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Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes

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ABSTRACT

Carbon farming in agricultural landscapes may provide a cost-effective mechanism for offsetting carbon emissions while delivering co-benefits for biodiversity through ecosystem restoration. Reforestation of landscapes using native tree and shrub species, termed environmental plantings, has been recognized as a carbon offset methodology which can contribute to biodiversity conservation as well as climate mitigation. However, far less attention has been paid to the potential for assisted natural regeneration in areas of low to intermediate levels of degradation, where regenerative capacity still remains and little intervention would be required to restore native vegetation. In this study, we considered the economics of carbon farming in the state of Queensland, Australia, where 30.6 million hectares of relatively recently deforested agricultural landscapes may be suitable for carbon farming. Using spatially explicit estimates of the rate of carbon sequestration and the opportunity cost of agricultural production, we used a discounted cash flow analysis to examine the economic viability of assisted natural regeneration relative to environmental plantings. We found that the average minimum carbon price required to make assisted natural regeneration viable was 60% lower than what was required to make environmental plantings viable (\$65.8 t CO_2e^{-1} compared to \$108.8 t CO_2e^{-1}). Assisted natural regeneration could sequester 1.6 to 2.2 times the amount of carbon possible compared to environmental plantings alone over a range of hypothetical carbon prices and assuming a moderate 5% discount rate. Using a combination of methodologies, carbon farming was a viable land use in over 2.3% of our study extent with a low \$5 t CO_2e^{-1} carbon price, and up to 10.5 million hectares (34%) with a carbon price of \$50 t CO_2e^{-1}. Carbon sequestration supply and economic returns generated by assisted natural regeneration were relatively robust to variation in establishment costs and discount rates due to the utilization of low-cost

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techniques to reestablish native vegetation. Our study highlights the potential utility of assisted natural regeneration as a reforestation approach which can cost-effectively deliver both carbon and biodiversity benefits.

1. Introduction

The carbon market has the potential to deliver significant outcomes for ecosystem restoration alongside the abatement of greenhouse gas emissions (Bradshaw et al., 2013). The demand for terrestrial carbon sinks is creating opportunities for avoided deforestation in tropical forests (Phelps et al., 2012; Venter and Koh, 2011), as well as landscape-scale restoration through afforestation and reforestation (Galatowitsch, 2009; Peters-Stanley et al., 2013; Silver et al., 2000). There is particular interest as to whether the carbon market can deliver positive outcomes not only for the climate and local economies, but also for biodiversity (Bekessy and Wintle, 2008; Smith and Scherr, 2003). A too narrow focus on maximizing sequestration of carbon (such as the planting of monocultures) can lead to a range of negative ecological impacts (Lindenmayer et al., 2012; Pittock et al., 2013), and will miss opportunities for co-benefits derived through restoration of natural ecosystems (Bullock et al., 2011; Gilroy et al., 2014; Dwyer et al., 2009; Rey Benayas et al., 2009).

Carbon farming is a term that is used to describe land-based practices which either avoid or reduce the release of greenhouse gas emissions, or actively sequester carbon in vegetation and soils, primarily in agricultural landscapes. Several studies have examined the economics of carbon farming through establishment of monocultures or environmental plantings (Bryan et al., 2014; Bryan and Crossman, 2013; Crossman et al., 2011; Paterson and Bryan, 2012; Paul et al., 2013; Polglase et al., 2013). Environmental plantings are a mixture of locally indigenous tree and shrub species which are planted or seeded on cleared land, and are not normally harvested (Paul et al., 2013). The potential for environmental plantings to deliver biodiversity co-benefits alongside carbon abatement has been a focus of recent work (Bryan et al., 2014; Carwardine et al., 2015; Goldstein et al., 2006; Lin et al., 2013; Nelson et al., 2008; Pichancourt et al., 2014; Renwick et al., 2014). Yet given the high up-front costs of direct planting (Chazdon, 2008; Schirmer and Field, 2000), it is surprising that there has been limited assessment of the economic viability of carbon sequestration through assisted natural regeneration of vegetation, despite the large potential biodiversity and economic benefits of this approach (Birch et al., 2010; Bradshaw et al., 2013; Butler, 2009; Dwyer et al., 2009; Funk et al., 2014; Smith and Scherr, 2003; Trotter et al., 2005).

Assisted natural regeneration (ANR, also known as managed regrowth) is recognized as a cost-effective forest restoration method that can restore biodiversity and ecosystem services in areas of intermediate levels of degradation, while also providing income for rural livelihoods (Chazdon, 2008; Ma et al., 2014). ANR relies on residual seeds and plants at the site, or dispersed from vegetation nearby. ANR utilizes low-cost techniques to assist in the natural re-establishment of vegetation, such as: restriction of livestock grazing through fencing and direct stocking rate management; cessation of tree control practices like burning and disturbance with machinery; the use of vegetation thinning to reduce competition and promote growth, and; in some circumstances, supplementary planting of seedlings (Smith and Scherr, 2003). Although most frequently applied in tropical forests (Rey Benayas, 2007; Shono et al., 2007), ANR is gaining momentum as an important mechanism for restoring forests across a range of ecosystems (Chazdon, 2008; Gilroy et al., 2014; Shono et al., 2007).

Vegetation that is allowed to naturally regenerate has several advantages for biodiversity conservation over plantings, even when plantings are comprised of native species. First, under ANR, the vegetation is more likely to be comprised of native species adapted to local conditions, resulting in vegetation that is more resilient to local climate variation and disturbance. Second, natural regeneration can result in high species diversity including trees, shrubs, forbs and grasses, whereas under environmental planting, generally only tree species are planted. Third, ANR often provides superior habitat for local fauna as a result of the increased plant and structural diversity (Bloomfield and Pearson, 2000; Bowen et al., 2009; Bruton et al., 2013; Fensham and Guymer, 2009). Finally, under the right conditions, the cost of establishing vegetation through ANR is much lower than active planting (Sampaio et al., 2007; Schirmer and Field, 2000; Smith, 2002).

Despite the potential advantages of ANR, a lack of awareness of its benefits and demonstrative results means it remains underutilized (Shono et al., 2007). ANR falls under the definition of afforestation/reforestation (A/R) under the Kyoto Protocol and Clean Development Mechanism (Smith and Scherr, 2003; Smith, 2002), but has attracted little attention as a carbon sequestration methodology compared to mechanisms such as active planting or avoided deforestation (Niles et al., 2002). ANR has most potential in locations that have not been intensively used (cropped or irrigated) or with a relatively short history of intensive land use. Across much of sub-tropical Australia most grassy eucalypt woodlands used for grazing land fall into this category (McIntyre and Martin, 2002). A window of opportunity therefore exists to achieve significant carbon and biodiversity outcomes through assisted natural regeneration across much of northern Australia (Fensham and Guymer, 2009; Martin et al., 2012),