Insights from Agricultural and Forestry GHG Offset Studies that Might Influence IAM Modeling

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1 Introduction

Integrated assessment modeling in the EMF context involves a multi-sectoral appraisal of greenhouse gas emission (GHGE) mitigation alternatives and climate change effects. Such a multi-sector evaluation encompasses analysis of climate change effects and possible mitigative actions within the agricultural and forestry (AF) sectors. In comparison with many of the other sectors covered by integrated assessment models, the AF sectors may mandate somewhat different treatment due to their critical dependence upon spatially varying resource and climatic conditions. In particular, in large countries like the United States, forest production conditions vary dramatically across the landscape. For example, in the US, just to name a few cases, some areas present conditions favorable to production of southern pine, while others allow production of redwoods and douglas fir. Furthermore, some of the US is simply not suitable for forest production. Similarly, in agriculture, the US has areas where citrus and cotton can be grown and other areas where barley and wheat are more suitable. This diversity across the landscape causes differential production alterations and greenhouse gas emission mitigation potential in the face of climatic changes and/or responses to policy or price incentives.

It is difficult within a nationally aggregated, integrated assessment model (IAM) of a large country or the globe to fully reflect the sub-national geographic production possibilities that influence AF response as alluded to in the paragraph just above. Regionally specific shifts in land use and agricultural/forest production would be expected to characterize AF response in the face of climate change altered temperature precipitation regimes as well as in association with mitigation (i.e. carbon price) incentives. This paper addresses incorporation of AF sectoral responses in the context of climate change mitigation studies. Specifically, we will draw upon findings regarding climate change mitigation possibilities that arise from a body of the US based AF sectoral studies that incorporate sub-national production detail. We intend to discuss characteristics of AF sectoral responses that could be incorporated within future IAM efforts directed toward analyzing climate change related policy issues.

2 Types of insights to be discussed

A number of studies have been done within the agricultural and forestry sectors regarding the competitiveness of alternative agriculture and forestry based GHGE mitigation strategies under different market conditions and time. Such studies reveal insights that may be of value to the integrated assessment modeling community.

The basic nature of the insights to be discussed will arise from studies of the portfolio share of various mitigation alternatives in a static and dynamic sense, the effect on production of traditional sector goods, the incidence of co-effects, regional heterogeneity, and fungibility. The fundamental sources for these findings are the dissertations by Schneider (2000), Lee (2002), and Kim (2004) plus follow-up work under various EPA, USDA, and DOE sponsored projects. Not all the studies were redone to yield one consistent set of data. Thus, we indicate to readers that the data in some places are based on runs with varying prices per metric ton of carbon while others are done based on prices per metric ton of carbon dioxide. In addition, readers should note that the results arise across various generations of the models involved.

2.1 Mitigation Portfolio – Composition

The fundamental data on which the first set of insights are based involves the relationship found in an AF sectoral study between the quantity of GHGE offsets and the offset price (Figure 1). The AF offsets are produced by employment of multiple GHGE mitigation alternatives that, in turn, are broadly characterized into 6 major categories as defined below. Such data were first developed in the thesis by Schneider (2000) and later by McCarl and Schneider (2001). The concept was subsequently generalized for a multi-period case in Lee's (2002) thesis and associated presentations (Lee et al (2005), McCarl et al (2005)) to a portrayal of the net present value (NPV) of the GHGE offset as it arises over time. Namely, following the conceptual approach discussed in Richards (1997), the time dependent contributions generated by a multi-period model of sectoral response are weighted back to the present using a 4% discount rate. A graphic of such results appears in figure 1 and summarizes dynamic results from the FASOMGHG (Lee (2002), Adams et al (1996)) model. In that figure, the tons of offsets are converted using 100 year global warming potentials to a carbon equivalent basis. The broad classes of GHGE mitigation alternatives that appear are:

- Afforestation-- the GHGE offsets that arise due to establishment of new forest on agricultural crop and pasture lands.
- Biomass -- the GHGE offsets that arise from substitution of agriculturally produced commodities for fossil fuel energy. The substitution occurs principally in the form of replacement of coal by switch grass and poplar for fueling electricity generation. The model also considers the potential substitution of crop or cellulosic based ethanol for gasoline (See Schneider and McCarl (2003) for details).
- CH_4 and N_2O -- the GHGE offset generated in terms of methane (CH_4) and nitrous oxide (N_2O) through use of a number of agricultural management alternatives including those targeted at emissions from livestock manure, livestock enteric fermentation, rice production, and nitrogen fertilizer usage

(McCarl and Schneider (2000) discuss the full set of alternatives). The majority of the offsets arise from livestock and fertilizer alterations.

- Forest Management -- the GHGE offset generated by altering management of existing forest principally through adoption of longer rotations or use of more intensive practices that promote growth.
- Crop Management FF -- the GHGE offset generated by altering agricultural management practices so as to conserve the amount of fossil fuel (FF) used.
- Soil Sequestration -- the GHGE offset generated by altering agricultural tillage practices and by changing land use from cropping to pasture or grasslands.

Now let us turn our attention to some of the insights generating through such analyses.

As can be seen from figure 1, the AF sectors are potentially multidimensional sources of offsets. The four biggest classes of contributions arise from agricultural soil sequestration, management of existing forest, biofuels, and afforestation. The non-CO_2 strategies and the offsets arising form alterations in agricultural fossil fuel usage patterns make smaller but still sizable contributions. This shows agriculture and forestry can play a role considerably beyond the often discussed sequestration role and leads to **Insight 1 – The agricultural and forestry potential greenhouse gas emission mitigation portfolio is diverse and composed of a number of alternatives.**

2.2 Mitigation portfolio – price dependency

As can also be seen in figure 1, the importance of the various portfolio elements depends upon the magnitude of the offset price. In particular, at low levels of offset prices, the cost effective strategies are agricultural soil sequestration and alterations in existing forest management. However, when the offset prices become higher, then biofuel production and afforestation take over. The reason for the shift involves basic economics. At low prices, the GHGE mitigation strategies employed continue to produce traditional agricultural and forestry commodities while also producing GHGE offsets. Such strategies yield relatively low per acre offset rates. At higher prices, the biofuel and afforestation strategies take over producing larger amounts of offsets per unit of land but diverting production from traditional commodities. For example, using data from West and Post (2002), agricultural soil sequestration generates roughly a quarter of a ton of carbon offset per acre while afforestation and biofuel generate offsets in excess of one ton per acre but require giving up traditional production. This leads to **Insight 2 – The most cost effective elements in the portfolio depend on the magnitude of the greenhouse gas emission offset (carbon) price.**

2.3 Mitigation portfolio – dynamics

While the above results show what happens in a static or net present value sense, it is also important to examine how offsets arise over time. In particular, biological phenomena underlying some of the agricultural and forestry GHGE mitigation alternatives (largely the sequestration ones) have characteristics that influence their potential dynamic contribution. Namely, the GHGE offset potential of forest management, afforestation, and soil sequestration have a "permanence" issue in the context of the international GHGE mitigation dialogue (see discussion in Marland et al (2001), Kim (2004), or McCarl (2005)). In particular, these strategies add carbon to the ecosystem but ecosystems exhibit what has been often called saturation. Namely, carbon may accumulate in the ecosystem under a particular management régime until the rate of carbon accumulation equals the rate of carbon decomposition and at that point sequestration ceases. West and Post (2002) argue this happens in 15 to 20 years when changing agricultural tillage while Birdsey (1996) present data that show carbon ceases accumulating in an undisturbed southern pine plantation after about eighty years. Under either circumstance this generally implies that these are limited duration strategies. On the other hand, biofuel and emission control strategies do not exhibit saturation.

Such characteristics are manifest in the figure 2 dynamic results drawn from Lee (2002) and subsequent papers (Lee et al (2005), McCarl et al (2005)). Figure 2 shows the cumulative contribution by strategies as they arise over time for three different offset prices. Generally the offsets from the sequestration strategies rise up quickly but then accumulation stops after 30 to 40 years and may even diminish over the longer run (the short time to effective saturation for forest occurs because harvest disturbances begin). However, the non-CO_2 emissions and biofuel strategies continue to exhibit larger and larger cumulative offsets. Further, at high prices the biofuel strategy dominates although it takes some time for these to penetrate the market. This leads to the collective observation that in the near-term and at low prices the sequestration strategies are employed whereas in the longer term and at higher prices the emission control and biofuel strategies dominate. This leads to **Insight 3 -- The cost-effectiveness and desirability of strategies vary with time largely due to the limited life involved with sequestration strategies and the market penetration time for biofuels.**

2.4 Mitigation portfolio – competitiveness of strategies

It is common in the AF GHGE mitigation related literature to find treatments that address only single strategies (i.e. the Lal et al.(1998) book on cropland based agricultural soil current sequestration). Such treatments frequently deal with the strategy in isolation and state some kind of a total potential GHGE offset quantity. However, this may be biased. Figure 3 presents the results of experiments relative to strategy potential in the context of agricultural soil carbon offsets drawn from the work of Schneider (2000) and McCarl and Schneider (2001). Two types of biases can be discussed.

First, when the potential estimate does not consider resource availability or economic costs of production it may overstate substantially the degree of reliance on the strategy at alternative prices. In figure 3 the vertical line to the far right is a US wide soil agricultural carbon offset potential estimate based on data in the Lal et al (1998) book (technical potential) whereas the monotonically increasing line to the left arises from an economic model that examines strategies at various prices when agricultural soil sequestration is the only available strategy (economic potential). These data show that as higher offset prices are paid that the technical potential is approached but never attained. Such results indicate that the physical estimate of potential can substantially overstate the economic estimate.

Second, the third and left most line that initially rises then falls portrays the quantity of soil sequestration offset generated by the GHGE mitigation strategy when other strategies are also available for use (competitive potential). The falling part shows the influence of resource competition since agricultural soil carbon sequestration,. Namely, biofuels and afforestation all share common resources (in this case principally the land base) and at higher prices the chosen offset strategies move land to afforestation and biofuels diminishing agricultural soil carbon sequestration.

Across both of these bias cases we see single strategy consideration clearly overstates the role of the individual strategy. A comparison of the single versus multiple strategy results also shows omitting strategies diminishes the estimate of total AF mitigation potential. Such findings also occurred during the recent EMF non-CO_2 study where consideration of non-CO_2 mitigation strategies were found to substantially increase total mitigation potential. This argues that if possible in integrated assessment a wide portfolio responsible of AF and other responses should be considered and leads to

Insight 4 – Omitting consideration of select strategies can overstate the importance of the remaining strategies and understate total mitigative potential.

The data in figure 3 also show that one should not rely on purely technical or even localized strategy by strategy evaluations of GHGE mitigation possibilities. Factors such as the competition for resources, as well as market forces and other economic considerations may, when considered, make substantial changes in the basic nature of the mitigation supply curve. This implies, for example, that it may be valuable to do a more comprehensive non-CO_2 study to generate better data on which integrated assessment can rely. It is our impression that the data used in the recently completed EMF study were largely based on regional case by case studies of individual strategies and leads to **Insight 5 --Appraisals of the importance of strategies should depend on economic consideration of resource substitution possibilities, costs, economies of scale up and local suitability.**

2.5 Mitigation portfolio – dynamics and economy wide role

The implication of insights 4 and 5 are that it is not appropriate to examine the potential of AF GHGE mitigation alternatives in isolation. Rather the AF alternatives should be examined in a full economy context via IAMs. However, we do note that some have argued that due to the permanence problems of AF sequestration activities that they need not be further considered. We disagree with this and chose to undertake a preliminary investigation on the dynamic role of agriculture and forestry GHGE mitigation in a total economy context. This work was reported in Sands et al (2003) with the principal results appearing in figure 4. In that figure, while the relative contribution of AF mitigation diminishes over time, as energy industry capability increases, we nevertheless found the AF contribution to be quite important in the near-term constituting initially more than 50% of potential mitigation. Later the share diminishes as investments in energy sector mitigation and technological developments in carbon capture-storage emerge. This indicates the desirability of future dynamic studies of the potential relevance of AF GHGE mitigation alternatives perhaps in part on data coming from extensions of the work discussed herein and leads to **Insight 6 -- While agricultural and forestry activities may not have unlimited duration, they may be very important in a world that requires time and technological investment to develop low-cost greenhouse gas emission offsets.**

2.6 Mitigation portfolio -- regional composition

Now we turn our attention to regional issues. Figure 5 portrays the major regional GHG mitigation activity choices across the set of US regions used in the FASOM model (Adams et al (1996)). These data show that across the landscape different strategies are pursued and leads to **Insight 7: The agricultural and forestry GHG mitigation portfolio varies across space with different regions employing different strategies depending on resource endowments and opportunity costs.**

In particular, if one looks at the data, one finds that agricultural activities dominate in major agricultural regions like the CornBelt and that forestry activities dominate in important forestry regions like the SouthEast. This underlines the importance of depicting subnational areas in obtaining a reasonable set of GHG mitigation responses for incorporation in an IAM.

2.7 Mitigation activities -- effects on traditional production

Another area of potential insights involves the interrelationship between the employment of GHGE mitigation alternatives and the volumes of traditional sectoral production. Figures 5 and 6 portray the relationship between total production indices and offset prices over time.

On the agricultural side these data show competition between traditional crop production and GHGE offset production. In particular, the data in figure 5 shows that as the offset price gets larger, then agricultural crop production generally decreases. This occurs because of resource substitution. Namely, as offset prices get larger more and more land is diverted from traditional agricultural crops to biofuels and afforestation. While not portrayed here, an index of total livestock production also shows declines although to a smaller extent. This leads to **Insight 8 -- Employment of agricultural mitigation activities generally involves reductions in production of traditional agricultural products.**

On the forestry side, the story becomes somewhat more complex as shown in figure 6. There one sees short term substitution but longer-term complementarity. In the short term, when carbon prices rise one finds that rotation lengths get longer and harvesting is held off reducing forest product supply. Afforestation is also occurring. Subsequently, in the longer run, both forest carbon and timber volume are accumulating and harvesting begins to occur. Such harvesting activity takes into account diminishing sequestration rates and the fact that some carbon will retained post-harvest in lumber and other products. This leads to **Insight 9: Employment of forestry mitigation activities generally involves short run substitution with traditional production, but a longer run complementary relationship arises.**

2.8 Mitigation and co-effects

A number of agricultural mitigation activities not only generate emission reductions or sequestration gains, but also exhibit environmental and economic byproduct effects. Such effects are generally called co-benefit or permitting cases where things may have costs, co-effects. Such co-effects arise in several arenas. For example, Schneider (2000) and Plantinga and Wu (2003) show substantial aggregate reductions in erosion when GHGE mitigation strategies were employed. Schneider (2000) shows reductions in phosphorus and nitrogen runoff. In turn, Pattanayak et al (2004) show this leads to improvements in regional water quality. Others indicate such actions affect species diversity and hunting opportunities (Matthews, O'Connor, and Plantinga (2002), Plantinga and Wu (2003)).

Economics effects have also been shown in terms of increases in producer income and decreases in governmental income support (Callaway and McCarl (1996), McCarl and Schneider (2001)). This occurs since the availability of profitable GHGE mitigation alternatives expands producer opportunities to sell goods and in turn income. On the other hand, findings indicate a worsening of the foreign trade balance, foreign interest welfare and domestic consumers' welfare. This leads to **Insight 10: Implementation of forestry and agricultural mitigation activities leads to co-effects.**

One should also be careful with co-benefits consideration in studies confined to AF possibilities as for example generation of AF GHGE offsets when society is operating under a fixed amount of total net allowable emissions implies that additional emissions can occur in the energy sector. When this allows more coal-fired generation there may be health and other effects due to particulate emissions of NOX and SOX (see discussion in Burtraw et al (2003) and Elbakidze and McCarl (2004)).

2.9 Fungibility

Different prices for lots of the same commodity at the same location are common in AF markets. Generally these arise because commodities are not perfect substitutes (as is commonly called fungibility) with prices differentiated by a market defined system of commodity grades. Such grades reflect differential use values on behalf of commodity consumers depending on commodity quality characteristics coupled with the production costs of achieving different commodity quality characteristics. For example, in plywood markets there are different prices depending upon the quality of the surface finish (smoothness, freedom from knots etc) while in the corn market there are differential prices depending upon moisture content, and foreign matter/broken kernel content.

It is virtually certain that grading standards will occur in a GHGE offset credits market. In a GHG market, the grading standards would reflect different characteristics that are important to the purchaser including a number of concepts that have arisen in the IPCC dialogue

- Permanence
- Additionality
- Leakage
- Uncertainty
- Heat trapping ability of different gases involved (as commonly called global warming potential or GWP).

Across the literature a number of estimates have arisen that indicate these factors can significantly reduce the amount of claimable AF mitigation offsets. Comments on each are made below

<u>Permanence</u> -- The total quantity of potentially creditable GHGE offsets generated by land-based, particularly sequestration, projects cannot be guaranteed to be permanent because of potential reversal of the practices that generated the potential offsets and the possible incidence of potential uncontrollable events that would lead to release of the sequestered GHGs. The permanence concern embodies a number of different concepts including:

- The likelihood that some sequestered carbon might be emitted in the future.
- The fact that differential annual amounts of GHGE mitigation may arise over time.
- Leasing and contract terms.

McCarl (2005) derives a formula for a permanence related discount that depends on duration of offset and cost to maintain the offset. Case evaluations of the formula indicates that as much as a 50% discount in the sale price relative to a pure emission.

Additionality -- The IPCC discussions reflect a desire to credit GHGE offsets only if they would not have occurred under the normal course of business (commonly called business as usual). The main additionality issues, given a proposed project, are

- How much of the potential GHGE offsets created by a project would have occurred in the absence of the program? and
- How much should the potential offsets created by the project be reduced to account for the activity that would have occurred in the absence of the program? Or equivalently, How much should the potential offsets be discounted to account for the non additional portion?

Kim (2004) derives estimates in the case of a Texas rice conversion showing as much as a 25% additionality discount due to business as usual rice acreage declines.

Leakage -- Market forces coupled with less than global coverage by a GHG regulatory program can cause net GHG emission reductions within one region to be offset by increased emissions in other regions. The main leakage issues are

- How much leakage does a GHG project stimulate? and
- How much should the potential offsets created by the project be reduced to account for the leakage stimulated? Or equivalently, How much should the potential project created assets be reduced to account for leakage?

Murray et al (2004) examine leakage potential from forest carbon sequestration projects in the U.S. They find that leakage potential varies widely - from 10 to 90 percent of direct project carbon sequestration benefits can be offset by leakage. For instance Wear and Murray(2004) show that a Pacific Northwest policy development (forest harvest cessation for species – "spotted owl" preservation) that is very similar to a forest preservation project that disallowed logging in some forests was found have a very high leakage potential as it just led to a shifting of logging to forests that were not covered by the policy.

Uncertainty -- Land-use based production of GHGE offsets will be subject to production and sampling uncertainty. Production uncertainty arises in much the same fashion as it does for any other agricultural or forestry commodity. Year-to-year weather variations along with the uncertain incidence of fire, diseases and pests coupled with many other factors will cause this uncertainty. Yields of crops commonly vary by 10% or more of their average value. Uncertainty also arises due to sampling issues. The main uncertainty issues given a proposed offset are

- ❖ What is the magnitude of the uncertainty?
- ❖ Will uncertainty based discounts arise that reflect the potential liability that a buyer would incur if found to have a net emissions in excess of mandated emission limits?
- ❖ Can the uncertainty be reduced?
- ❖ How much should the potential offsets created by the project be reduced to account for the uncertainty about the total volume generated? Or equivalently, How much should the potential project created assets be reduced to account for the uncertainty?

Kim (2004) derive estimates in the case of a Texas rice showing as much as a 10% discount due to uncertainty in regional 5 year accumulation rates.

2.9.1 Fungibility related insights

In all likelihood grading standards will differentiate based on the characteristics listed above between a "perfect" offset price and the price for potential offsets from a number of sources. Likely recipients of differentiated offset prices are sequestration offsets, carbon dioxide emission offsets, nitrous oxide emission offsets and methane emission offsets.

This raises some issues relevant to IAMS but we note some of the concerns may in part already be handled. Namely, IAM due to their often comprehensive economy wide, and geographic coverage along with less common multi-period coverage may well take care of additionality, leakage, and possibly permanence concerns. In particular, additionality is concerned with the difference in offsets from a baseline and if the baseline is right in the IAM then the issue is covered. On the leakage side, the global coverage of IAMs may handle the issue provided that the aggregation inherent in the models is not so great that the leakage related substitution possibilities are overlooked. Multiperiod IAMs may cover permanence issues but only if they have data on the permanence related path of offsets. Uncertainty is unlikely to be reflected in IAMs as we understand them at this time. AF models like FASOMGHG also partially handle these issues covering additionality, internal US leakage and permanence issues. Uncertainty is not handled nor is leakage to countries outside the US.

However while the IAM and sector models may incorporate these phenomena they may have some difficulty reflecting incentives if the market place adopts a set of grading standards that take these phenomena into account. In particular, if non permanent sequestration assets were paid at, for example, 50% of the rate of emission offsets, then the private incentives would be different than those for other GHGE mitigation alternatives. Furthermore, under such systems when for example a lease expired and the forest was harvested then emissions of the sequestered carbon might not be counted against country emissions. It is a modeling challenge to reflect such a situation.

Nevertheless these potential discount factors are important and empirical studies have shown that discounts vary across different kinds of strategies in different locations in the country. This leads to **Insight 11 greenhouse gas emission offsets from agricultural and forestry activities may not be perfect substitutes for offsets from other sources.** In addition, we should note that empirical studies have shown that when discounts are considered the portfolio composition changes. For example McCarl et al (2001) looked at the effect of permanence related sequestration discounts on portfolio share using a static AF sector model. In that study a 50% discount was applied to the price paid for agricultural soil carbon sequestration relative to that paid for non sequestration offsets. Simultaneously a 25% emission reduction was applied to carbon sequestration arising from forest management and afforestation. The results (Figure 8) show a portfolio composition shift with less sequestration and more biofuels leading to **Insight 12: The consideration of fungibility or grading standards based discounts shifts the portfolio of "best" mitigation strategies**.

3 Toward implementation of these insights

Generation of the insights above is not of much use if it's not backed by some sort of data incorporating the phenomena inherent in the insights that IAM builders might be able to use to improve the portrayal of the AF sectors. An ongoing US based project is attempting to generate response function information that encapsulate these insights and may be useful in IAMs. The first results of this effort are in Gillig et al (2004) and Gillig and McCarl (2004) and presents a set of response curves that give the role of various strategies as offset prices increase and also take into account shifts in demand and energy prices. Several hundred functions are presented therein and in the associated spreadsheet giving commodity effects, welfare effects, co-benefits etc. Both static NPV like functions and dynamic functions have been estimated. These have been used in a preliminary fashion in an IAM exercise by Sands et al(2003). Currently we are in the process of developing a data set that gives the effects over time as a function of current and lagged offset prices so we can begin to better incorporate the ecosystem “saturation” characteristics in IAMs. Upon completion of that exercise we will work with some of the IAM teams to fully integrate these results. We are also in touch with teams attempting to construct similar sectoral analyses in Europe and Asia.

4 Concluding Comments

A number of results from agriculture and forestry sectoral specific studies contribute insights that may be useful in the future formulation of integrated assessment models and the conduct of studies related to greenhouse gas emission mitigation possibilities. We hope that the discussion above adequately explains some of these insights and look forward to working with the integrated assessment community to better assess the potential role of agriculture and forestry.

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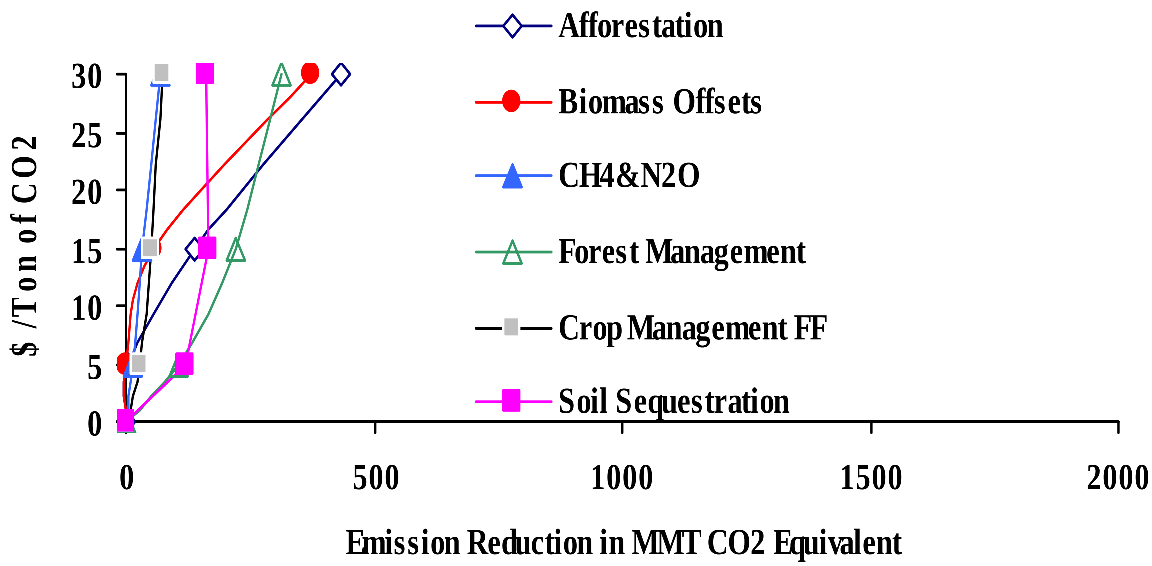
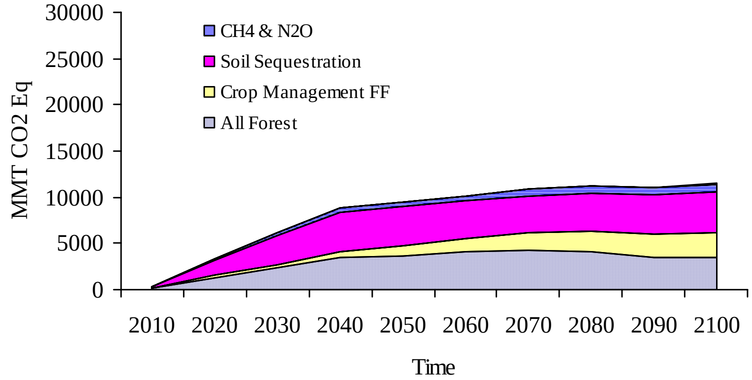
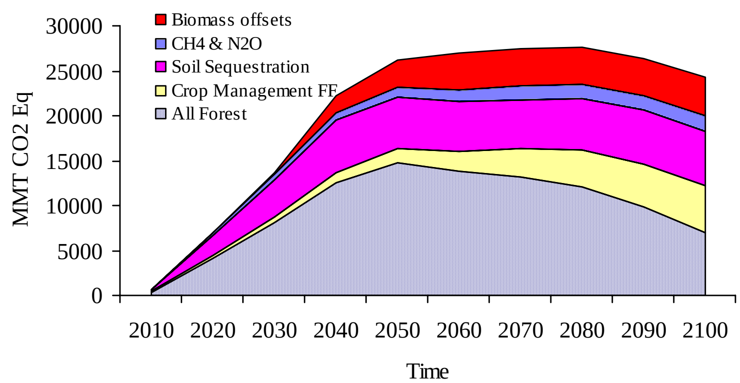


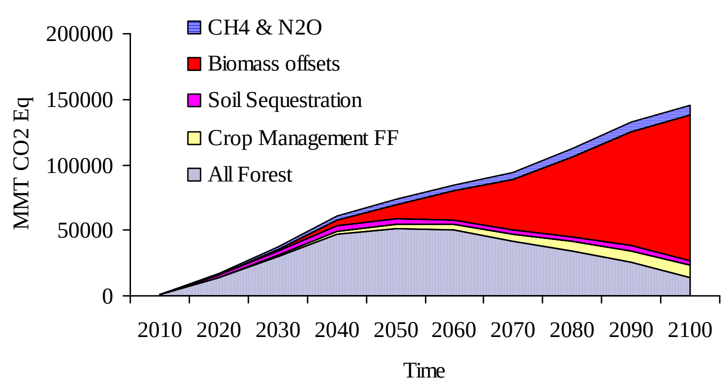
Figure 1: NPV Porfiolio of Mitigation Strategies



Panel a: Cumulative Contribution at a $5 per tonne CO2 Price



Panel b: Cumulative Contribution at a $15 per tonne CO2 Price



Panel c: Cumulative Contribution at a $50 per tonne CO2 Price

Figure 2: Dynamic Porfiolio of Mitigation Strategies

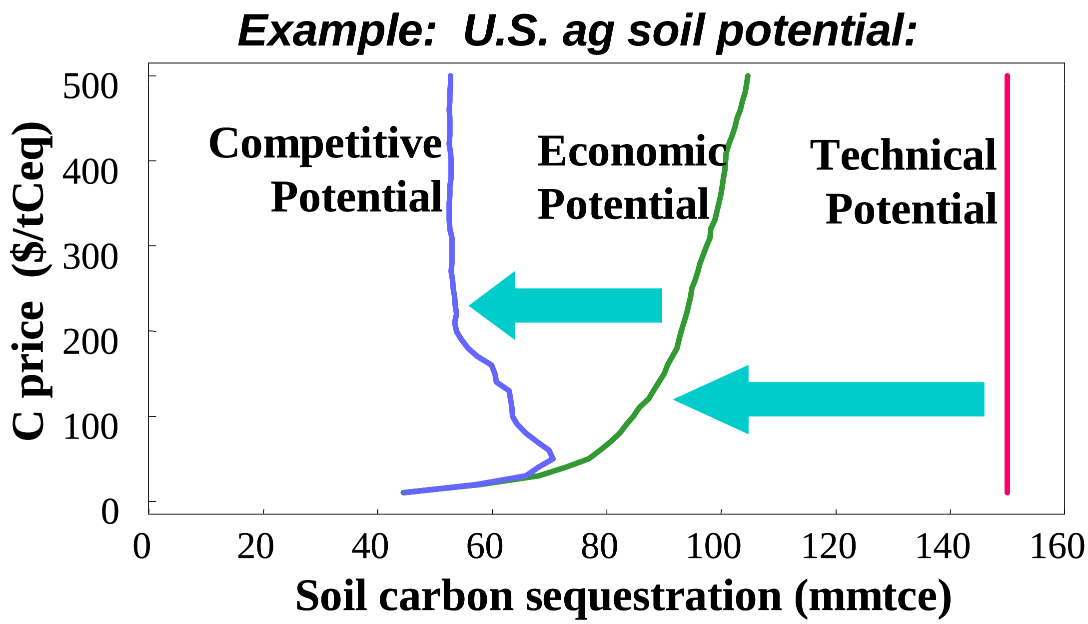


Figure 3: Estimates of soil carbon sequestration potential under varying assumptions

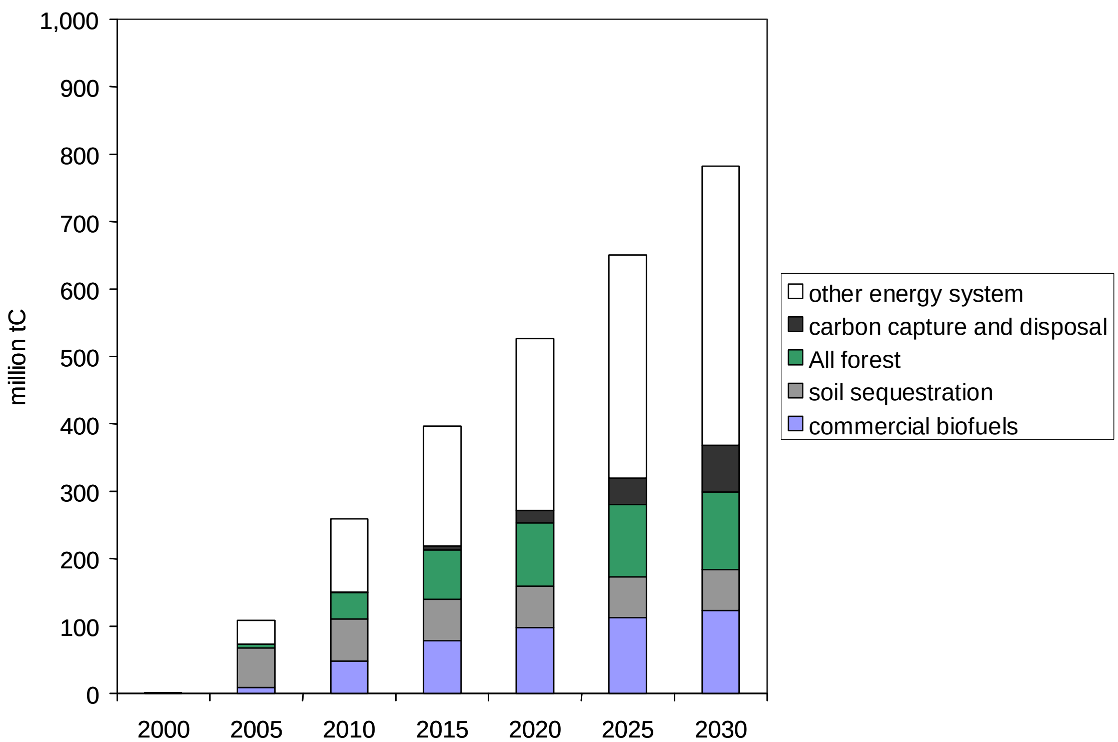


Figure 4: Economy wide dynamic portfolio of Mitigation Strategies

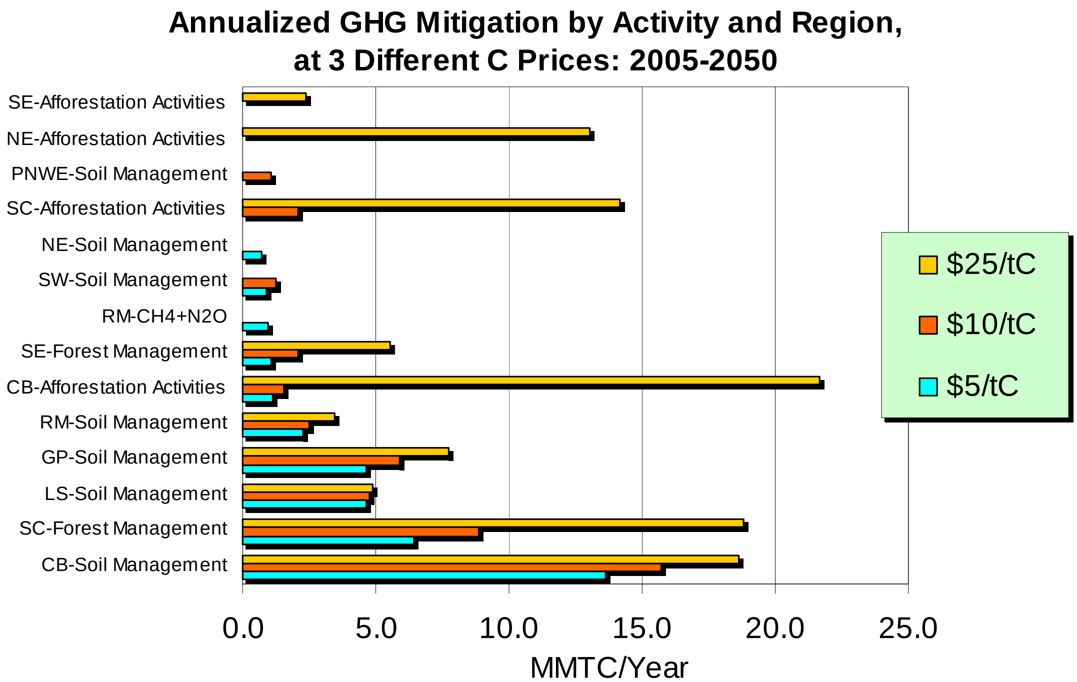


Figure 5: Regional NPV portfolio of Mitigation Strategies

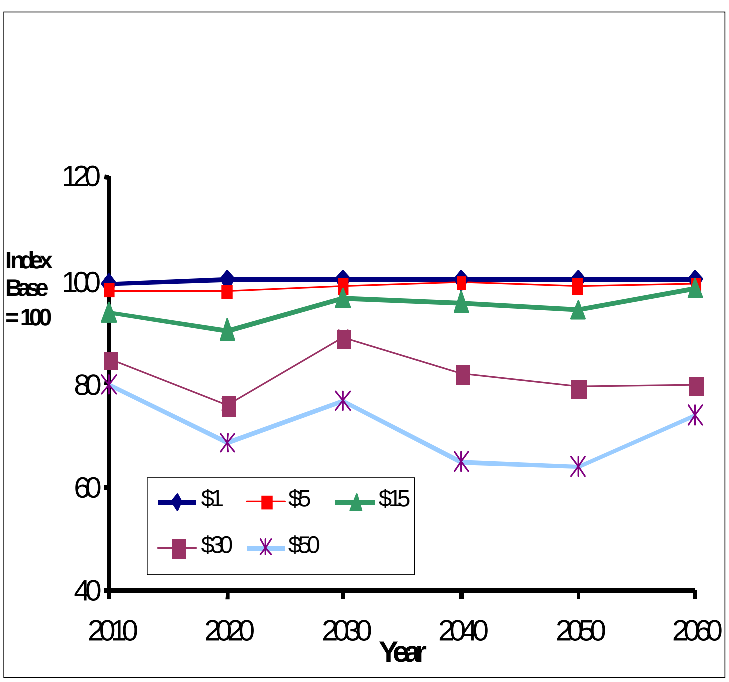


Figure 6: Agricultural crop production as carbon prices increase

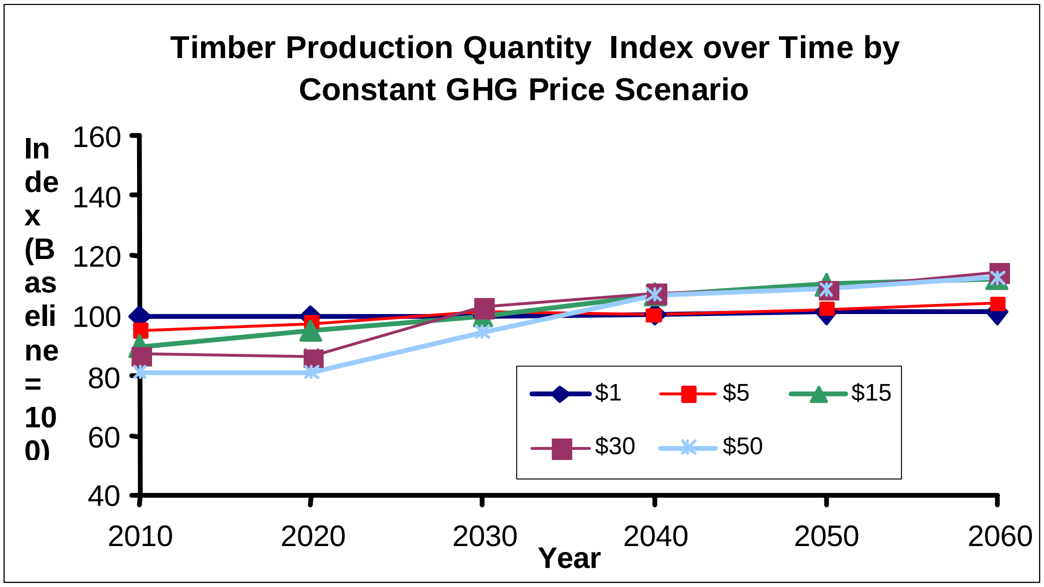


Figure 6: Dynamic Timber production pattern as carbon prices increase

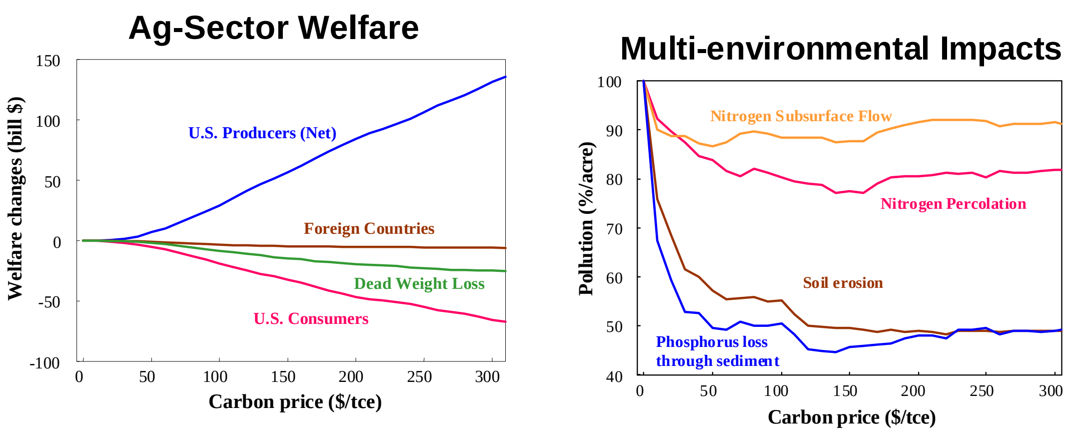


Figure 7: Co-benefit account changes as carbon prices increase

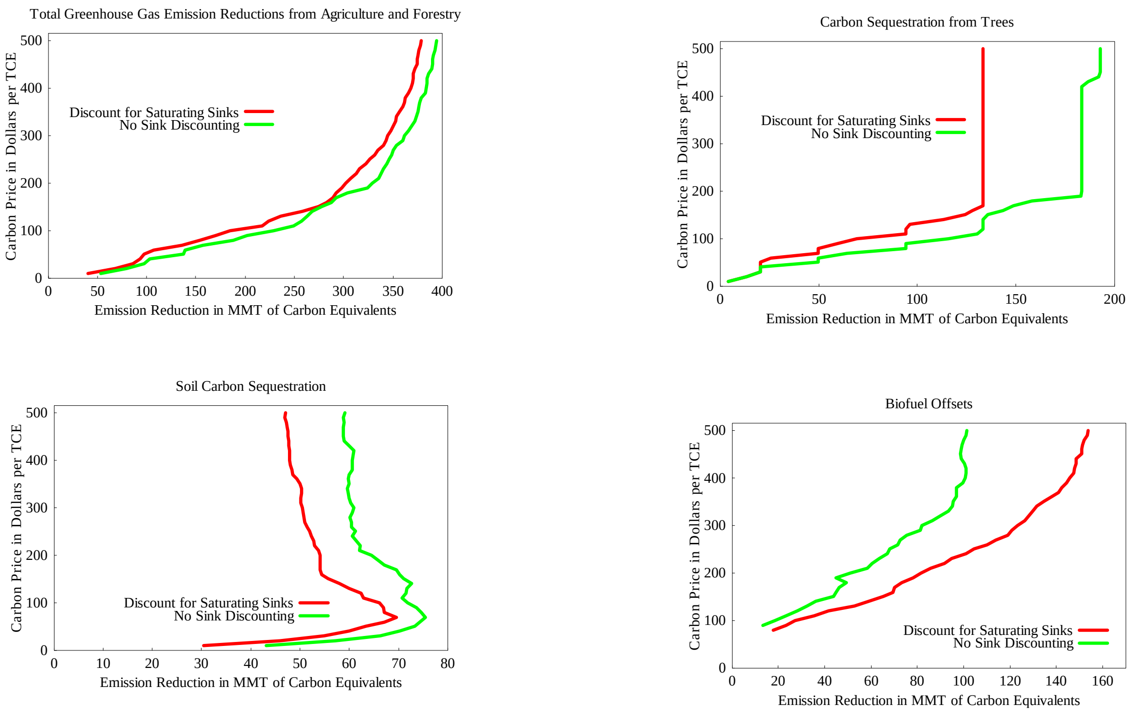


Figure 8: Effects of permanence discounting on portfolio share