Agriculture, Ecosystems and Environment 148 (2012) 44–64

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Carbon management of commercial rangelands in Australia: Major pools and fluxes

Christopher Dean[a,b,*], Grant W. Wardell-Johnson[b], Richard J. Harper[c]

[a] School of Biological, Earth and Environmental Sciences, University of NSW, Sydney, NSW 2052, Australia
[b] Curtin Institute for Biodiversity and Climate, School of Science, Curtin University, GPO Box U1987, Perth, WA 6845, Australia
[c] Alcoa Chair of Sustainable Water Management, School of Environmental Science, Murdoch University, Murdoch, WA 6150, Australia

ARTICLE INFO

Article history:
Received 7 April 2011
Received in revised form
19 November 2011
Accepted 21 November 2011
Available online 16 December 2011

Keywords:
Carbon sequestration
Carbon emission
Rangelands
Deforestation
Regrowth
Soil organic carbon

ABSTRACT

Land-use emissions accompanying biomass loss, change in soil organic carbon (ΔSOC) and decomposing wood-products, were comparable with fossil fuel emissions in the late 20th century. We examine the rates, magnitudes and uncertainties for major carbon (C) fluxes for rangelands due to commercial grazing and climate change in Australia. Total net C emission from biomass over 369 Mha of rangeland to-date was 0.73 (±0.40) Pg, with 83% of that from the potentially forested 53% of the rangelands. A higher emission estimate is likely from a higher resolution analysis. The total ΔSOC to-date was −0.16 (±0.05) Pg. Carbon emissions from all rangeland pools considered are currently 32 (±10) Tg yr^{-1}—equivalent to 21 (±6)% of Australia's Kyoto-Protocol annual greenhouse gas emissions. The ΔSOC from erosion and deforestation was −4.0 (±1.6) Tg yr^{-1}—less than annual emissions from livestock methane, or biomass attrition, however it will continue for several centuries. Apart from deforestation a foci of land degradation was riparian zones. Cessation of deforestation and onset of rehabilitation of degraded rangeland would allow SOC recovery. If extensive rehabilitation started in 2011 and erosion ceased in 2050 then a ΔSOC of −1.2 (±0.5) Pg would be avoided. The fastest sequestration option was maturation of regrowth forest in Queensland with a C flux of 0.36 (±0.18) Mg ha^{-1} yr^{-1} in biomass across 22.7 Mha for the next 50 yr; equivalent to ~50% of national inventory agriculture emissions (as of mid 2011); and long-term sequestration would be 0.79 (±0.40) Pg. Due to change in water balance, temperature and accompanying fire and drought regimes from climate change, the forecast ΔSOC from the forested rangelands to 0.3 m depth was −1.8 (0.6) Pg (i.e. 38 (12)% of extant SOC stock) resulting from a change in biomass from 2000 to 2100. For improved management of rangeland carbon fluxes: (a) more information is needed on the location of land degradation, and the dynamics and spatial variation of the major carbon pools and fluxes; and (b) freer data transfer is needed between government departments, and to the scientific community.

1. Introduction

Since establishment of the IPCC in 1988 there has been enthusiasm to address anthropogenic climate change by reducing growth in atmospheric greenhouse gasses (GHG). However, annual anthropogenic carbon (C) efflux has not decreased and urgency has arisen owing to increasing positive feedback from climate change and the preference to stabilise CO_2-e concentration below 550 ppmv (Anderson and Bows, 2008). Managing C fluxes requires comprehensive accounting, of both past activity and future options. For example, the measurement of reduced C sink efficiency has been questioned due to the similar effect from uncounted land-use emissions (Gloor et al., 2010).

The net anthropogenic reduction in woody biomass for pasture, urbanisation, and crops (agricultural, forestry and energy) from the late Pleistocene to the present day, has had a trend of increasing influence on global warming (Edney et al., 1990; Caseldine and Hatton, 1993; Rudiman, 2003; Salinger, 2007; Olofsson and Hickler, 2008; Metz, 2009; Pinter et al., 2011). Future land-use processes may emit a further 100 Pg of C (Schimel, 1995). Soil organic carbon (SOC) concentration is generally correlated with long-term biomass stock (Jackson and Ash, 1998; Wynn et al., 2006), primarily due to root turnover and litterfall. Thus, in the long-term, decline in biomass generally causes decline in SOC. Emissions from both biomass and SOC, due to land degradation, contribute to climate change, and in places there is feedback to further land degradation (Sivakumar, 2007).

Around 40–60% of anthropogenic emissions since pre-industrial times remain in the atmosphere (House et al., 2002; Elmegreen

* Corresponding author. Present Address. PO Box 3520, Rundle Mall, Adelaide, SA 5000, Australia. Tel.: +61 8 8268 8230.
E-mail addresses: cdeanspace@gmail.com, christopher.dean@unsw.edu.au, christopher.dean@curtin.edu.au (C. Dean).

0167-8809/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2011.11.011

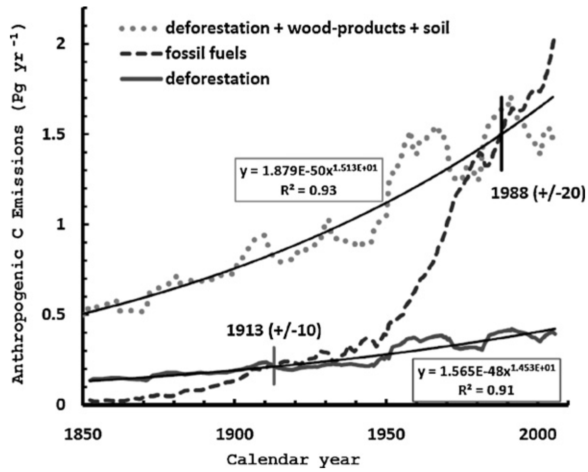

Fig. 1. Comparison of major sources of anthropogenic C emissions. *Data sources*: deforestation and fossil fuels, Steffen (2009); deforestation plus wood-products and soil change, Houghton (2008). (N.B. Houghton assumed zero change in soil carbon with timber harvesting.)

Rafelski et al., 2009) and continue to contribute to climate change. Future anthropogenic impact from land-use is forecast to be 9–22% of the total anthropogenic increase in CO_2 to 2100 (Sitch et al., 2005). Emissions from fossil fuel usage overtook those from land-use in 1959 (±7) (Woodwell et al., 1983). From more recent data (Houghton, 2008; Steffen, 2009) and by assigning polynomials to emission trends (Fig. 1) it appears that it was in 1913 (±10) that the C efflux from fossil fuel combustion, exceeded that from biomass loss due to anthropogenic deforestation and forest degradation. However, when decomposition of wood-products and change in SOC (ΔSOC) from land-use are included then fossil fuel emissions only overtook emissions from land-use in 1988 (±20). Fossil fuel emissions may have only surpassed those from land-use even more recently than that, as Houghton (2008) had assumed zero ΔSOC with timber harvesting, which is unlikely (e.g. Diochon et al., 2009; Zummo and Friedland, 2011). Emissions from land-use and wood-products both have positive future trends. Thus, for the purposes of C management, land-use influences on SOC are significant and are worthy of scrutiny, especially as their emissions can be less immediate (and hence less easily measured) than those from fossil fuel combustion.

This study is centred on the Australian commercial rangelands, which differ from those elsewhere (e.g. the grasslands of South America and the Great Plains of the USA), in that they are predominantly shrubland and woodland with lesser amounts of scrub, heath and herbland (Carnahan, 1977; Luly, 1993). Nevertheless, Australia and the USA share similarities in the industrialisation of their arid and semiarid rangelands (e.g. investment, speculation, social mores and exports) (Heathcote, 1969). There are also parallels between the historical livestock-driven environmental degradation processes in Australia, the Americas and southern Africa (Pickup, 1998).

The Australian commercial rangelands are essentially dedicated to the export market of livestock products, whereas prior to European settlement (1788) they were used by subsistence-based societies. The accompanying changes in Australia's native forests have principally been through degradation, timber extraction, deforestation, regrowth and woody-thickening. Ongoing degradation of Australian rangelands emits CO_2, whereas less-degrading management would reduce those emissions; furthermore, reversing degradation could sequester C (Howden et al., 1991; McKeon et al., 1992; Glenn et al., 1993; Walker and Steffen, 1993; Henry et al., 2002; Hill et al., 2006).

Estimates of ΔSOC accompanying rangeland deforestation and regrowth in Australia have high uncertainty (Henry et al., 2002), which is one reason they were not included in Australia's adoption of the Kyoto Protocol GHG accounting. Similarly, ΔSOC accompanying slower processes such as woody re-colonisation or forest degradation from erosion, are not currently included; also as they correspond to 'grazing management', which was excluded from Australia's Kyoto-Protocol accounting. Such fluxes are examined in this study in order to provide estimates of scientific relevance, rather than to be guided by an administrative selection.

In recent decades the highest rates of deforestation in Australia were in the State of QLD, which maintains the most comprehensive records in Australia of deforestation from LANDSAT remote-sensing (Queensland Department of Natural Resources, 2000). Emissions from biomass due to deforestation over the last decade were ~11 Tg-C yr^{-1} (from ~0.375 Mha yr^{-1}), and the deforestation rate is decreasing (DNRW, 2008). Emissions from deforestation in QLD, from all sources, are likely to remain approximately at 2006 levels (Raison et al., 2009). Changed forest use in QLD offers the highest, net sequestration in the rangelands nationally, through reduced deforestation and managed regeneration, but also with biodiversity plantings and plantations (Bray and Golden, 2008; Fensham and Guymer, 2009).

This study examines (a) the magnitudes and timescales of major emissions and sequestration for the commercial rangelands of Australia with change of forest cover, and (b) the effect of climate change on SOC; and we illustrate the options and hurdles in recognising, assessing and managing the larger carbon pools and fluxes in rangelands. As a subset of the national rangelands, we examine the commercial rangelands in QLD, where management has the most practical capacity to reduce emissions.

2. Materials and methods

2.1. Study region

The Australian rangeland zone covers 661 Mha (Donohue et al., 2005). Excluding from that zone, reserves and mesic arable land, the commercial livestock properties occupy ~369 (±5) Mha (Fig. 2). Subsections of that area were selected for examination of livestock watering points and forest regrowth (Section 2.2). State and Territory cadastre maps, combined with federal land-use maps were used to determine the commercial grazing land in GIS compatible format. In all calculations carbon was considered to be 50% by weight of dry biomass.

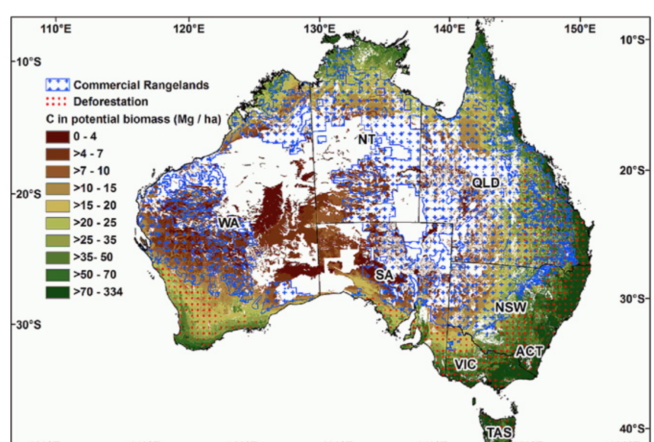

Fig. 2. Distribution of C in potential forest aboveground biomass across Australia, showing intersection with the commercial rangelands and areas of deforestation.