use change is also accounted for with the term OC_t or opportunity costs $= PFE$ (profit at full equity) $* \Delta DSE_t$ or the change in dry sheep equivalent (DSE) carrying capacity at time *t*. The term $(1+i)^t$ is applied in calculation of future value where we applied a discount rate (i) of 5.26 which is the average costs of borrowing for a small business. A spatial map of livestock carrying capacity (DSE) was derived from NRM management regions (Local Land Service regions) which was validated using technical expert review. To account for reduced pasture productivity from increasing trees growth over time, a decay function was applied following empirically derived estimates (Gowen & Bray, 2016).

Climate scenarios

Along with historical climate measurements (current climate), two future climate scenarios were examined, based on shared socioeconomic pathways (SSP): low emissions, SSP245 (CO_2=480ppm) and high emissions SSP585 (CO_2=621 ppm). Historical (current climate) daily climate data from 1979-2018 were downloaded for 2096 SILO sites across NSW (https://www.longpaddock.qld.gov.au/silo/). Monthly future projections of climate data generated by 19 GCMs were downloaded from CMIP6 (https://pcmdi.llnl.gov/CMIP6/), here we report results for one GCM - ACCESS-CM2,AC2. Bias-corrected monthly future climate data were statistically downscaled to daily climate data for the 2096 sites following Liu and Zuo (2012). Current and future, values for number of frost days, rain days, maximum and minimum temperature and total rainfall were required as input to 3-PG input. The site-specific values of each input variable were interpolated to a 1 km grid to run 3-PG for 33385 grid cells (1km^2) suitable for HIR across NSW. This meant that 3-PG predicted a value for carbon for each independent grid cell.

Carbon sequestration

A process-based model, 3-PG (Physiological Processes Predicting Growth) (Paul et al 2007) was parameterized for Australian species (Wang et al. unpublished). We ran 3-PG for 33385 grid cells (1km^2) suitable for HIR across NSW under the current climate and future climate change scenarios to predict above ground biomass (AGB) (t C ha^{-1}) which was converted to carbon dioxide equivalent (t CO_2e ha^{-1}).

Results

Carbon supply estimates from 3-PG under current and future climate scenarios and absolute differences in current and future supply is given for a range of carbon prices ($5, $12, $20, $30 and $40 per Mt$CO_2$e) with the medium pasture decay (0.3) and fencing ($24 ha^{-1}) cost in Fig. 2. Here, at a low (<AUD$20 t CO_2e) carbon price, carbon farming under HIR became more economically viable under both future climate scenarios than under current climate. For low emissions scenario, carbon supply was higher across all NRM regions at all carbon prices, except the high population density regions of Greater Sydney and North Coast. Semi-arid Western and NW regions provided the highest levels of carbon supply at all carbon prices. All regions achieved more than 70% supply at $20 t$CO_2$e, except for Greater Sydney (52%, 0.1 MtCO_2e), the Western Division achieved 87% supply (86 MtCO_2e) at $12 t CO_2e, an increase of 36 Mt CO_2e (71%) compared with the current climate. For the high emissions scenario, carbon supply was also higher across most regions achieving more than 70% supply at $20 t$CO_2$e. The western region achieved 82% supply (82 MtCO_2e) at $12 t$CO_2$e which is an increase of 32 MtCO2e (63%) compared to the current climate, having the largest absolute difference. Spatial changes in AGB (t ha^{-1}) for one GCM model (ACCESS-CM2, AC2) at 2030 and 2050 under the two climate scenarios are shown in Fig.3. Changes in AGB in 2030 show ~ 30-40 t ha^{-1} increase in central and northern NSW with higher increases further east ~ 65-70 t ha^{-1}. These increases are associated with a rainfall gradient of 300-600mm MAR (central and northern NSW) and 600-700 mm MAR in the east. These increases in AGB were magnified under a high emissions scenario largely due to CO_2 fertilisation effect which are most evident in low rainfall areas <600 mm MAR (not presented).

Discussion

Most of the economic carbon supply (>90%) was found to be exhausted at $30 t$CO_2$e under both future climate scenarios with HIR cost-effective for nearly 50% of land at $10 t$CO_2$e^{-1} (data a not shown). With a current carbon price of ~$12-16 t$CO_2$e, supply could be significantly increased if this price were doubled. The greatest future changes in AGB can be expected in NE and central NSW, offering the potential to expand the geographic distribution of current activities whilst delivering considerable abatement. However, we did not develop an agricultural productivity layer under future climate and while the comparisons made here are presented as a proof of concept, additional estimates of agricultural NPV under the climate change scenarios should be developed. The 3-PG modelling showed that increased carbon sequestration and greater economic competitiveness of carbon farming predicted for climate change scenarios were primarily driven by an increased CO_2 effects which is not currently accounted for by the Australian government. The role of the CO_2 fertilisation effect requires further examination, and forms part of ongoing research.

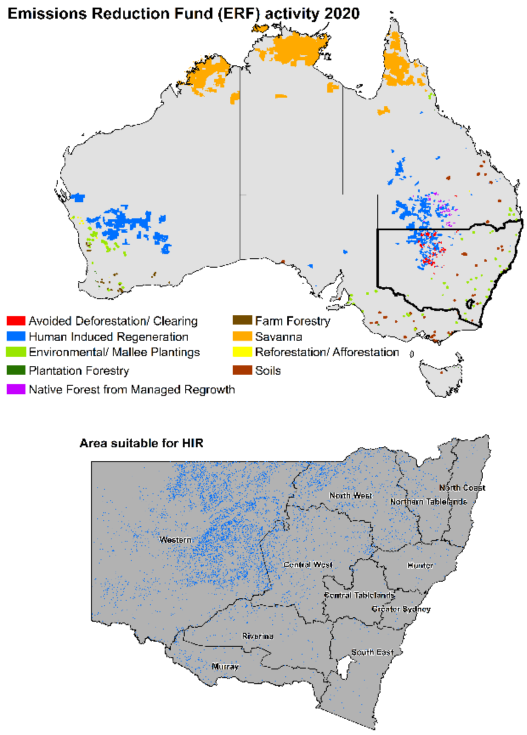

Fig.1. Current distribution of carbon farming activities under 10 different management practices (above) and distribution of potential areas (blue) suitable for Human-induced regeneration (HIR) in NSW with the location of Local Land Service NRM regions (below).

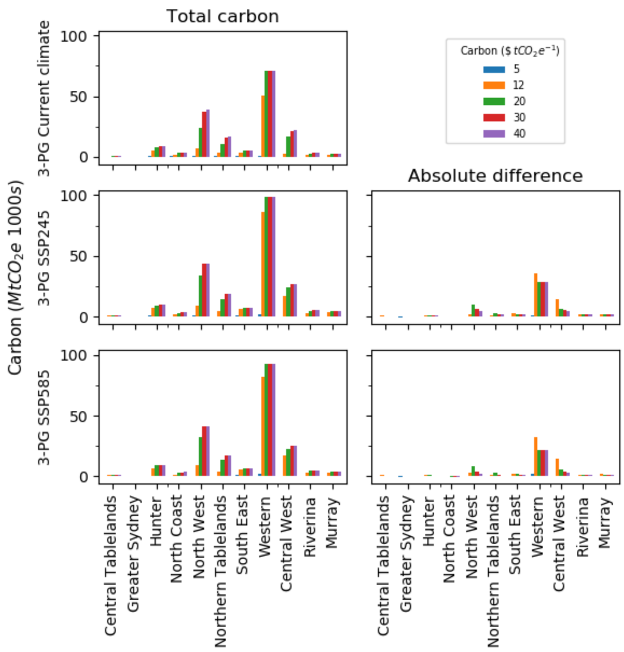

Fig.2. Carbon economic carbon supply modelled using 3-PG estimates under the current and the two climate scenarios for Local Land Service NRM regions.

50 Years

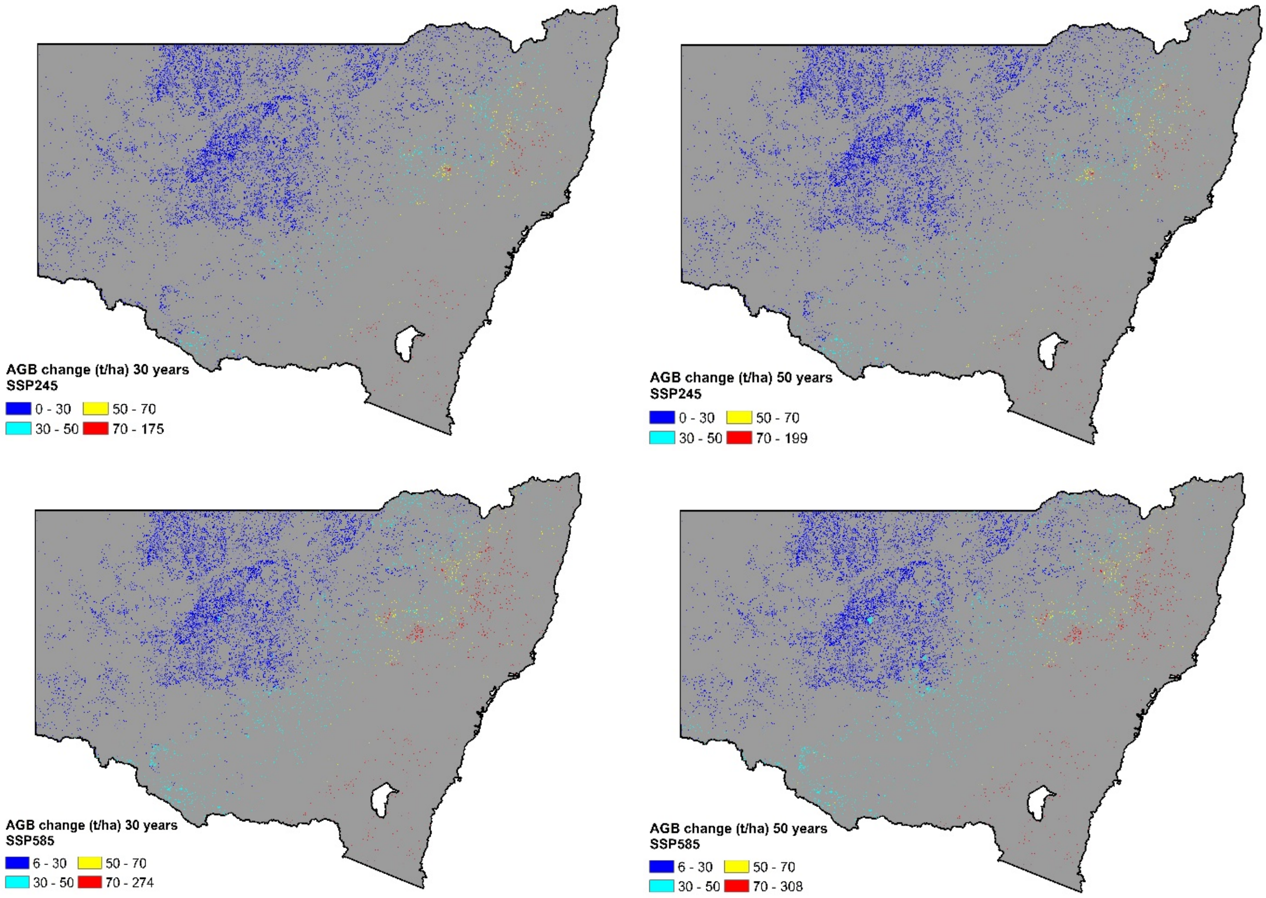

Fig.3. Predicted changes in above ground (AGB t ha^{-1}) biomass at 2030 and 2050 for Human-induced revegetation under a low (SSP245) and high (SSP585) emissions scenarios based on the 3-PG model output.

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