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Review

Biophysical risks to carbon sequestration and storage in Australian drylands

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A B S T R A C T

Carbon abatement schemes that reduce land clearing and promote revegetation are now an important component of climate change policy globally. There is considerable potential for these schemes to operate in drylands which are spatially extensive. However, projects in these environments risk failure through unplanned release of stored carbon to the atmosphere. In this review, we identify factors that may adversely affect the success of vegetation-based carbon abatement projects in dryland ecosystems, evaluate their likelihood of occurrence, and estimate the potential consequences for carbon storage and sequestration. We also evaluate management strategies to reduce risks posed to these carbon abatement projects. Identified risks were primarily disturbances, including unplanned fire, drought, and grazing. Revegetation projects also risk recruitment failure, thereby failing to reach projected rates of sequestration. Many of these risks are dependent on rainfall, which is highly variable in drylands and susceptible to further variation under climate change. Resprouting vegetation is likely to be less vulnerable to disturbance and have faster recovery rates upon release from disturbance. We conclude that there is a strong impetus for identifying management strategies and risk reduction mechanisms for carbon abatement projects. Risk mitigation would be enhanced by effective co-ordination of mitigation strategies at scales larger than individual abatement project boundaries, and by implementing risk assessment throughout project planning and implementation stages. Reduction of risk is vital for maximising carbon sequestration of individual projects and for reducing barriers to the establishment of new projects entering the market.

Contents

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1. Introduction

Market-based incentives to protect vegetation and revegetate degraded landscapes are an important component of carbon abatement policies around the world. For example, the UN's REDD+ programme now operates across 64 developing countries (UN, 2016), while Australia's Emissions Reduction Fund has established AUD$2.55 billion for abatement (Australian Government, 2014). In addition to providing a mechanism for offsetting carbon emissions, these projects offer a range of social and environmental co-benefits, including diversified income streams for rural landholders, job creation, improvements to biodiversity, reduced erosion and nutrient runoff, concomitant improvements to water quality in freshwater and marine environments, pollination services, livestock shelter, salinity control and increased amenity values (Cunningham et al., 2015). However, these projects may also have adverse impacts, for example forestry activities that impact on water availability or biodiversity conservation, and limiting land access for agricultural production (Australian Government, 2014).

For vegetation-based carbon abatement projects to succeed in mitigating climate change, they must store carbon over an extended time period, otherwise any benefits accrued may be lost. However, there are a number of biophysical risks to maintaining these long-term carbon stores, including fire, drought and heat stress, grazing by livestock and wild herbivores, recruitment failure after active regeneration, and changes in climate. These risks can result in reduced rates of sequestration and the release of stored carbon back to the atmosphere (Galik and Jackson, 2009). For example, wildfires are estimated to reduce the annual terrestrial carbon uptake by 0.32 Pg C yr^1, which accounts for around 20% of the total annual terrestrial carbon sink in a world without fire (Yue et al., 2015). In 2003, drought and heatwaves in Europe were estimated to reduce ecosystem gross primary productivity by 30% and resulted in net carbon emissions of 0.5 Pg C yr^1 (Ciais et al., 2005). These risks not only affect the environmental and economic value of existing carbon abatement projects, but may also inhibit their uptake by additional landholders, effectively reducing carbon abatement potential. Thus, understanding potential risks to carbon abatement projects is crucial to their success in mitigating climate change.

Here, we undertake a review of risk factors for vegetation-based carbon abatement initiatives, with a focus on Australian drylands. Drylands are characterised by infrequent, highly variable rainfall, and are defined as regions with an aridity index (which is the ratio of mean annual precipitation to potential evapotranspiration) below 0.65 (UNCCD, 2000). We focus on drylands because they offer considerable opportunities for carbon sequestration due to their extensive land area, covering around 30% of Earth's land surface (Lal, 2004) and 70% of Australia (Fig. 1; Eamus et al., 2016). In Australia, carbon projects that involve either avoided clearing of vegetation or regeneration of previously cleared or degraded vegetation are concentrated in drylands, with a large number of projects under the Australian Emissions Reduction Fund located in rural properties in the semi-arid region of western New South Wales (Fig. 1). These initiatives offer opportunities to mitigate climate change, rehabilitate degraded landscapes and drive economic stability (Dean et al., 2012, 2015).

Assessment of the risks to carbon abatement projects requires elucidation of both the likelihood and consequences of identified risk factors for carbon storage and sequestration. In this review we identify and examine each of the following risk factors: (i) unplanned fire; (ii) drought and heat stress; (iii) grazing by livestock and wild herbivores; (iv) factors leading to recruitment failure; and (v) climate change. For each risk factor we evaluate the likelihood of occurrence and the potential consequences for carbon storage and sequestration. Finally, we (vi) identify management strategies and

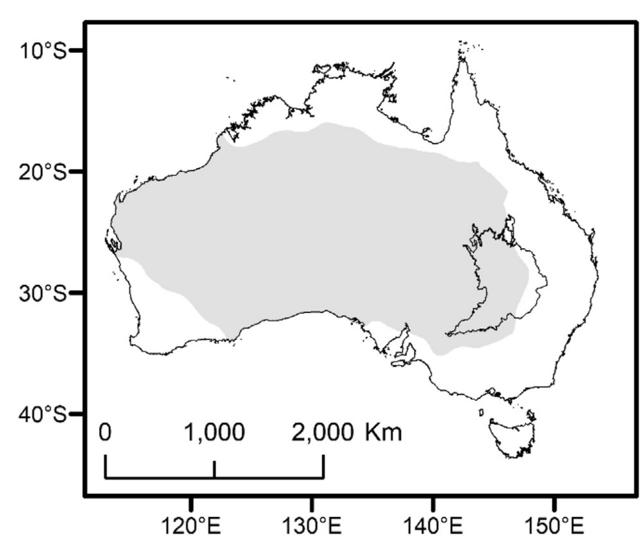

Fig. 1. Location of drylands in Australia, with a majority of carbon farming projects under the Australian Emissions Reduction Fund located within the bioregions bounded by the black polygon.