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Management flexibility, price uncertainty and the adoption of carbon forestry

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ABSTRACT

A price on carbon has the potential to drive significant land use change through reforestation. Understanding the likely locations and extent of these changes is therefore a key focus for researchers and policy makers. Models of reforestation based on net present values (NPV) typically compare the economic returns of carbon forestry to alternative land uses. However, these models often neglect the impact of uncertainty. Two sources of uncertainty highly relevant to carbon forestry are the opportunity cost of the land on which the trees are established (i.e. future returns from alternative land uses) and carbon prices. In addition to foregoing the current land use, a landowner making a permanent land use change such as carbon forestry is also giving up the opportunity to change management in the future, for example by changing crop mix in response to commodity price changes. We develop a Monte Carlo model to demonstrate the value of management flexibility, based on a case study property in Australia. While in the absence of management flexibility carbon forestry is more profitable than the current land use, under uncertain future commodity prices it is less attractive to a landowner. We go on to show that, even if the returns from carbon exceed those from more flexible agricultural land use, uncertainty over future carbon prices is likely to delay the adoption of carbon forestry. Overall the models presented in this paper demonstrate that the adoption of carbon forestry is likely to be substantially lower, and slower, than models based on static values would suggest.

Introduction

Reforestation has the potential to sequester significant amounts of carbon from the atmosphere, and so could play a major role in efforts to mitigate climate change. For example in Australia, carbon forestry has been estimated to have the potential to cost-effectively sequester tens or even hundreds of millions of tonnes of carbon-dioxide equivalent (CO_2-e) per year over the next few decades, depending on the modelling assumptions used (e.g. Lawson et al., 2008; Burns et al., 2009, 2011; Polglase et al., 2008, 2013; Paul et al., 2013a,b). The potential scale of tree planting for carbon sequestration has led to concerns about impacts on agricultural production and ecosystem service provision (Jackson et al., 2005; Crossman et al., 2011; Dymond et al., 2012; Bryan et al., 2014). It is therefore important to understand the likely scale of land use change towards carbon forestry.

Models of land use change typically calculate the net present value (NPV) of the expected returns from carbon forestry under various carbon price scenarios and compare this to returns from current land uses. They assume either that current returns are maintained into the future (e.g. Crossman et al., 2011) or that decision-makers have perfect foresight over future price changes (e.g. US EPA, 2005). However, decisions involving uncertainty, irreversibility and flexibility may not be adequately addressed by this conventional NPV modelling approach (Musshoff and Hirschauer, 2008).

Where carbon forestry is established on existing farmland there will be a loss of agricultural production values, which represents an opportunity cost of forestry. Returns from agriculture vary greatly over time. The prices farmers receive for agricultural commodities fluctuate, and there can also be changes in yields due to new technologies and practices or emerging pests and diseases. Farmers can respond to trends in commodity prices and yields by changing their crop mix (within the constraints imposed by crop rotation and infrastructure requirements), and this management flexibility has

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value in addition to the expected future returns from the current land use.

If carbon sequestration is to reduce the level of carbon dioxide in the atmosphere it must be permanent. This means that trees grown to sequester carbon must be retained indefinitely (unless replaced by an alternative carbon sink) even after they have stopped growing. Adopting carbon forestry therefore entails a significant loss of management flexibility for a farmer. This means that quantifying the value of the agricultural production being foregone should not simply be a case of considering the expected future returns from the current land use, as the lost management flexibility itself has value. Carbon forestry should only be adopted if the expected benefits exceed the expected costs, including the loss of future management flexibility.

If the benefits of investment are still considered to exceed the opportunity costs, a related question is when to make the investment. Reforestation can only be done once on any given piece of land. Even if carbon forestry were more profitable than the alternatives today, in the future it could be more profitable still if prices increase. There is an expectation that prices will rise in real terms (i.e. by more than the rate of inflation) in the future as caps on greenhouse gas emissions become tighter and demand for offsets increases (e.g. Australian Government, 2011). However, this is by no means certain, and regardless of any overall trend the market price will fluctuate.

It is therefore necessary to carefully consider the timing of investment. A farmer with a suitable piece of land has an opportunity to invest in carbon forestry at some point in time, which is analogous to holding a perpetual call option (Dixit, 1989). Such an option will increase in value if the returns from carbon forestry increase in the future, but it has limited downside – if the returns decrease a farmer can simply choose not to invest. Traditional NPV estimates do not consider the value of retaining an option; essentially they assume that an investment is made now or never. The real options approach can augment investment decision-making by adding 'maybe later' to the decision space. Real options valuation is relevant when there is uncertainty around future returns, (partial) irreversibility of investment and flexibility in timing (Odening et al., 2005). It shows that there can be value to delaying even if the current benefits are expected to exceed the costs (Dixit, 1992).

This method of real options valuation has been applied to a number of agricultural decision-making settings to show that uncertainty around future returns can delay the optimal timing of investment in a new technology or practice (e.g. Odening et al., 2005; Stokes et al., 2008; Tozer, 2009; Tozer and Stokes, 2009; Musshoff, 2012). This may account for the low levels of uptake of new practices which have been observed among farmers, even when such practices are profitable at current price levels (Carey and Zilberman, 2002; Richards and Green, 2003; Odening et al., 2005). Di Corato et al. (2013) demonstrate the uncertainty around the future opportunity cost (in terms of foregone agricultural production) can delay the adoption of forestry for bio-energy, unless subsidies are provided.

The aim of this paper is to go beyond static NPV calculations to consider the impact of commodity price uncertainty on the adoption of carbon forestry, including both the opportunity cost of foregone management flexibility and the future returns from carbon. This is done by developing a model parameterised around a case study property in northern Tasmania, Australia, and examining the returns from alternative decision-making strategies. Monte Carlo simulation is applied to estimate the returns from alternative land use choices and investment thresholds. Our study principally uses a mean reverting process, which provides an appropriate model for the evolution of agricultural commodity prices (Bessembinder et al., 1995; Isik, 2006).

We use the model to value retaining management flexibility in a cropping/grazing system as compared with returns from carbon forestry. It shows that, while forestry may offer higher returns than either alternative at current prices, retaining the ability to switch between cropping and grazing in response to future price changes is more valuable still. The model is extended to a series of hypothetical land uses to demonstrate how the value of management flexibility increases with the number of alternative management options, along with the volatility of prices. Monte Carlo simulation is applied to estimate the optimal carbon price at which a landowner should invest under various levels of price volatility and discount rate. The mean reverting model is compared to an alternative stochastic process (geometric Brownian motion) which is commonly applied to real options analyses.

Methods

The model

The model is based around a farm which is suitable for both sheep and dryland cropping. Gross margin data for the region (DPIW, 2008) suggest that typical costs (all prices are Australian dollars) for running a flock of sheep would be around $100/ha (net of animal purchases and sales), with a yield of around 30 kg of wool. At a price of $7/kg this would give a gross margin of $110/ha/year. A dryland crop such as barley would cost around $600/ha to grow, and could be expected to yield around 3 tonnes of grain. At a price of $250/t this would have a gross margin of $150/ha/year. Many such farms produce both sheep and grain, and would have flexibility (subject to constraints) to switch a particular parcel of land between them.

With the emergence of carbon markets, many farmers are considering carbon forestry as an alternative land use. Sequestration rates for eucalypt (*Eucalyptus nitens*) plantations are provided by a regional case study (Beadle et al., 2011). For an unharvested plantation approximately 153 tonnes of carbon would be sequestered per hectare, which is equivalent to 560 tonnes of carbon dioxide-equivalent (CO_2-e). Carbon credits were assumed to be allocated over the first 40 years post establishment based on average growth rates, which is 14 t CO_2-e/year; after year 40 no further credits were allocated. This was used to calculate the net present value (NPV) of carbon forestry over 80 years at a given carbon price ($23/t CO_2-e). Establishment costs were assumed to be $1500/ha, based on the average costs reported from the region by Beadle et al. (2011), with a higher value of $3000/ha (within the range estimated by Summers et al., 2015) also tested. NPVs were also calculated for barley and sheep production over the same 80-year time span. The discount rate was set at 7% ('real', i.e. after inflation), following Australian Government guidelines (see Harrison, 2010), with sensitivity analyses performed at 5% and 9%. Prices, yields and costs were assumed to remain unchanged in real terms.

Valuing flexibility when future crop prices are uncertain

In the absence of management flexibility, variation in commodity prices would affect the risk profiles of the alternative crops but not the NPV so long as average values are used in the model. However, if the farmer is able to switch between barley and sheep as commodity price trends emerge, then the results may be quite different. This was tested by allowing the price of each commodity to follow a stochastic path through time (yields and production costs were held constant). A mean reversion process allows the price to fluctuate from year to year while also pulling it towards some mean value. This process can represent a situation in which prices fluctuate in response to short term perturbations in supply and demand