

Permanence Discounting for Land-Based Carbon Sequestration

By

Man-Keun Kim

Post Doctoral Fellow

Joint Global Change Research Institute

University of Maryland

College Park, MD 20740

man-keun.kim@pnl.gov

Bruce A. McCarl

Regent Professor

Department of Agricultural Economics

Texas A&M University

College Station, TX 77843-2124

mccarl@tamu.edu

And

Brian C. Murray

Director

Center for Regulatory Economics and Policy Research

RTI International

Research Triangle Park, NC 27709

bcm@rti.org

Permanence Discounting for Land-Based Carbon Sequestration

1. Introduction

Land-based soil carbon sequestration has been widely suggested as a potentially cost-competitive means for reducing net greenhouse gas (GHG) emissions as well as a way to increase opportunities for farmers and foresters (Dixon *et al.*, 1993; Sampson and Sedjo, 1997; Marland and Schlamadinger, 1999). Additionally, practices for sequestering carbon in soil or forests have other agricultural and environmental benefits (co-benefits) for example increasing biodiversity or decreasing soil erosion (Lal *et al.*, 1998; Antle and Diagana, 2003). Various studies have explored the potential of land-based carbon sequestration strategies in the US such as afforestation, reforestation and other land use changes (Adams *et al.*, 1993; McCarl and Schneider, 2001; Parks and Hardie, 1995; Plantinga *et al.*, 1999; Stavins, 1999). These studies not only show that considerable potential for sequestration exists but also that the strategy might be a low cost one.

One major concern regarding sequestration that has been widely discussed in the international debate over potential GHG abatement policy (See Intergovernmental Panel on Climate Change, 2001 for discussion and references) involves the issue of permanence. Permanence encompasses several fundamental issues related to the time dynamics of sequestration options:

- (i) Differential rates of accumulation over time and a long run decline to a near zero rate of net sequestration. In particular, carbon will be accumulated only until the ecosystem becomes effectively saturated in a given land management system (often called *saturation*). This has been called an “attainable maximum” or the equilibrium stock of carbon under a given management practice (Ingram and Fernandes, 2001).

- (ii) The possibility that carbon will remain sequestered over the long term.

Generally, sequestered carbon can be rapidly released back to the atmosphere if the carbon sequestering practice is discontinued or when certain random events occur like a forest fire (commonly called *volatility*).

- (iii) Contract terms that either only require generation of sequestration **offset** for a limited time period (i.e., “leasing” carbon for 20 years then having no continuing obligation) or incorporate costs that are not a function of carbon uptake (a maintenance costs to maintain the practice beyond the saturation point.

These permanence issues arise somewhat uniquely under the sequestration case.

A number of alternative strategies are not subject to such concerns. For example, methane capture and combustion in subsequent energy production permanently avoids a methane emission. In such a case, the mitigated GHG is not volatile, nor are there saturation or leasing concerns.

The question addressed in this paper is whether the permanence concerns associated with sequestration may alter the value of the resultant carbon offsets in the market place. Namely, from an offset purchaser’s point of a view, a ton of carbon emission offset created through a impermanent sequestration asset may be worth a different amount than one created though other means -- the offsets are not fungible.

The potential for differential values of commodities with heterogeneous characteristics is an important consideration in many markets. Commonly, grading standards have commonly evolved to differentiate among heterogeneous products as discussed in Tomek and Robinson (2003) (e.g., gasoline grades exhibit differential prices by octane level or corn grades exhibit different prices and are defined in terms of

moisture and broken kernel content etc.). Grading standards are generally defined based on consumers' preferences. In turn, the market reflects the different prices that consumers are willing to pay for commodity units of different qualities. In the context of a carbon market, the purchaser's willingness to pay may be determined, in part, by rules established by the market's governing entity to ensure that impermanence risks are properly remedied. In other words, carbon credits may need to be discounted relative to permanent emissions reductions to meet the rules of the market.

In this paper, we develop a grading standard type discount based on a theoretical comparison of an impermanent characteristics versus a permanent offset then we we illustrate the empirical magnitude of that discount under range of conditions.

2. Sequestration Contract Characteristics

Purchasers of GHG offsets are likely to have to assert that their activities have caused GHGs to be not emitted to or removed from the atmosphere in the current and all subsequent years or for some longer term future (a commitment period). Permanence considerations may complicate this for sequestration activities. Namely if

- a lease runs out before the end of the commitment period,
- an unplanned event occurred causing release of sequestered carbon
- the producer discontinues the practice causing release

then the offset purchaser paying for carbon sequestered could be responsible for making up the shortfall or would face a noncompliance penalty (Marland, Fruit and Sedjo, 2001). In such cases, the offset purchaser would likely be required to buy the same amount of offset from other sources. Alternatively, the offset purchaser can offer incentives (a

maintenance cost) to insure the sequestered carbon is maintained beyond the point that the seller might otherwise maintain it.

3. Analytical Development of a Permanence Discount

The reason prices might differ between two alternative goods is that the purchaser's use value of the alternatives may differ, due to difference in characteristics. In economics, this is referred to as the *hedonic* characteristics of differentiated goods. In turn the price difference between the goods would be the amount that the purchaser determines makes the use value the same for the two alternatives.

We will use an approach based on equalizing use values to derive a price discount. Suppose the offset purchaser faces two alternatives. One has impermanence characteristics including possibilities for saturation, volatility and leasing terms while the other does not and is herein called perfect. Assume that the offset purchaser would be willing to pay the same effective price ton of offset that could be claimed.

3.1 Perfect Prospect

We define a perfect prospect from the standpoint of permanence as one involving (i) a permanent offset that does not exhibit volatility, (ii) zero transaction costs (i.e., costs other than the direct cost of acquiring the offset). Given current and future carbon prices P_t then the total cost for an offset at time t would be $TC_t^p = P_t \cdot Q_t$. The superscript, p , refers to the perfectly permanent offset prospect.

The current cost of an offset (TC_{Today}) can be developed using the (net) present value concept as $TC_{Today}^p = \sum_{t=0}^T P_t \cdot Q_t \cdot (1+r)^{-t}$, where T is the duration of the contract or the total length of the time period being considered, and r is the annual interest (discount) rate.

To get a cost per ton we need an amount expressed in current tons by which we can divide total cost. To do this we use the Richards (1997) concept of discounted carbon that argues a ton next year equals a ton today discounted by the interest rate.

Applying this the current equivalent quantity offset today is $Q_{Today}^p = \sum_{t=0}^T Q_t \cdot (1+r)^{-t}$.

Under these circumstances, the effective price (PE) today paid for a future stream of offsets is the present value of cost divided by the present value of the offset quantity

$$(1) \quad PE = \frac{TC_{Today}^p}{Q_{Today}^p} = \frac{\sum_{t=0}^T P_t \cdot Q_t \cdot (1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}.$$

A critical element of equation (1) is the carbon price and its path. If we assume that the carbon price is constant over time ($P_t = P_0$)¹, then PE in equation (1) simply equals P_0 . If we assume that the carbon price is increasing at the interest rate over time

($P_t = P_0 \cdot (1+r)^t$), the PE in equation (1) equals $\frac{P_0 \cdot \sum_{t=0}^T Q_t}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}$.

¹ which implicitly assumes constant marginal damages from increasing emissions of GHG. However, in a pure market setting, this assumption will not generally be the case, rather the market will set the price at the point where the buyer's marginal willingness to pay equals supplier's marginal cost. The buyer's willingness to pay will generally be a function of the value of the costs they can avoid by purchasing the offset rather than the value of the environment of avoided damages.

3.2 Impermanent Prospect

Now suppose we consider a generalized imperfect prospect that exhibits impermanence related characteristics. Suppose these manifest themselves in some mixture of

- the contract for a sequestration project is for a fixed time less than the total purchaser's commitment time and that at the end of the contract the purchaser has to go into the market place and buy new offsets to cover those held through the then expired lease defined as a "buyback" of credits in year t , or B_t .
- there may be costs incurred that are not related to the amount of carbon sequestered that we will call a *maintenance cost*, M_t that are part of the contract scheme to compensate for efforts to maintain sequestered carbon perhaps past the time when effective saturation in the land use practice is attained (i.e. a payment to maintain reduced tillage after the period when carbon has ceased accumulating). Note that the maintenance costs are fixed amounts under the contract that are incurred even if no current carbon increments are being sequestered and thus they are unrelated to the amount of carbon sequestered.
- The quantity of carbon sequestered varies over time.

Under such circumstances the total cost at time t under the impermanent prospect would be $TC_t^s = P_t \cdot Q_t + P_t \cdot B_t + M_t$, where the superscript, s , indicates the impermanent sequestration prospect. Note that we assume for simplicity that the perfect prospect sequesters the same amount of carbon in each year as does the imperfect prospect, thus (so that Q_t here is the same Q_t as in equation (1)). In turn, today's effective cost per ton

(PE^s) of an offset (TC_{Today}) can be developed again using the (net) present value concepts as follows:

$$(2) \quad PE^s = \frac{TC_{Today}^s}{Q_{Today}^s} = \frac{\sum_{t=0}^T (P_t \cdot Q_t + P_t \cdot B_t + M_t)(1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}.$$

3.3 Permanence Discount

Given the above two formulae for the current effective cost per ton under the perfect and impermanent prospects we may now define a permanence discount that equates the current cost per ton. Namely suppose a purchaser equates the current cost per ton from each prospect by introducing a permanence discount ($PDisc$) that reduces the effective carbon price paid for the impermanent sequestered carbon relative to the price paid for a perfect offset. A rewrite of the above equation (2) introducing this is

$$(3) \quad PE^s = \frac{TC_{Today}^s}{Q_{Today}^s} = \frac{\sum_{t=0}^T (P_t \cdot (1 - PDisc) \cdot Q_t + P_t \cdot B_t + M_t)(1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}},$$

> Here note $PDisc$ is applied to the price paid per ton but not to the buyback as we assume that replacement has to be paid at the prevailing "perfect" market price.

3.3.1 Discount under constant carbon prices

Now we can derive the permanence discount by equating equations (1) and (3). Initially we will also assume that carbon price is constant over time.

$$(4) \quad P_0 = \frac{\sum_{t=0}^T (P_0 \cdot (1 - PDisc) \cdot Q_t + P_0 \cdot B_t + M_t)(1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}.$$

Dividing through by P_0 and then solving for $PDisc$, we get:

$$(5) \quad PDisc = \frac{\sum_{t=0}^T (B_t + M_t / P_0)(1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}.$$

Equation (5) shows that the permanence discount is a function of the buyback term and the extent of the maintenance cost relative to the carbon price divided by the present value of the quantity of offsets. Consideration of the terms in this formula leads to the following conclusions:

- (i) A permanence discount will only exist when a buyback, and or a maintenance are present.
- (ii) The rate of accumulation by itself causes no discount although it does determine the size of the discount.
- (iii) If a carbon sequestration project (such as no-till agriculture) is profitable, such that land owners would continue this management system after the carbon reaches saturation without any payment or incentive then no discount for maintenance cost is needed. However if they can resell the carbon and the buyer loses rights then a discount would be in order.

3.3.2 *Increasing Carbon Price over Time*

A critical element of equation (3) is the carbon price path. The value of $PDisc$ can be significantly affected by the carbon price path. As discussed in Herzog, Caldeira and Reilly (2003), an increasing carbon price reflects a view that the additional carbon holding capacity of the atmosphere is a fixed resource that should be allocated over time. We

assume that the carbon price increases at the interest rate over time. By equating equations (1) and (3);

$$(6) \frac{P_0 \cdot \sum_{t=0}^T Q_t}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}} = \frac{\sum_{t=0}^T (P_0 \cdot (1+r)^t \cdot (1-PDisc) \cdot Q_t + P_0 \cdot (1+r)^t \cdot B_t + M_t)(1+r)^{-t}}{\sum_{t=0}^T Q_t \cdot (1+r)^{-t}}.$$

Dividing through by P_0 and then solving for $PDisc$, we get:

$$(7) \quad PDisc = \frac{\sum_{t=0}^T (B_t \cdot (1+r)^t + M_t / P_0)(1+r)^{-t}}{\sum_{t=0}^T Q_t}.$$

Equation (7) is slightly different from equation (5) but yields the same basic conclusions.

4. How big is the discount: Case applications

Now suppose we illustrate the magnitude of our permanence discounts under some hypothetical alternatives ased on empirical data for potential forest and agricultural projects.

4.1 Agricultural soil carbon sequestration project cases

Suppose a project involves conversion from conventional tillage to zero tillage (“no till”). The data for a hypothetical project in this class will be based on the average soil carbon accumulation pattern given in West *et al.* (2004), which is based on an average across more than 250 field observations of changes in soil carbon. In those data the carbon accumulation occurs over 25-year period, with maximum sequestration rates occurring between 5 and 10 years. Carbon accumulation then stops in year 25. We will set up project duration to be 100 years. We assume that the initial carbon price, P_0 , is \$30/ton, and the annual interest rate is 4%.

Case 1 -- Perfect sequestration

Suppose the no till system is more profitable than conventional till at the end of the 25 years of accumulation so the farmer does not revert once the carbon payments cease. In such a case, the practice continues on indefinitely without the need for either maintenance or buyback permanence considerations. The permanence discount is zero under both constant and increasing carbon price assumption and this implies that soil carbon sequestration is equivalent to the perfectly permanent offset.

Case 2 -- Maintenance costs needed

Suppose that after the carbon accumulation ceases and the contract specifies a maintenance cost that is 16.67% of the carbon price starting in year 25 that is needed to maintain use of the tillage practice (\$5 per acre in this case) which is in the neighborhood of Kurklova et al's conclusion that we would need \$3 per acre above and beyond the profitability difference between the two systems. Under a constant carbon price, the permanence discount is 36.3%. In other words, the price paid for sequestered soil carbon that equates effective cost per ton is 63.7% of that paid for a perfect emission offset so a purchaser would pay the creator of such an impermanent offset only about 2/3 of the amount that they would pay for a perfect permanent offset. Under an increasing carbon price, the permanence discount is found to be 27.8% and thus they would pay 72.2% of the price paid for a perfect prospect.

Case 3 -- Buyback needed

Suppose that lease terms are established. In year 25 the lease expires and in year 26, the purchaser must replace 100% of the offsets attained over the entire project at the market price. In this case, the permanence discount is 49.1% under a constant carbon price. This implies the amount paid for the non-permanent sequestration generated offset quantity would be 50.9% of the amount paid for the perfectly permanent offset. Under

the increasing carbon price, the permanence discount will be 100% because we need to buy back all the carbon sequestered. In other words, soil carbon sequestration has no use value in this case.

4.2 Afforestation

Now consider a forest-based offset. Such a case adds additional considerations because there is a need to include possible timing of forest harvest, future carbon fate of harvested products and whether reforestation occurs after harvest. The time to saturation and post harvest carbon profiles are based on data from Birdsey (1996). Again, we assume that the initial carbon price, P_0 , is \$30/ton, and the annual interest rate is 4%. In the case of afforestation, there are six cases. More explanations for each case can be found in Kim (2004).

Case 1 -- No Harvest -- Forest Preserve

Suppose the forest is never harvested and is kept forever so that there is no possibility for volatility. However, maintenance cost (assumed to be 16.67% of the carbon price) is required to maintain forests after the carbon quantities cease to accumulate (exhibiting saturation) beginning at year 85. Under a constant carbon price, the permanence discount for this case is found to be 0.2%. Thus carbon in such a preserve would be paid a price equal to 99.8% of that paid for a perfect offset. Under an increasing carbon price, the permanence discount is found to be 0.07% or that carbon would be paid for 99.93% of that for a perfect offset.

Case 2 -- Harvest year 85 -- Carbon buyback required

Suppose the forest is harvested in year 85 but is not reforested so that a buyback is needed in year 85 of all the project carbon at the market price. In this case, the permanence discount is 9.8% under a constant carbon price and 100% under an increasing carbon price and this project has no use value.

Case 3 -- Harvest year 20 without reforestation -- Carbon buyback required

Suppose shorter rotation forestry is employed with the forest primarily managed for pulpwood and harvested at year 20. Subsequently reforestation is not done so the offset purchaser must buyback all the carbon in year 21. In this case, under a constant carbon price the permanence discount is 71.5% while under an increasing carbon price the permanence discount would be 100%.

Case 4 -- Harvest year 20 with reforestation -- Some carbon buyback required

This case depicts short rotation forestry with harvest followed by reforestation. In this case, we need to buy back the carbon lost at harvest time but accumulation begins again. Note that about 10% of stored carbon would be released to the atmosphere right after deforestation (See Figure 4 and 5 in West et al. (2004)) (- BCM pointed out this number is too low. MK COMMENT: need to talk to anyone who knows this number. I just use number from Figure 4 in West et al which indicates that percentage carbon loss right after deforestation brian should we change this to 50%). In this calculation, buyback is assumed to be 10% of total stored carbon. In this case, the constant price permanence discount is 7.2% and the increasing carbon price one is 10.0%. Note that the permanence discount is not 100% in this case because we do not need to buy back all the carbon sequestered.

Case 5 -- Harvest year 50 without reforestation -- Carbon buyback required

Now suppose we consider longer rotation forestry where stands are primarily managed for sawtimber and are harvested at year 50 without reforestation. Again the offset purchaser must buy the carbon back from the market place but gets credit for the carbon retained in products. The permanence discount is 30.7% under the constant carbon price while the permanence discount is 100% under the constant carbon price.

Harvest year 50 with reforestation -- Some carbon buyback required

This is the above longer rotation forestry case but with reforestation after harvest. At harvest time, the offset purchaser needs to buy back the carbon lost at harvest time. Again, this is assumed to be about 10% of total stored carbon. The constant price permanence discount is 3.2% and the increasing price one is 10.1%.

5. Concluding comments

Land-based carbon sequestration can have different characteristics from other greenhouse gas offsets in terms of saturation, volatility, maintenance costs and limited term leases. We investigate the differential value of offsets in the face of such characteristics by forming a price discount that equalizes the effective price per ton between a "perfect offset" and one possessing impermanent characteristics. The resultant discount is critically the need to acquire future carbon under contract expiration or practice reversal, the maintenance cost that may need to be paid beyond the time of effective increases in sequestration in order to maintain practices. In particular, a permanence discount only exists if there is a quantity that must be bought back or a maintenance cost is paid. Empirically, the permanence discount was found to be potentially large with amounts between 0 and 50% computed depending under constant real carbon prices. In case of buybacks (lease contract), the permanence discount rises to 100% when prices increase at the Hotelling rate equal to the interest rate meaning impermanent sequestration has no value. This suggests that permanence effects must be accounted for, rather than ignored, in setting up trading terms for offsets created by land-based carbon sequestration projects.

References

- Adams, R., D. Adams, J. Callaway, C. Chang, and B. McCarl. "Sequestering Carbon on Agricultural Land: Social Cost and Impacts on Timber Markets." *Contemporary Policy Issues* 11(1993):76-87.
- Antle, J.M., and B. Diagana. "Creating Incentives for the Adoption of Sustainable Agricultural Practices in Developing Countries: The Role of Soil Carbon Sequestration." *American Journal of Agricultural Economics* 85(2003):1178-1184.
- Dixon, R.K., K.J. Andrasko, F.G. Sussman, M.A. Lavinson, M.C. Trexler, and T.S. Vinson. "Forest Sector Carbon Offset Projects: Near-Term Opportunities to Mitigate Greenhouse Gas Emissions." *Water, Air and Soil Pollution* 70(1993):561-577.
- Herzog, H., K. Caldeira and J. Reilly. "An Issue of Permanence: Assessing the Effectiveness of Temporary Carbon Storage." *Climatic Change* 59(2003):293-310.
- Ingram, J.S.I., and E.C.M. Fernandes. "Managing Carbon Sequestration in Soils: Concepts and Terminology." *Agricultural, Ecosystems and Environment* 87 (2001):111-117.
- Intergovernment Panel on Climate Change, *Third Assessment Report – Climate Change 2001: The Scientific Basis*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, 2001.
- Kim, M. "Economic Investigation of Discount Factors for Agricultural Greenhouse Gas Emission Offsets." PhD Dissertation, Department of Agricultural Economics, Texas A&M University, College Station, TX, 2004.

- Lal, R., L.M. Kimble, R.F. Follett, and C.V. Cole. *The Potential of US Cropland to Sequester C and Mitigate the Greenhouse Effect*. Ann Arbor Press, Chelsea, MI, 1998.
- Marland, G., K. Fruit, and R. Sedjo. "Accounting for Sequestered Carbon: The Question of Permanence." *Environmental Science and Policy* 4(2001):259-268.
- Marland, G., and B. Schlamadinger. "The Kyoto Protocol Could Make a Difference for the Optimal Forest-Based CO₂ Mitigation Strategy: Some Results from GORCAM." *Environmental Science and Policy* 2(1999):111-124.
- McCarl, B.A., and M. Kim. "Can You Sell All That You Measure?" Presented at Carbon Measurement and Monitoring Forum, Manhattan, KS, October 2003. Available at http://www.oznet.ksu.edu/ctec/Fall%20Forum%20pdf%20files/Friday/Bruce_McCarl.pdf
- McCarl, B.A. and U.A. Schneider. "The Cost of Greenhouse Gas Mitigation in US Agriculture and Forestry." *Science* 294(2001):2481-2482.
- Parks, P.J. and I.W. Hardie. "Least-Cost Forest Carbon Reserves: Cost-Effective Subsidies to Convert Marginal Agricultural Land to Forests." *Land Economics* 71(1995):122-136.
- Plantinga, A.J., T. Mauldin, and D.J. Miller. "An Econometric Analysis of the Cost of Sequestering Carbon in Forest." *American Journal of Agricultural Economics* 81(1999):812-824.

- Richards, K. "The Time Value of Carbon in Bottom-up Studies." In *The Economics of Terrestrial Carbon Sequestration*, Ed. by Sedjo, Sampson and Wisniewski, CRC Press, Boca Rotan, 1997.
- Stavins, R.N. "The Costs of Carbon Sequestration: A Revealed-Preference Approach." *American Economic Review* 89(1999):994-1009.
- Sampson, R.N. and R.A. Sedjo. "Economics of Carbon Sequestration in Forestry: An Overview." *Critical Reviews in Environmental Science and Technology* 27(1997):S1-S8.
- Tomek, W.G, and K.L. Robinson. *Agricultural Product Prices*. Fourth Edition, Cornell University Press, New York, 2003.
- West, T.O, G. Marland, A.W. King, W.M. Post, A.K. Jain, and K. Andrasko. "Carbon Management Response Curves: Estimates of Temporal Soil Carbon Dynamics." *Environmental Management* 33(2004):507-518.