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An open-access method for targeting revegetation based on potential for emissions reduction, carbon sequestration and opportunity cost

Andrew Longmire*, Chris Taylor, Craig J. Pearson

Melbourne Sustainable Society Institute, University of Melbourne, VIC 3010, Australia

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ABSTRACT

We propose a simple heuristic that uses open-access models and government data on agricultural activities to estimate total carbon emissions from agriculture, the gross carbon benefit and the opportunity cost per tonne CO_2-e from revegetating to environmental plantings or plantation forestry. We test this across ten areas of mixed land-use that represent diverse Australian agricultural systems along a rainfall transect. The local value of agricultural production was obtained from government statistics and used to estimate the current economic opportunity cost of converting cleared agricultural land to mixed environmental plantings for carbon sequestration. Gross carbon benefit from revegetation was closely related to current agricultural use, as was financial opportunity cost. These were not related simply to site productivity potential or rainfall. The proportion of land cleared for agriculture that would need to be re-vegetated to achieve a localised zero-carbon land-use scenario was calculated by the ratio of current agricultural emissions to gross carbon benefit from revegetation; this ranged from 13% to 66% for groups of agricultural industries across Australian rainfall transects. While the heuristic does not capture the detail of models built specifically for local research questions it does provide a different lens on the questions policy makers and land managers may ask about the costs and benefits of revegetating agricultural land, and provides open-access methods to guide them.

Introduction

Climate change and the taxing of carbon emissions by some governments have given momentum to research on revegetation, particularly reforestation of agricultural land. Our search of literature using Google Scholar revealed over 130,000 peer-refereed papers on land-use change and revegetation, most of which fall into categories of either analysis of ecosystem impacts arising from historical land-use change or biologically-based models and scenarios that assess likely impacts of revegetation. Despite this sizeable literature, neither policy-makers nor individual land managers have simple heuristics to assist them in deciding which land would most appropriately be revegetated. This lack of clarity is particularly concerning for agricultural organisations and individual farmers who manage the majority of cleared land in countries such as Australia and we believe it provides a barrier to full engagement in discussion about how to transition to land-uses with low or zero aggregate carbon emissions.

The purpose of our research was to propose a simple process to assess which areas, and what proportion of areas, would best be revegetated. For transparency and widespread use, we believed that this process should use publicly-available data and models and be scalable, that is, applicable to possible national policy (at continental scale, in the case of Australia), regions, and individual farms (where local data will likely be most accurate). Because of its simplicity, our proposal is necessarily coarse and may be refined with additional considerations, although further refinement and complexity may mitigate against its adoption.

Our model is tested on diverse regions within Australia, a good case-study because of the importance and diversity of agriculture, its large spatial extent and large contribution to gross national carbon emissions. The model estimates the opportunity cost of revegetating agricultural (cropping, horticulture or grazing) land and requires only measures of gross carbon benefit from revegetation, agricultural emissions, and economic value of major agricultural activities. As such, we draw on the work of Crossman and Bryan (2009) who modelled "hot spots" where the ratio of environmental benefit (increase in natural capital) to farm profitability was greatest. We acknowledge a growing literature,

* Corresponding author. Tel.: +61 3 9035 7592.
E-mail addresses: andrew.longmire@unimelb.edu.au, andrew.longmire.melbourne@gmail.com (A. Longmire), ctaylor@unimelb.edu.au (C. Taylor), c.pearson@unimelb.edu.au (C.J. Pearson).

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mostly using sophisticated models developed for the purpose, that assesses likely changes in land-use e.g., between agriculture and environmental plantings for carbon sequestration, as local conditions and enterprise profitability vary (e.g., Bryan and Crossman, 2013; Crossman et al., 2011; Eady et al., 2011; Paul et al., 2013a,b; Radeloff et al., 2012), sometimes identifying the amount of direct (government) payments that would make a particular enterprise more profitable than say, agriculture (e.g., Crossman et al., 2011). In some cases, we have independently chosen to use the same biological models. However, our approach, although much more simplistic, is also different in purpose: we evaluate the opportunity cost (and carbon benefit) of changing between enterprises, rather than of each stand-alone enterprise. We do not e.g., evaluate costs of production, nor cost of land (c.f., Paul et al., 2013a,b) which we consider peripheral to decisions about changing between enterprises, though crucial to evaluating whether to purchase a property to begin an enterprise.

The carbon benefit from revegetation requires models that predict growth rates and carbon sequestration in the landscape, based on soil types, climate patterns, topography, plant species and land management practices (e.g., Landsberg and Waring, 1997; Silver et al., 2000; Stavins and Richards, 2005; Roxburgh et al., 2006). The Full Carbon Accounting Model (FullCAM; Richards et al., 2005) has been used extensively by the Australian government to estimate and monitor Australian continental carbon stocks and flows and potential carbon sequestration (DCCEE, 2012a,b; Kesteven and Landsberg, 2004). Carbon emissions from a variety of agricultural practices are found in publications specific to industries and regions (e.g., Eckard et al., 2008).

Our focus on opportunity cost (i.e. minimising the cost of displacing current agricultural uses) contrasts with, but should arrive at the same conclusions, as research that asks what price for carbon would justify revegetating particular areas. For example, Polglase and colleagues (2011) concluded that at an establishment cost of \$3000/ha, no areas were likely to be reforested until the price for carbon sequestration exceeded \$40/t.CO_2-e. Similar approaches demonstrate high sensitivity to carbon pricing. Lawson et al. (2008) estimated that revegetation of approximately 5.8 Mha of Australia's agricultural land would be economically viable at a carbon price of \$20.88/t.CO_2-e, whereas the potential area increases to 26 Mha at >\$29.20/t.CO_2-e. This would represent 6–26% of the 100 million hectares of previously forested and wooded land cleared for agriculture in Australia (ABARES, 2010).

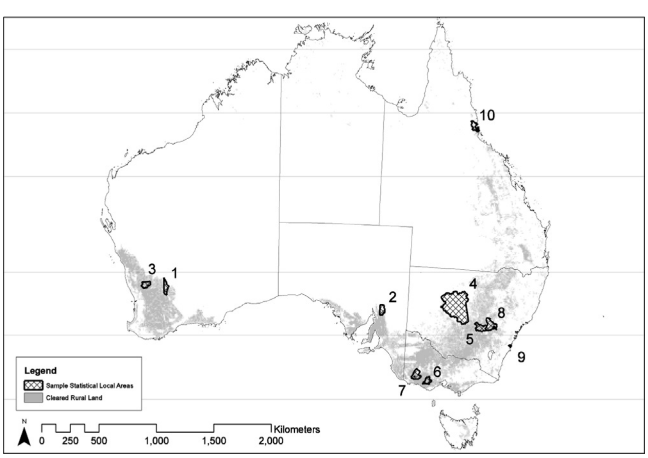

Fig. 1. Locations of ten statistical local areas (SLA's) and cleared land (grey) in agriculturally productive areas of Australia. (1) Westonia, (2) Orroroo, (3) Wongan, (4) Cobar, (5) Forbes, (6) Corangamite, (7) S. Grampians, (8) Cabonne, (9) Kiama, (10) Cardwell.

We suggest that the method demonstrated in this paper provides a sensible and accessible basis for producing scenarios for efficiently changing land-use so that the sum of carbon emissions from agriculture and forestry is zero or negative in a region, an aspiration for a "zero carbon land use". While our primary objective was to develop a simple, evidence-based method for identifying areas for revegetation at regional and continental scales, we believe the method proposed in this paper has as much applicability and potentially greater accuracy at catchment or farm scales. Our use of publicly-available software and transparent arithmetic makes our methods accessible to a wide range of land managers, including catchment managers, local governments and individual landholders. Throughout the paper we present often contrasting sequestrations, emissions and opportunity costs for both single characteristic industries, and for groups of activities representative of the local mix, illustrating the intra-region and on-farm variability driven by different activities. This will assist decision-makers to assess the magnitude of greenhouse emissions from land use activities and the impact of policies that may eventually be introduced to reduce these at the farming system or landscape level.

Methods

The heuristic uses three equations:

1. Gross carbon benefit (from sequestration potential following revegetation and reduction of agricultural emissions):

$$\mathrm{GCB}(\mathrm{t.CO_2\text{-}e/ha/year}) = \mathrm{SP(sequestration\ potential)} + \mathrm{AE(agricultural\ emissions)}$$

2. Opportunity cost (not taking account of one-off costs such as cost of establishment of forests and woodlands, which could be included):

$$\mathrm{OC}(\$/\mathrm{t.CO_2\text{-}e/ha/year}) = \frac{\mathrm{LVAP}}{\mathrm{GCB}}$$

where LVAP is local value of agricultural production (\$/ha/year), available from annual reports (e.g., ABS, 2008a), and is taken as a surrogate for local agricultural value. LVAP does not approximate profit of individual farm within an SLA as it takes no account of e.g., debt charges, but LVAP is a good surrogate for what might be gross profit for an unencumbered, efficient farm.

3. Proportion of land that would need to be converted from agriculture to carbon-sequestering vegetation within any area (continental, regional, or farm) to achieve aggregate zero-carbon emissions from land use within that area:

$$P = \frac{\mathrm{AE}}{\mathrm{SP{+}AE}}.$$

These were applied to diverse industries and regions within ten statistical local areas (SLAs). The SLAs were selected to represent various farming systems common in Australia, located along a rainfall gradient. This selection represents the vast bulk of land cleared for agriculture and the uncleared but highly modified rangeland in Australia and largely follows Pearson et al. (2003; Fig. 1, Table 1). Agricultural land-use across this transect does not necessarily follow average annual rainfall (AAR). For example, Orroroo, Wongan and Forbes receive approximately 80% of AAR between May and October and support mixed dryland cropping (and irrigated dairying at Forbes) whereas unpredictable cyclonic rainfall at Cobar supports only low-yield cropping and low-density grazing of native vegetation. Unless otherwise specified, data sourced