A time to change? The supply of climate mitigation products from land-use change in northern NSW.

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Abstract:

With the impending introduction of an Australian Carbon Pollution Reduction Scheme, farmers and landholders in rural Australia have increased opportunities to participate in the market. This includes the adoption of land-use change to sequester additional carbon in exchange for carbon credits and the production of a renewable energy source (biofuels). However, these land-use changes compete with existing farm enterprises and may contain significant transaction costs. Therefore it is necessary for the institutional arrangements to provide adequate incentives for landholders to adopt these land-use changes. This paper examines the potential supply of these land-use changes for climate mitigation from landholders in a northern NSW catchment. These results will allow further investigation of how incentive structures and policy instruments may be developed to increase the supply of these goods from landholders.

Keywords: Border Rivers-Gwydir, carbon sequestration, land-use change

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1. Introduction

Greenhouse gas (GHG) concentrations in the atmosphere have risen from 280 parts-per-million (ppm) to in excess of 380ppm since the industrial revolution (Srinivasan 2008). These concentrations are predicted to continue rising at a rate of 6ppm per year (Stern 2007). While still being debated by some scientists (Plimer 2009), anthropogenic influences are considered to have contributed to this increase. There is concern that this increase in atmospheric GHG levels is causing a rise in the earth's temperature and it has been suggested, by Garnaut (2008), that a temperature rise above 2 ^{o}C could be detrimental. As such, there is currently both a national and global emphasis on the development of technologies and policies to reduce GHG emissions in the atmosphere.

One area that is being investigated is the agricultural sector. This sector has the potential to provide significant contributions to any GHG reduction policies as it is both a source and a sink of GHG emissions. Suggestion has been made that modification of current agricultural management practices is a relatively low cost method of offsetting GHG emissions (Antle *et al.* 2002). Garnaut (2008) highlighted that there are several ways in which the Australian agricultural industry may contribute. These include: (a) reduction of farm emissions; (b) increase in farm soil carbon; (c) production of bioenergy; (d) production of second-generation biofuels; (e) capture of carbon dioxide (CO_2) through wood or carbon plantations; and (f) removal of CO_2 from the atmosphere through the use of conservation forests. Currently, CO_2 accounts for the largest proportion of all the GHGs accumulated in the atmosphere. CO_2 emissions contribute 90 per cent of the annual increase in GHGs (Hansen & Sato 2004). Therefore the mitigation of increasing levels of CO_2 released into the atmosphere is highly valued.

In diverse situations, trees grown to sequester carbon have lower marginal costs than emission abatement and other mitigation techniques (Plantinga, Mauldin & Miller 1999; Stavins 1999; Kauppi & Sedjo 2001). The potential supply of carbon mitigation through land use change depends on the availability and costs of different technologies and resource endowments, which are partly determined by location. Landholders' opportunity costs for converting their properties to carbon mitigation land uses can be aggregated to provide a marginal abatement cost curve for the potential supply of carbon mitigation (Antle & Valdivia 2006). The economic returns, and hence the opportunity costs, vary significantly between different agricultural land use types and also spatially within the same land use type (Antle *et al.* 2003; Antle & Valdivia 2006; Bryan *et al.* 2009). This heterogeneity leads to a convex supply function and is a vital component to consider when designing environmental polices.

In addition, to operate in a carbon market, these land use services must be certified by an independent authority before they can be sold. This may involve substantial transaction costs (Woerdman 2001; Fitchner, Graehl & Rentz 2003; Cacho, Marshall & Milne 2005; Cacho & Lipper 2007). The addition of transaction costs shifts the supply curve up and to the left, reducing the size of the market and increasing the price required to achieve a given level of mitigation. Whilst these transaction costs are known to cause shifts to the supply curves, there appears to be a paucity of quantitative analyses of transaction costs.

To evaluate the feasibility of landholders' participation in carbon markets, both abatement and transaction costs must be considered (Cacho, Marshall & Milne 2005). Cacho, Hean and Karanja (2008) found, in their review of carbon sequestration from land use changes, that there was strong evidence for land-use systems to significantly contribute to climate mitigation efforts. They did, however, note that it will be necessary for landholders to receive incentives to encourage these changes in land use. Scientific, institutional and economic factors influence these incentives.

The aims of this paper are to investigate the potential supply of carbon sequestration in the Border Rivers-Gwydir Catchment region. The data, model and assumptions used to simulate these land-use changes are described in Section 2. The results are presented and discussed in Sections 3 and 4. Potential for further research, along with concluding comments, are presented in Section 5.

2. Data, assumptions and method

This study examines the potential supply of carbon mitigation services from land use change in the Border Rivers-Gwydir catchment in northern NSW (see Figure 1). This catchment covers an area of approximately 5,000,000ha. Average annual rainfall ranges between 600mm to 1,200mm (Australian Bureau of Meterology 2010). The principal agricultural enterprises across the region are grazing and cropping.

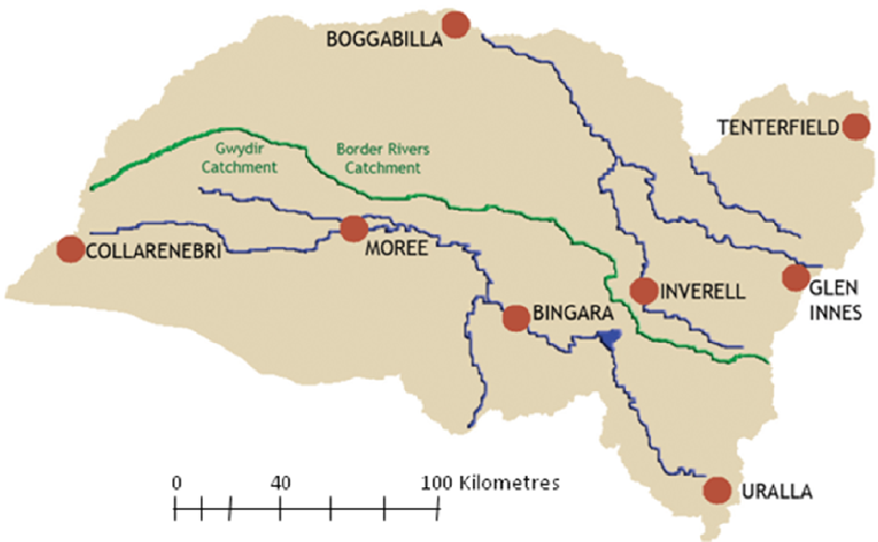

Figure 1: Border Rivers-Gwydir Catchment. Source: NSW Government (2009).

This analysis involves a modified application of the model developed in Cacho *et al*. (2008). The model simulates the abatement cost, in terms of dollars per tonne of carbon sequestered, over a range of proposed land use changes. Six current land uses of the region were analysed, including: conventionally tilled sorghum, conventionally tilled wheat, cattle on improved pastures, sheep on improved pastures, cattle on native pasture and sheep on native pasture. From these 6 current land uses, a further 6 land use change systems were proposed. These include the establishment of: mixed species environmental plantings, *Eucalyptus cladocalyx* plantations, *E. globulous* plantations, *Pinus radiata* plantations, no-till sorghum crops and no-till wheat crops.

For this study we examine the supply of carbon sequestration and abatement costs from 500 landholders across the region. In this hypothetical simulation, it was assumed that landholders would only undertake a proposed land use change on a proportion of their properties. This was assumed to be between 100 and 5,000 hectares. A landholder's current land use was based on the proportion of landholders in the region currently undertaking each given current land use analysed.

For a given year, the carbon eligible for receipt of a credit payment is only equivalent to the quantity of carbon above what would be achieved with the baseline activity. That is, only carbon levels above the land use type that would otherwise be undertaken are eligible. Using the equation employed by Cacho *et al*. (2008), for a given year, we determine the eligible carbon (C_t) as:

$$C_t = C_{p,t} - C_{C,t} \tag{1}$$

where $C_{P,t}$ and $C_{C,t}$ are the expected carbon quantities of the proposed land use and the current land use in year t, respectively. Carbon sequestration levels across the region were estimated using the FullCAM model which has been calibrated for regions and land use types around Australia (Paul & Polglase 2004; Paul *et al.* 2008).

Landholder abatement costs are the cost of producing one unit of (uncertified) carbon-sequestration (Cacho *et al.* 2008). These costs can be estimated as the opportunity cost of undertaking the carbon-sequestration activity rather than the most profitable alternative activity. This is shown in Equation 2.

$$v_{Aj} = a_j \sum_t \left(r_{0t} - r_{jt}\right)(1 + \delta_s)^{-t} \tag{2}$$

where for the j^{th} landholder, v_{Aj}, is the abatement cost, a_j is the total area of the land use change, r_{0t} and r_{jt} represent the net revenues per hectare, in year t, for the baseline and proposed land use change respectively and δ_S is the landholder's discount rate. Data for determining the abatement costs were derived from a variety of secondary sources (Australian Bureau of Statistics 2008; Polglase *et al.* 2008; ABARE 2009; NSW Department of Industry and Investment 2009).

In order to derive supply curves for the region, based on those undertaken by Cacho *et al*. (2008: 56), the following steps were undertaken:

1. Values were assigned to the driving variables: total number of farms (n), the net present values (NPV) of both the current land uses and the proposed land uses. A mean was obtained, however due to limited data, no variance statistics were available. As such, variance between landholders NPV was introduced through the inclusion of a coefficient of variation of the mean. Four simulations were undertaken using coefficients of variation of 0.2, 0.4, 0.6 and 0.8 to test the sensitivity of their use.
2. Lognormal distributions of the carbon sequestration for each of the current and proposed land use changes were derived from FullCAM simulations of the respective land uses across the region. A set of n random numbers were drawn and applied to these distributions. This resulted in a set of carbon-potential values for the farm population.
3. A set of n random numbers was drawn and applied to the land use size distribution (uniform distribution between 100 and 5,000 hectares) to determine the size of the individual farm land use change.
4. A set of n random numbers were drawn from a normal distribution for the NPVs defined in step 1. This resulted in a set of NPVs for the individual farms.
5. For each element in the sets created in steps 2, 3 and 4, the minimum positive opportunity cost land use (v_A) for each landholder was calculated, based on their current land use activity. The selection of only land use changes with positive opportunity costs is undertaken to comply with the additionality rule, which states that only proposed land-use changes that wouldn't otherwise be undertaken, i.e. they provide a positive financial

benefit, even in the absence of carbon credit incentives should not be funded (Cacho *et al.* 2008).

6. The set of v_A values were sorted in ascending order, along with the quantity of carbon sequestered from the corresponding farm. These carbon quantities were cumulated and plotted against their corresponding cost to provide supply curves.

As noted by Cacho *et al.* (2008), this procedure does not allow for any stochastic dependency between the size of the land use change, the carbon sequestration potential and the NPV of the proposed land use changes because the random numbers in steps 2, 3 and 4 are drawn independently of each other. This assumption could influence the shape of the supply curves and will be investigated in further studies.

3. Carbon sequestration projections

Carbon stocks over time, for each of the 6 land use changes, under the 6 current land use systems, were simulated across the region. This allowed for the quantification of carbon sequestered from the given land use changes. The changes in carbon biomass above the baseline activities, for each of the proposed land use changes, in terms of regional average, are shown in Figure 2. Noticeably there is a substantial variance in the quantity of carbon sequestered both temporally and between the different land uses.

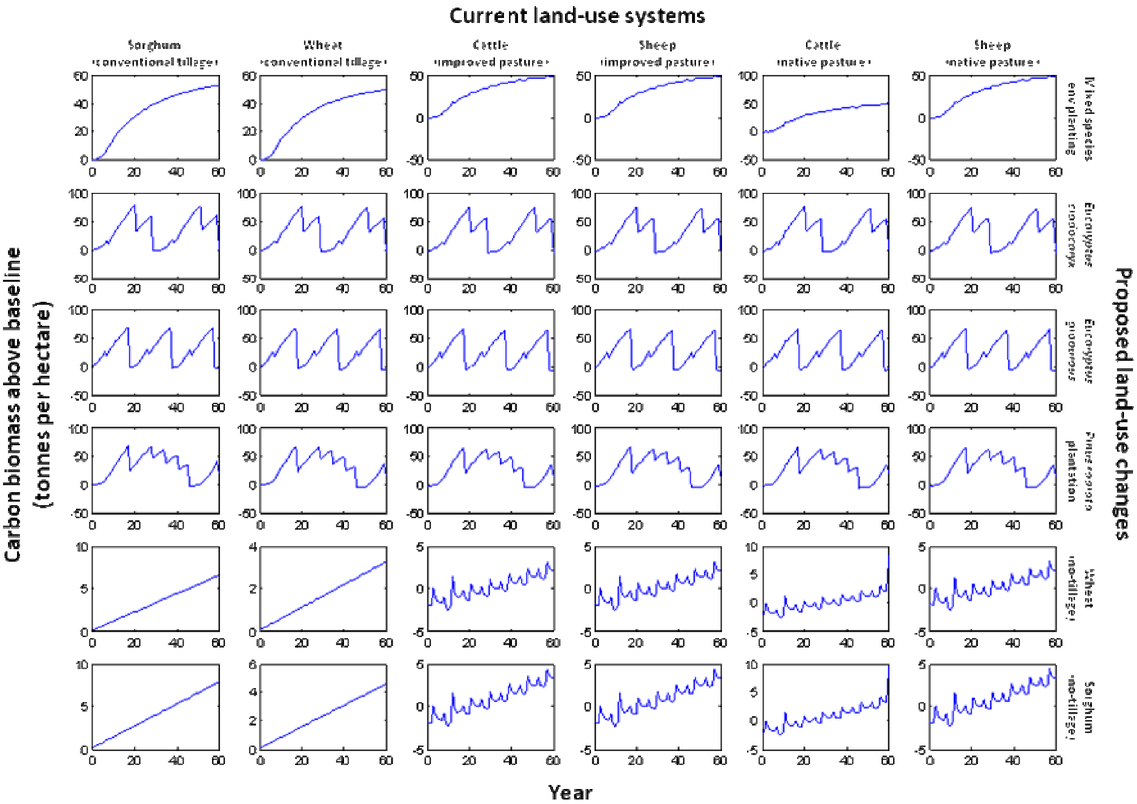

Figure 2: Carbon-sequestration trajectories for the proposed land-use changes.

The average carbon biomass was calculated to be largest for the *Pinus radiata* plantations, with an average carbon biomass of 38.5 tonnes carbon per hectare over the 60 year simulation period. In contrast, the conversion to a no-till wheat management strategy resulted in lowest average carbon biomass, with only 4.3 tonnes carbon per hectare over the 60 year simulation period.

4. Supply of carbon abatement products

The opportunity cost of changing to one of the proposed land use changes depends on the current land use. In this study, we found that the average opportunity cost of the proposed land use changes varies between -$631 and $1,821 per tonne of carbon sequestered, when a 7% discount rate was applied over a 60 year period (Table 1). These results show that, even in the absence of transaction costs, the costs of sequestering carbon from land use change in the region can be relatively large. Conversion of conventionally-tilled wheat to no-till wheat has the highest opportunity cost per tonne of carbon sequestered. This occurs due to the relatively slow accumulation of additional carbon through the adoption of this land use change.

Table 1: Average opportunity cost of LUC per tonne carbon sequestered (60 yr discounted value [0.07 discount rate]).

Current Land Use	Sorghum	Wheat	Improved Pasture		Native Pasture	
Proposed Land Use	(conv. till)	(conv. till)	Cattle	Sheep	Cattle	Sheep
Mixed spp. env. planting	59	180	112	106	48	46
Eucalyptus cladocalyx	15	109	49	49	-1	-3
Eucalyptus globulus	-3	101	39	43	-22	-23
Pinus radiata	52	154	91	93	40	42
Wheat (no-till)	-631	1,149				
Sorghum (no-till)	43	1,821				

Land use changes that incur a negative opportunity cost are assumed to not be considered for carbon credit payments. This is because they are considered beneficial to the landholder, even in the absence of a carbon incentive payment, and as such would not meet the additionality requirement on financial grounds (Cacho *et al.* 2008). Therefore, in the calculation of the minimum cost strategy for each landholder, a constraint was added to allow only those land-use changes with a positive opportunity cost to be considered.

Across the different land use systems simulated, no single proposed land use change provided the minimum cost strategy across the pool of landholders. Table 2 displays this variance between the minimum cost strategies for the different landholders and the different current land use systems. This suggests that any policy to sequester carbon from land use change across a region may include a range of different land uses as part of an optimal solution.

Table 2: Proportion of landholders undertaking the current land use where the proposed LUC is the minimum cost strategy.

Current Land Use / Proposed Land Use	Sorghum (conv. till)	Wheat (conv. till)	Improved Pasture		Native Pasture	
			Cattle	Sheep	Cattle	Sheep
Mixed spp. env. planting	16.3%	26.5%	14.4%	27.8%	46.7%	30.2%
Eucalyptus cladocalyx	55.8%	39.7%	44.0%	30.6%	52.5%	68.9%
Eucalyptus globulus	20.9%	19.1%	38.4%	33.3%	0.8%	0.9%
Pinus radiata	4.7%	11.8%	3.2%	8.3%	0.0%	0.0%
Wheat (no-till)	2.3%	2.9%				
Sorghum (no-till)	0.0%	0.0%				

The supply curves derived from the procedure outlined in Section 2 are shown in Figure 3. These curves imply increasing marginal cost of carbon sequestration. Properties on these curves will allow the calculation of the incentives required to encourage landholders to participate in a carbon market. We do, however, point out that transaction costs are not included in the calculation of these cost curves. Cacho, Marshall and Milne (2005) suggest that transaction costs incurred through landholder participation in a carbon market may be significant. Therefore, these supply curves may substantially alter, in both their size and shape, once the full transaction costs are accounted for. The impact of the use of different coefficients of variations when determining the variance between individual landholder's abatement costs is also displayed in this figure.

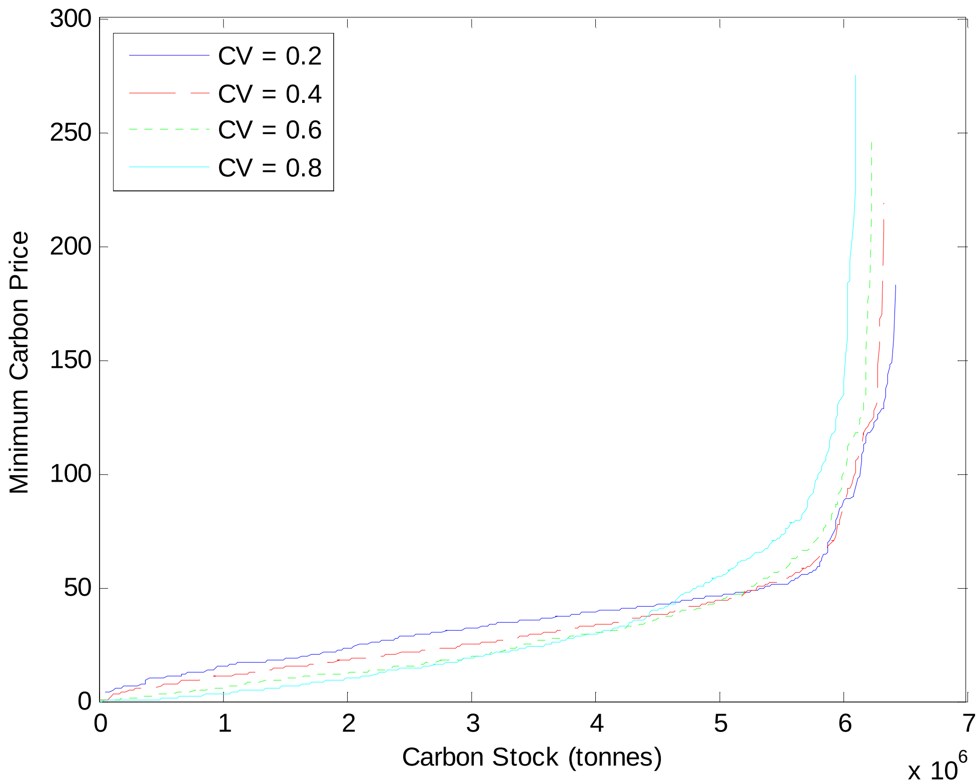

Figure 3: Estimated carbon supply from LUC in the Border-Rivers Gwydir region.

In this study, we adopted a 7% discount rate. This is in keeping with the discount rate of 6.9% used by Polglase *et al*. (2008). We also conducted sensitivity analyses on the discount rate, exploring the impact of using both a 3% and 10% discount rate (Tables 3 and 4 respectively). These analyses demonstrated that the abatement costs are sensitive to the choice of discount rate. This highlights the importance in the choice of an appropriate discount rate.

Table 3: Opportunity Cost of LUC per tonne carbon sequestered (60 yr discounted value [0.03 discount rate]).

Current Land Use / Proposed Land Use	Sorghum (conv. till)	Wheat (conv. till)	Improved Pasture		Native Pasture	
			Cattle	Sheep	Cattle	Sheep
Mixed spp. env. planting	95	309	184	191	64	65
Eucalyptus cladocalyx	-139	37	-70	-71	-182	-175
Eucalyptus globulus	-132	68	-58	-51	-176	-174
Pinus radiata	-16	166	51	59	-48	-49
Wheat (no-till)	-1,261	2,210				
Sorghum (no-till)	84	3,468				

Table 4: Opportunity Cost of LUC per tonne carbon sequestered (60 yr discounted value [0.10 discount rate]).

Current Land Use / Proposed Land Use	Sorghum (conv. till)	Wheat (conv. till)	Improved Pasture		Native Pasture	
			Cattle	Sheep	Cattle	Sheep
Mixed spp. env. planting	56	129	86	87	44	42
Eucalyptus cladocalyx	43	117	69	74	36	34
Eucalyptus globulus	27	106	64	67	16	14
Pinus radiata	68	128	89	97	56	55
Wheat (no-till)	-455	850				
Sorghum (no-till)	32	1,373				

5. Conclusions and future work

Currently these preliminary results do not include an allowance for transaction costs. Polglase *et al*. (2008) provided an analysis of the potential to use forestry and carbon plantations on farms in Australia. However, they failed to include a full account for transaction costs and instead applied a single allowance of $10 per hectare up-front for legal transactions and $40 annually for carbon monitoring (in 2006 AUD). Their model did not allow these costs to vary across the different farms or regions of Australia. Transaction costs can vary significantly across different farms, regions, land use changes and policies (Boyd & Simpson 1999; UNDP 2006).

Considering Fitchner, Graehl and Rentz (2003) found that transaction costs varied between 7 to more than 100 per cent of the production costs of carbon sequestration they reviewed, this simplifying assumption may provide misleading results and contribute to ineffective policy design. Likewise, Flugge and Abadi (2006) in their analysis of the potential for Western Australian farmers to plant trees for carbon sequestration limited their inclusion of transaction costs to a one-off upfront cost of $5,000 (in 2006 AUD) irrespective of the project size. Future work will include a quantitative analysis of the transaction costs incurred through the participation in carbon markets based on the typology of Cacho, Marshall and Milne (2005). Variance in these costs, between different policies, landholders and regions will also be estimated.

There is a plethora of literature which investigates the economically optimal strategy for a given land use change, in a given area (such as Spring, Kennedy & Mac Nally 2005; Pohjola & Valsta 2007; Daigneault, Miranda & Sohngen 2010). The majority of these papers utilise bioeconomic optimisation models to determine the strategy which maximises the profitability of the given land use, with respect to carbon sequestration. Whilst providing useful information, these studies only investigate the optimal strategy for a given land use change and may be ignoring other lower cost land use change strategies. McCarl, Schneider and Murray (2001) suggested that solely relying on an individual strategy, such as policies to increase agricultural soil carbon, is inefficient and that consideration of the entire portfolio of possible solutions leads to a lower cost. The preliminary analysis conducted in this study has shown the potential variance in abatement costs, both between landholders and land-use types. Also, it has shown how several different land use changes may form part of the optimal solution over a given region. Further quantitative analyses on the transaction costs will allow the impact of these costs on the potential supply to be assessed.

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