STATEMENT OF JOSEPH GLAUBER,
CHIEF ECONOMIST, U.S. DEPARTMENT OF AGRICULTURE
BEFORE THE HOUSE AGRICULTURE COMMITTEE,
SUBCOMMITTEE ON CONSERVATION, CREDIT, ENERGY, AND RESEARCH

December 3, 2009

Mr. Chairman, members of the Subcommittee, thank you for the opportunity to discuss the effects of greenhouse gas (GHG) offset programs on U.S. agriculture. In previous testimony I have summarized the Department's analysis of how the American Clean Energy and Security Act (H.R. 2454) would likely affect production costs for U.S. farmers and ranchers across a wide range of commodities and regions. Today I will address how farmers and ranchers can potentially gain through the GHG offset program provided for in H.R. 2454.

The role of offsets is important for agriculture as well as to the rest of the economy. First, offsets provide a potential low-cost option for compliance to GHG emissions reduction targets for covered sectors under a cap-and-trade system. Offsets reduce the costs of compliance for covered entities which results in smaller increases in allowance prices that are then passed on to consumers—including farmers—as increased energy prices. Conversely, limited offset availability could result in higher costs to the economy. In its analysis of H.R. 2454, the Environmental Protection Agency (EPA) estimates that allowance prices would be almost 90 percent higher if international offset markets were not allowed.[1] In a similar analysis, the Energy Information Administration (EIA) estimates that allowance prices would be 64 percent higher with no international offsets market.[2] The Congressional Budget Office estimates that if

[1] The EPA analysis of H.R. 2454 can be found at
http://www.epa.gov/climatechange/economics/economicanalyses.html

[2] The EIA analysis of H.R. 2454 can be found at:
http://www.eia.doe.gov/oiaf/servicerpt/hr2454/index.html

no offsets were allowed, allowance prices would more than triple.[3] These analyses do not consider how allowance prices would change if both international and domestic offsets were not available, but the effect would likely be magnified. This is because when international offsets are not available, demand for domestic offsets increases substantially and acts as a limiting factor on allowance price increase.

Second, offsets are a potential income source for agricultural producers and forest landowners through changes in land management practices (e.g., reduced tillage, increased fertilizer efficiency, afforestation/tree planting), animal management (e.g., dietary modifications), and manure management (e.g., biogass capture). And while the profitability of management practices varies widely by region, as does the amount of carbon storage attainable, net revenues from agricultural offsets can mitigate the effects of higher production costs due to higher energy costs.

Lastly, a carbon offsets program could affect land use and agricultural production and prices. If afforestation is the primary source of carbon offsets, for example, cropland and pastureland would be converted to forests which would raise farm prices and increase farm income, but also result in higher food prices for both domestic and foreign consumers. Other sources of possible offsets such as conservation tillage and other agricultural management practices that reduce nitrous oxide and methane emissions could have potentially smaller effects on land use and agricultural production and prices but would be more difficult to monitor and verify.

Note that the analysis presented here does not examine the impacts of international offsets on the U.S. farm sector. International offsets, particularly reduced deforestation offsets

---

[3] Congressional Budget Office. *CBO Cost Estimate: H.R. 2454 American Clean Energy and Security Act of 2009*, June 5, 2009. p.18.

that limit agricultural expansion globally can also affect U.S. farmers by raising farm prices. As found in the EPA and EIA analyses, international offsets are important for avoiding high allowance prices, which will lead to more moderate energy price increases but also result in lower prices for domestic offsets.

The Role of Offsets

Agriculture and forestry have a wide variety of production and land management practices that can lower GHG emissions and/or increase the quantity of carbon stored in soils and vegetation. These include shifting cropland into trees or permanent grasses, managing existing forests to store additional carbon, adopting no-till or reduced tillage systems on a long-term basis, eliminating fallow periods, planting cover crops, changing nitrogen fertilizer management practices (including rates, application method, timing, and use of inhibitors), altering livestock feed mixes, and changing manure management practices.

A number of recent economic studies have focused on how farmers and forest land owners would respond to various incentives designed to increase the use of production practices and land uses that increase carbon sequestration and/or reduce emissions associated with commodity production. For six of these studies, table 1 details the types of mitigation activities assessed, the regional and sector coverage, and the quantity of GHG mitigation achieved by specific activities at selected prices.

The studies summarized in table 1 employ different methodologies and make alternative assumptions regarding key underlying variables, trends, and other factors. Additionally, the studies were designed to look at different research questions and so differ with respect to geographic focus, sector coverage, activity coverage, inclusion of relevant federal policies and measures and time period considered. When viewed collectively, however, several overall conclusions emerge regarding the potential of the U.S. agriculture and forestry sectors to supply greenhouse gas mitigation within the context of a cap-and-trade system.

Collectively, the studies found, depending on the CO_2 price, farmers and forest land owners generate measurable amounts of greenhouse gas mitigation through changes in tillage practices, crop rotations, elimination of fallow periods, switching marginal cropland to permanent grassland, reducing methane (CH_4) and nitrous oxide (N_2O) emissions from agricultural sources, making changes in forest management, and afforestation.

The offset supply curves from these studies indicate than even at low CO_2 prices, the domestic agriculture and forestry sectors could supply a significant amount of GHG offsets to entities covered under a cap-and-trade system. At very low CO_2 prices (e.g., under $10 per ton), these offsets would be generated mostly by changes in agricultural production practices. Lewandrowski et al (2004), EPA (2005), and Antle et al. (2001, 2007) found some shifting to less GHG intense production practices (such as increased adoption of no-till, elimination of fallow periods, and shifts to less energy intensive rotations) at CO_2 prices of $5 per ton or less. In many areas no-till, conservation tillage, and conventional tillage systems are practiced in relatively close geographic proximity. This suggests the economic returns to different tillage systems are often relatively similar. Where this is the case, a relatively small economic incentive favoring one system over another – such as a carbon market could provide for no-till, would be sufficient to induce some farmers to change tillage systems. Similar reasoning applies to increases in the use of other less GHG intense production practices and rotations.

Results in the two studies that include forest management as a mitigation option (EPA 2005, 2006) suggest these activities would also start generating significant offsets at a CO_2 price as low as $5 per ton. At a CO_2 price of about $10 per ton, afforestation becomes economically attractive and dominates mitigation activities in the agricultural sector. Although explicitly accounted for only in the EPA (2005) study, changes in forest management dominate mitigation activity in the forest sector. Across studies, afforestation accounts for an increasing share of total offsets as CO_2 prices rise – at least through the price ranges considered ($33.1 per ton in Lewandrowski et al., $50 per ton in EPA (2005), and $54.4 per ton in Lubowski et al.). Opportunities to generate offsets from reducing N_2O and CH_4 emissions from agricultural sources appear positive but relatively modest through the range of CO_2 prices considered (EPA, 2005 and 2006). Results in the one study that looks at farms and forests as suppliers of biofuel feedstocks for electricity generation suggest this activity could be important source of offsets at CO_2 prices above $30 per ton (EPA 2005).

Finally, the studies by Lewandrowski et al. and EPA (2005) discuss the difference between the technical and economic potentials of the agriculture and forestry sectors to mitigate GHG emissions through changes in production and land management practices. As with the empirical results, these discussions are not directly comparable. Lewandrowski et al. combine published technical assessments of the carbon sequestering potential of various crop and livestock activities with published estimates of the total land suitable for each practice to develop a table describing the aggregate technical potential of specific farm sector activities to sequester carbon (see Lewandrowski et al., table 2.2, page 5). The discussion in EPA (2005) is conceptual and drawn from an earlier paper McCarl and Schneider (2001). Also, the studies differ in terms of evaluation period, as the EPA 2005 results are from 2010-2100 while the Lewandrowski et al. study evaluates a shorter, 15 year time period.

It is also important to understand the regional economic implications of a national cap-and-trade framework such as contained in H.R. 2454. Insights regarding these impacts can be developed from the studies by Lewandrowski et al. (2004) and EPA (2005). Although the studies vary significantly in timeframe and other underlying assumptions, this brief synopsis highlights the regional difference in adoption rates of offset options, using afforestation as an example.

Regional results of offset potential by source from Lewandrowski et al. with GHG mitigation priced at $34 per ton CO_2, and, EPA (2005) with GHG mitigation priced at $30 per ton CO_2 are shown in figures 1a and 1b. In both cases, afforestation is the largest potential source of offsets[4]. In the EPA (2005) study , 90 percent of the 434.9 MMT of CO_2 sequestered by afforestation occurs in the Corn Belt and South Central regions. The remainder occurs in Southeast, Lake States, and Rock Mountain regions. In the Lewandrowski et al. study, over 60 percent of the CO_2 sequestered by afforestation occurs in Appalachia, the Southeast, Delta States, Lake States, and Corn Belt. One region where the afforestation results differ significantly between the two studies is the Pacific Northwest and California. In Lewandrowski et al, these areas sequester 160 MMT CO_2 via afforestation (all from conversion of pasture to trees). It is worth noting that in this study, afforestation in the PNW region requires a relatively high price for CO_2 before it is economically attractive. At prices below $15 per ton CO_2 virtually no afforestation occurs. In the EPA (2005) analysis the PNW and California sequester only 4.7 MMT CO_2 from afforestation.

Agricultural Offsets in H.R. 2454

The economic profitability to supply offsets depends on the price that industries in covered sectors are willing to pay for offsets. The June EPA analysis of H.R. 2454 (2009)

[4] In the Lewandrowski et al. study,afforestation was assumed to be zero in the North Plains, South Plains and Mountain regions.

estimates the real ($2005) price of allowances to increase from about $13 per ton of carbon dioxide equivalent (CO_2eq) in 2015 to over $70 per ton CO_2eq by 2050; an increase of 5 percent per year[5] (table 2).

To estimate the economic potential for agriculture and forestry to supply offsets we rely on EPA allowance prices and detailed modeling analysis provided by EPA.[6] The results presented are similar to but not identical to the results provided in the EPA (2009) analysis of H.R. 2454 or our preliminary analysis of H.R. 2454 (USDA, OCE, 2009). The results presented in this analysis reflect the estimates from FASOM based on an average of two scenarios: an inflation adjusted carbon allowance price of $5 per ton in 2010 and increasing at 5 percent per year over time and an inflation adjusted carbon allowance price of $15 per ton in 2010 and increasing at 5 percent per year over time. The average of these carbon prices paths generates a carbon price path that approximates the carbon price allowance path estimated by EPA. In addition, in this paper we focus exclusively on agricultural activities and include afforestation as an agricultural activity.

The FASOM modeling did not account for several categories of GHG reductions, including: improvements in organic soil management; advances in feed management of ruminants; changes in the timing, form, and method of fertilizer application; and alternative manure management systems other than anaerobic digesters.[7] The model only evaluates

---

[5] For the June EPA H.R. 2454 analysis, scenario 2 was used. The EPA analysis of H.R. 2454 can be found at: http://www.epa.gov/climatechange/economics/economicanalyses.html.

[6] To estimate the economic potential of the agriculture and forestry sectors in the United States to provide carbon offsets, EPA (2009) used an economic model, the Forest and Agricultural Sector Optimization Model (FASOM), developed by Bruce McCarl at the Texas A&M University. The results presented in this paper reflect simulations during March 2009. A more complete description of FASOM modeling framework and a complete list of commodities can be found at: http://agecon2.tamu.edu/people/faculty/mccarl-bruce/FASOM.html

[7] Because of how it is handled in the FASOM model, agricultural soil sequestration does not show significant supply. However, detailed FASOM output indicates a 50 percent increase in the percent of cropland using

additional no-till adoption relative to a historic baseline. To the extent legislation awards offsets to no-till prior to the start of the program, it is not accounted for here. It is important to note that these emissions reductions would not be additional relative to the baseline.

It is also important to note that, as with any economic model, predictions far out into the future are inherently more uncertain than nearer term estimates. USDA typically only forecasts agricultural prices and incomes a handful of years into the future. As such, results – particularly for 2030 and 2050 - should not be interpreted as precise estimates but rather as indications of the direction and magnitude of the expected effect.

From 2015 to 2050, the total amount of offsets that would be supplied by the agricultural sector increases from 59 million metric tons of carbon equivalent ($MMTCO_2eq$) per year to over 420 $MMTCO_2eq$ by 2050 (table 3). With allowance prices increasing over time, the real gross revenues resulting from agricultural offsets increases from about $800 million per year in 2015 to almost $30 billion per year by 2050.

The primary source of agricultural offsets would be increased carbon sequestration through afforestation of crop and pastureland.[8] The gross revenues –before accounting for the cost of the offset-generating activity--associated with offsets from afforestation account for about 85 percent of the total agricultural offset revenues from 2015 to 2050 (table 3). Reductions in methane (CH_4) and nitrous oxide (N_2O) emissions account for second largest share of agricultural offsets. These offsets total about 11 MMT CO_2eq in 2015 and 78 MMT CO_2eq in 2050. Many of the opportunities to generate these offsets would be concentrated among specific

---

conservation tillage and no-till by 202 in response to a $15/ton CO_2 incentive payment. Because overall land area in crops declines due to afforestation, the modeling indicates a net decrease in total agricultural soil carbon storage as carbon is transferred from the agricultural soils pool to the afforestation carbon pool.

[8] This includes soil carbon sequestration on afforested agricultural lands, in addition to carbon sequestered from new trees.

groups of producers. Examples include changes in manure management practices for confined dairy, hog, and poultry operations, changes in diet for confined cattle operations, changes in fertilizer management for nitrogen intensive commodities such as corn and cotton, and, changes in rice production practices.

Regionally, the Corn Belt region is the largest supplier of GHG offsets across time periods and the Lake States region is the second largest supplier (table 4).[9] In each 5-year period between 2015 and 2050, the Corn Belt region accounts for between 30 and 50 percent of all agricultural sector offsets supplied while the Lake States region account for between 20 and 30 percent of the total supply of agricultural offsets. The South Central, Northeast, and Rocky Mountain regions account for, on average and respectively, 11, 8, and 6 percent of all agricultural offsets supplied between 2015 and 2050.

Implications for Land Use

Providing offsets through afforestation has clear land use implications. As the value of carbon allowances increase, FASOM estimates show that afforestation occurs on larger amounts of crop and pastureland (table 5). In 2015, when the price of carbon allowances is about $13 per ton of CO_2eq, additional afforestation occurs on about 8 million acres. This represents a 3 percent increase in forestland against the projected baseline. By 2030, when the price of carbon allowances increases to almost $27 per ton of CO_2eq, additional afforestation occurs on almost 27 million of acres. By 2050, when the price of carbon allowances increases to $70 per ton of CO_2eq, additional afforestation occurs on almost 60 million acres, 35 million acres of which comes from cropland (14 percent decline from baseline) and 24 million acres from pasture (almost 9 percent decline from baseline).

[9] FASOM regions are presented in Figure 1.

As the value of carbon allowances increase, the share of cropland used for afforestation also increases. For example, in 2015, when the price of carbon allowances is relatively low, almost all the afforestation occurs on pastureland. By 2030, when price of carbon allowances rises to about twice the price in 2015, slightly more than half of the additional afforestation occurs on cropland. The source of land being used for afforestation matters as well. In the early periods, more pastureland is converted to forests than cropland. By 2050, when the price of carbon allowances increases to over $70 per ton of CO_2eq, about 60 percent of the afforestation occurs on cropland compared to about 40 percent for pastureland. Studies that have shown a greater portion of mitigation coming from pasturelands have shown smaller aggregate impacts on commodity production and food prices (de la Torre Ugarte et al. 2009).

The amount of land where additional afforestation occurs also varies by region. As shown in table 6, in 2015, almost all of the additional afforestation occurs in four regions of the country: the Corn Belt, Lake States, Rocky Mountains, and South Central. While most of the additional afforestation occurs in the Corn Belt, there is also a growing concentration of afforestation over time. In 2015, for example, about 55 percent of the afforestation occurs in the Corn Belt and Lake States. By 2050, almost 65 percent of the additional afforestation in the United States occurs in those two regions.

Impacts on Crop Production and Prices

Afforestation of cropland will have production and price impacts. As carbon allowance prices increase, the magnitude of the impact compared to baseline production and prices grows. In 2015, the commodity production impacts are relatively modest except for rice (table 7). Corn and soybean production are 3.5 and 1.4 percent lower, respectively, compared to baseline production levels. By 2030, corn and soybean production are about 7 and 9 percent lower, respectively, when compared to baseline levels of production in 2030. By 2050, corn and soybean production are 22 and 29 percent lower than baseline levels.

It is important to note that under the FASOM baseline, crop production generally increases over time due to yield growth. Thus, the impacts of higher carbon allowance prices on future production relative to current levels are less than the impacts compared to baseline levels. For example, while corn production is 22 percent less than baseline production levels for 2050, this lower level of production is 13 percent higher than baseline levels of production in 2015. Only for soybeans and sorghum are 2050 levels of production under cap-and-trade less than baseline levels of production in 2015.

Lower levels of production relative to baseline levels translate into higher real prices. As shown in table 8, by 2030, corn, rice, and wheat prices are 15, 5.5, and 3 percent higher compared to baseline prices. By 2050 corn, rice, wheat prices are 28, 8, and 13 percent higher, respectively, compared to baseline prices. In addition, soybean, cotton, sorghum, and barley prices are 21, 25, 40, and 57 percent higher compared to baseline prices. While baseline corn yield growth mitigates increases in corn, wheat, rice and oat prices over time, crop prices in real terms are higher in 2050 compared to current prices for sorghum, barley, cotton and soybeans.

Lower domestic crop production and higher prices could spur increases in agricultural production abroad as producers make up for reductions in U.S. crop exports relative to the baseline. These trade impacts could moderate the anticipated rise in crop prices over the baseline. At the same time, expansion of agricultural production abroad could lead to emissions leakage if forests and grasslands are cleared to produce crops. However, international offset programs, such as reducing deforestation, could limit this effect.

Implications for Livestock

Higher real commodity prices also affect livestock production and prices through higher production costs. Hog slaughter is estimated to fall by about 7 percent in 2030 and fed beef slaughter is estimated to fall by about 3 percent compared to 2030 baseline production levels (table 9). As greater and greater amounts of cropland are afforested and crop prices rise, the impacts on livestock producers increase. By 2050, hog slaughter is 23 percent lower compared to baseline levels while fed beef slaughter is estimated to fall by almost 10 percent compared to baseline levels. Milk production is estimated to fall by about 7 and 17 percent compared to baseline levels in 2030 and 2050, respectively. Chicken, turkey, and egg production appear to be relatively less impacted.

Lower livestock supplies will cause real prices to increase relative to baseline levels (table 9). Those livestock categories which showed the largest production impacts translate into the smallest price changes. For example, for 2030, the 7 and 3 percent declines in hog and fed beef slaughter result in price increases of 12 and 4 percent, respectively; by 2050, the decline in hog and fed beef slaughter result in price increases of 27 and 14 percent, respectively. However, while egg, broiler, and turkey production are only 2, 7, and 8 percent lower than baseline production levels in 2050, respectively; egg, broiler, and turkey prices are 20, 16, and 15 percent higher, respectively. The prices for eggs, broilers, and turkeys are far more responsive to a change in production relative to the prices for beef and hogs. Similarly, milk prices are expected to increase by 33 percent in 2050 compared to the baseline in response to the 17 percent decline in production. The relatively larger price impacts for eggs, broilers, turkeys, and milk compared to beef and pork reflects the availability of alternatives in consumers food spending. Price increases for beef and pork are limited because consumers can switch to relatively lower priced alternatives such as chicken and turkey. However, there are few alternatives in the consumer food basket to chicken, turkey, and milk.

Price increases in livestock due to cap-and-trade could be mitigated in part if foreign producers increase their production of livestock beyond baseline levels in response to higher prices. Similar to the trade impacts associated with changes in crop production, increase in foreign livestock production could lead to increases in GHG emissions abroad if producers clear native ecosystems to expand pastureland. As with crop production, well designed international offset programs could limit this effect.

Implications for Farm Income/Producer Surplus

Higher real commodity prices coupled with lower production, changes in input costs and offset net revenues will have an impact on net farm income or producer surplus. FASOM modeling results provided by EPA show the annuity value of changes in producer surplus over the entire simulation period.[10] As was presented in my December 2 testimony, the annuity value of the change in producer surplus is expected to be almost $22 billion higher; an increase of 12 percent compared to baseline producer surplus (table 9). About 78 percent of this increase is due to higher commodity prices as a result of the afforestation of cropland. Only about 22 percent of the increase in producer surplus is due to GHG related payments. Almost 30 percent of the gains would occur in the Corn Belt followed by the South East region (16 percent of the gains), Great Plains region (13 percent), and South Central region (10 percent).

The producer surplus impacts exclude earnings from the sale of carbon from afforestation. USDA estimates the annuity value of the gross revenues associated with the sale

[10] FASOM estimates the impact on producer surplus, a measure of farm income. The annuity value is calculated over the period 2015-2075.

of afforestation offsets would result in approximately $3 billion of additional farm revenue.[11] About 90 percent of that additional revenue would be generated in four regions of the country: the Corn Belt (40 percent), Lake States (25 percent), South Central (14 percent), and Northeast (11 percent). However, part of that increase in revenue will be offset by the continued costs associated with maintaining afforestation projects.

Impacts on Consumer Food Prices

Higher commodity prices will also affect the prices consumers pay for food.[12] The predicted effect on the overall Food CPI is dependent upon the assumed relationship between the Food at Home (FAH) and Food Away from Home (FAFH) price indices. An upper and lower bound estimate is presented based on the following two possible assumptions: a lower bound estimate which assumes the FAFH index is not changed by higher costs and an upper bound estimate which assumes that FAFH effects are the same as the FAH effects. Combining the FAH and FAFH results to the overall CPI for Food implies that the changes in food costs due to higher commodity prices will increase the Food CPI by 0.1 to 0.2 percentage points above the expected inflation trend in 2015 and 1.2 to 2.1 percentage points in 2050. In comparison, the average annual food inflation rate has been 3.1 percent over the past 20 years. Adding the impact of higher energy costs could add an additional 0.4 to 0.8 percentage points to the Food CPI in 2015 and an additional 1.4 to 2.5 percentage point to the Food CPI by 2050. Thus, the total increase to the food CPI from both higher commodity and energy prices is expected to be 0.5 to 1.0 percentage points in 2015 and 2.6 to 4.6 percentage points in 2050.

---

[11] The annuity value of afforestation offsets were not directly taken from model results but estimated based on the EPA allowance prices, the amount of offsets in each region, and a real discount rate of 5 percent.

[12] FASOM does not estimate the impact of changes in primary and secondary commodity prices on the consumer prices index (CPI). To estimate the impacts on the CPI, USDA's Economic Research Service matched the FASOM results to analogous categories of Producer Price Index (PPI) food items. The analysis assumes that consumer spending patterns remain relative constant over time. To the degree to which there may be shifts in consumption patterns due changes in tastes and preferences, the effects may be overstated or understated.

Conclusions

The ability to generate and sell offsets provides an additional source of farm income which can more than compensate for any loss in income due to higher energy costs, in addition to increased revenues from higher commodity prices. The agricultural sector is estimated to supply 59 to 150 MMT CO_2 eq. in offsets annually between 2015 and 2020 at a carbon price starting around $10 per ton and rising at 5 percent per year (assuming they are all additional reductions relative to the baseline). With the real (inflation adjusted) price of carbon allowances estimated at about $13 per ton CO_2eq in 2015 and $16 per ton CO_2eq in 2020, potential gross offset revenue to farmers is between $0.8 and $2.4 billion annually in the early years of the program. Between 2025 and 2035, agriculture is estimated to supply 167 to 342 MMT CO_2eq per year, generating $3.5 to $11.6 billion per year. In the longer-term, from 2040 to 2050, agriculture is estimated to supply over 400 MMT CO_2eq per year, which generates $18 to $30 billion per year in gross revenue at carbon allowance prices of $43 to $70 per ton CO_2eq.

Providing offsets through afforestation will also take land out of agricultural production. The impact of less land in agricultural production leads to higher overall returns to agricultural producers. The effect of higher prices outweighs the effect of less production and, on average, net returns to agricultural producers are about 12 percent higher, with an annuity value in excess of $20 billion.

Consumers will feel the effect of higher commodity prices through increases in the prices paid for food. The overall impact on the Food CPI is estimated to be an increase of about 0.1 to 0.2 percentage points above the expected historical trend in the Food CPI in 2015 and 1.2 to 2.1 percentage points above the expected historical trend in the Food CPI in 2050 with the years in between showing steady increases in the index.

Allowing domestic agriculture and forest offsets into a regulatory cap-and-trade system has a significant effect on the costs of allowance prices. By allowing agriculture and forestry to provide offsets to regulated entities, the cost associated with meeting GHG reduction goals can be greatly reduced and, if implemented correctly, provide the same environmental benefits.

References Cited

Antle, J.M., S.M. Capalbo, S. Mooney, E.T. Elliot, and K.H. Paustian. 2001. "Economic Analysis of Agricultural Soil Carbon Sequestration: An Integrated Approach." *Journal of Agricultural and Resource Economics*. 26(2): pp. 344-367.

Antle, J.M., S.M. Capalbo, K. Paustian, and Md Kamar Ali. 2007. "Estimating the economic potential for agricultural soil carbon sequestration in the Central United State using an aggregate econometric-process simulation model". *Climatic Change*. 80: pp. 145-171.

Congressional Budget Office. 2009. "CBO Cost Estimate: H.R. 2454 American Clean Energy and Security Act of 2009", June. Available at: http://www.cbo.gov/ftpdocs/102xx/doc10262/hr2454.pdf

De La Torre Ugarte, D., B. C. Englis, C. Hellwinckel, T.O. West, K.L. Jensen, C.D. Clark, and R. J. Menard. 2009. "Analysis of the Implications of Climate Change and Energy Legislation to the Agricultural Sector." Department of Agricultural Economics, Institute of Agriculture, The University of Tennessee. November. Available at: http://www.25x25.org/storage/25x25/documents/ut_climate_energy_report_25x25_november11.pdf

Department of Energy. Energy Information Administration. 2009. "Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009." July. Available at: http://www.eia.doe.gov/oiaf/servicerpt/hr2454/index.html

Lewandrowski, J., M. Peters, C. Jones, R. House, M. Sperow, M. Eve, and K. Paustian. 2004. *Economics of Sequestering Carbon in the Agricultural Sector*. USDA ERS Technical Bulletin no 1909. (April).

Lubowski, R.N., A.J. Plantinga, and R.N. Stavins. 2006. "Land-use change and carbon sinks: Econometric estimation of the carbon sequestration supply function". *Journal of Environmental Economics Management*. Vol. 51(2006): pp. 135-152

McCarl, B.A., and U.A. Schneider. 2001. "Greenhouse Gas Mitigation in U.S. Agriculture and Forestry." *Science*. 294: 2481-82.

U.S. Department of Agriculture. Office of the Chief Economist. 2009. "A Preliminary Analysis of the Effects of H.R. 2454 on U.S. Agriculture." July 22. Available at http://www.usda.gov/oce/newsroom/archives/releases/2009files/HR2454.pdf

U.S. Environment Protection Agency. 2005. *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*. EPA 430-R-05-006. November.

U.S. Environmental Protection Agency. 2006. *Global Mitigation of Non-CO2 Greenhouse Gases*. EPA 430-R-06-005 (June).

U.S. Environmental Protection Agency. 2009. "EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the 111th Congress". June 23. Available at http://www.epa.gov/climatechange/economics/economicanalyses.html

Table 1: GHG offset potential for selected practices and CO_2 prices from recent studies*

GHG Mitigation Practice	Study	Coverage	Potential GHG mitigation(MMTCO_2e/yr @ $ per ton CO_2)
Tillage			
Conservation tillage (primarily no-till)	Lewandrowski et al. (2004)	US agriculture sector	31 @ $13.62 101 @ $34.06
	EPA (2005)	US agriculture and forestry sectors	In 2015: 194 @ $15.00 191 @ $30.00 In 2025: 204 @ $15.00 187 @ $30.00
	Antle et al. (2007)	Central US cropland	No-till corn-soy-feed systems 14.6 @ $16.4 18.6 @ $27.3 No-till wheat systems 1.9 @ $16.4 2.2 @ $27.3
Other Agricultural Management Practices			
All Agricultural CH4 and N2O	EPA (2005)	US agriculture and forestry sectors	In 2015: 28 @ $15.00 48 @ $30.00 In 2025: 36 @ $15.00 76 @ $30.00
	EPA (2006)	Global Agriculture US Cropland sources	In 2020 (Base = 200 MMT CO2) 21% Reduction @ $15 26 % Reduction @ $30
		US Livestock sources	In 2020 (Base = 171 MMT CO2) 11.8% Reduction @ $15 19.8% Reduction @ $30
Reduced fossil fuel use	EPA (2005)	US agriculture and forestry sectors	In 2015: 35 @ $15.00 46 @ $30.00 In 2025: 32 @ $15.00 49 @ $30.00

Biofuel Offsets (primarily biomass for power generation)	EPA (2005)	US agriculture and forestry sectors	In 2015: 0 @ $15.00 16 @ $30.00 In 2025: 0 @ $15.00 21 @ $30.00
Cropland to permanent grass	Antle et al. (2001)	Northern US Great Plains	8.7 @ $24.9 13.6 @ $49.2
Continuous cropping (reducing fallow)	Antle et al. (2001) Antle et al. (2007)	Northern US Great Plains Central US	44.9 @ $14.4 63.4 @ $28.7 2.23 @ $16.35 2.85 @ $27.25
Afforestation			
Afforestation	Lewandrowski et al. (2004)	US agriculture sector	265.7 @ $13.62 74.1 from cropland 191.6 from grassland 488.8 @ $34.06 147.2 from cropland 341.7 from grassland
	EPA (2005)	US agriculture and forestry sectors	In 2015: 145 @ $15.00 557 @ $30.00 In 2025: 228 @ $15.00 806 @ $30.00
	Lubowski et al. (2006)	US land base	734 – 917 @ $13 2,110-2,899 @ $27.2 (range shows with & without harvests)
Forest Management			
Forest management (e.g., extend rotations, thin, and fertilize)	EPA (2005)	US agriculture and forestry sectors	In 2015: 227 @ $15.00 271 @ $30.00 In 2025: 156 @ $15.00 250 @ $30.00

* Some values have been derived from numerical results or interpreted off of graphs in associated publications. Some studies report results in units of carbon. In this table, all GHG values have been converted to metric tons of CO_2.

Table 2. EPA Estimated Allowance Prices

Year	2015	2020	2025	2030	2035	2040	2045	2050
Allowance Price ($2005 per ton CO_2eq)								
	$12.64	$16.31	$20.78	$26.54	$33.92	$43.37	$55.27	$70.40

Source: USEPA. EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the *111th Congress*. June 23, 2009.

Table 3. Agricultural Offsets - by Source, Quantity, and Gross Offset Revenue

	2015	2020	2025	2030	2035	2040	2045	2050
Agricultural Offsets (MMT CO_2eq per year)								
Afforestation	48	132	146	170	307	372	368	344
Animal Wastes CH4	3	4	6	8	10	12	17	25
Other Ag CH4 & N2O	8	12	15	19	26	35	44	53
Ag Soils	0	0	0	0	0	0	0	0
Total	**59**	**148**	**167**	**197**	**342**	**419**	**429**	**422**
Annual Gross Offset Revenue ($2004 billion)								
Afforestation	0.6	2.1	3.0	4.5	10.4	16.1	20.3	24.2
Animal Wastes CH4	0.0	0.1	0.1	0.2	0.3	0.5	1.0	1.8
Other Ag CH4 & N2O	0.1	0.2	0.3	0.5	0.9	1.5	2.4	3.8
Ag Soils	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.8**	**2.4**	**3.5**	**5.2**	**11.6**	**18.1**	**23.7**	**29.7**

USDA analysis based on FASOM simulations provided by EPA.

Table 4. Annual Agricultural Offsets and Gross Offset Revenue by Region

Year	2015	2020	2025	2030	2035	2040	2045	2050
Agricultural Offsets (MMT CO_2eq per year)								
U.S. Total	59.0	148.4	167.5	197.4	342.4	419.0	429.0	422.0
Corn Belt	26.5	70.8	82.4	79.3	109.0	138.0	127.1	141.7
Great Plains	5.4	7.5	8.5	8.8	10.3	20.0	28.6	37.0
Lake States	16.8	36.4	48.5	47.7	70.4	96.0	92.0	108.9
Northeast	1.5	6.4	10.4	15.0	35.7	53.0	49.4	45.0
Rocky Mountains	4.9	6.2	9.6	10.0	13.5	19.6	24.2	39.2
Pacific Southwest	1.9	2.1	3.4	1.3	2.1	2.2	1.6	2.4
Pacific Northwest	0.7	0.8	0.7	0.7	1.0	1.3	1.2	3.0
South Central	0.1	15.9	0.9	24.4	86.0	68.7	69.9	15.4
Southeast	0.0	0.9	1.0	7.7	9.9	17.1	32.1	25.0
South West	1.3	1.4	2.0	2.5	4.3	3.1	3.0	4.4
Annual Gross Offset Revenue ($2004 billion)								
U.S. Total	$0.8	$2.4	$3.5	$5.2	$11.6	$18.1	$23.7	$29.7
Corn Belt	0.3	1.2	1.7	2.1	3.7	6.0	7.0	10.0
Great Plains	0.1	0.1	0.2	0.2	0.4	0.8	1.6	2.6
Lake States	0.2	0.6	1.0	1.3	2.4	4.1	5.1	7.7
Northeast	0.0	0.1	0.2	0.4	1.2	2.3	2.7	3.2
Rocky Mountains	0.1	0.1	0.2	0.3	0.5	0.9	1.3	2.8
Pacific Southwest	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.2
Pacific Northwest	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
South Central	0.0	0.3	0.0	0.7	2.9	3.0	3.9	1.1
Southeast	0.0	0.0	0.0	0.2	0.3	0.7	1.8	1.8
South West	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.3

USDA analysis based on FASOM simulations provided by EPA.
Totals may not add due to rounding.

Table 5. National Changes in Land Use.

	2015	2020	2025	2030	2035	2040	2045	2050
Million Acres								
Forest	8.3	16.6	20.3	26.6	34.4	43.6	55.4	59.0
Cropland	0.1	-6.0	-10.2	-14.6	-21.0	-28.3	-32.5	-35.0
Pasture	-6.7	-8.5	-9.7	-12.0	-13.3	-15.3	-22.8	-24.0

USDA analysis based on FASOM simulations provided by EPA.

Table 6. Regional Changes in Acres.

	2015	2020	2025	2030	2035	2040	2045	2050
Forest (million acres)								
Corn Belt	2.9	4.9	6.9	9.7	13.5	16.3	20.1	22.5
Great Plains	--	--	--	--	--	--	--	--
Lake States	1.7	3.1	4.9	7.0	8.7	10.6	13.4	15.1
Northeast	-0.1	1.1	1.9	2.5	3.2	3.2	3.2	2.4
Rocky Mountains	2.3	3.4	4.0	4.7	5.5	6.2	7.0	7.7
Pacific Southwest	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Pacific Northwest	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
South Central	1.2	3.3	2.1	2.0	2.8	6.0	10.4	10.0
Southeast	-0.1	0.4	0.2	0.3	0.4	1.2	1.2	1.1
South West	--	--	--	--	--	--	--	--
Cropland (million acres)								
Corn Belt	-2.3	-4.2	-6.3	-8.5	-12.2	-15.5	-18.1	-20.6
Great Plains	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	1.7	1.7
Lake States	-1.2	-2.2	-4.0	-5.2	-6.9	-8.7	-10.5	-12.1
Northeast	0.6	0.0	-0.7	-1.2	-1.5	-1.5	-1.5	-1.9
Rocky Mountains	-0.4	-1.0	-1.6	-2.3	-3.1	-3.8	-4.6	-5.3
Pacific Southwest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pacific Northwest	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
South Central	-0.2	-2.0	-2.1	-2.1	-2.1	-3.1	-7.0	-6.4
Southeast	0.6	0.3	1.4	1.7	1.7	1.1	1.2	1.2
South West	3.1	3.1	3.1	3.1	3.1	3.1	6.0	8.2
Pasture (million acres)								
Corn Belt	-0.5	-0.4	-0.4	-1.1	-1.0	-0.6	-1.8	-1.8
Great Plains	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-3.8	-3.8
Lake States	0.0	-0.2	-0.2	-1.1	-1.1	-1.2	-2.2	-2.2
Northeast	-0.5	-1.1	-1.2	-1.2	-1.7	-1.7	-1.7	-0.5
Rocky Mountains	-1.2	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Pacific Southwest	-0.2	-0.2	-0.2	-0.2	-0.2	0.0	0.0	0.0
Pacific Northwest	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
South Central	0.7	0.4	0.4	0.2	-0.7	-3.0	-3.4	-3.6
Southeast	0.3	0.1	-1.1	-1.6	-1.7	-1.9	-2.0	-1.9
South West	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-6.0	-8.2

USDA analysis based on FASOM simulations provided by EPA.

Note: FASOM does not allow afforestation in the Great Plains and Southwest regions and does not allow agriculture in the west side of the Pacific Northwest region.

Table 7. Crop Production Impacts

Crop (unit)		2015	2020	2025	2030	2035	2040	2045	2050
		millions							
Cotton (bales)	Baseline	16.1	18.0	18.6	18.6	19.6	19.9	20.6	20.8
	Scenario	16.3	17.3	17.9	18.3	19.1	18.8	17.7	18.2
	% Change	1.2	-3.9	-3.6	-1.5	-2.7	-5.3	-14.1	-12.5
Corn (bushels)	Baseline	14,222	14,619	15,585	16,520	17,536	17,547	18,274	20,627
	Scenario	14,022	14,212	14,735	15,326	15,852	16,003	15,794	16,109
	% Change	-1.4	-2.8	-5.5	-7.2	-9.6	-8.8	-13.6	-21.9
Soybeans (bushels)	Baseline	2,609	2,671	2,734	2,777	2,888	2,818	2,861	2,848
	Scenario	2,518	2,539	2,534	2,527	2,481	2,319	2,126	2,028
	% Change	-3.5	-5.0	-7.3	-9.0	-14.1	-17.7	-25.7	-28.8
Wheat (bushels)	Baseline	2,433	2,509	2,601	2,660	2,795	3,108	3,212	3,412
	Scenario	2,433	2,498	2,563	2,611	2,724	2,988	3,059	3,065
	% Change	0.0	-0.4	-1.5	-1.8	-2.6	-3.8	-4.8	-10.2
Sorghum (bushels)	Baseline	522	317	300	289	307	304	315	333
	Scenario	588	325	304	297	303	262	262	251
	% Change	12.7	2.6	1.3	2.8	-1.4	-13.7	-16.9	-24.5
Rice (cwt)	Baseline	273	346	391	444	484	536	590	632
	Scenario	237	306	334	359	397	419	440	474
	% Change	-13.1	-11.4	-14.5	-19.2	-18.0	-21.7	-25.3	-25.1
Oats (bushels)	Baseline	114	96	104	114	134	190	212	217
	Scenario	127	102	100	108	110	140	154	149
	% Change	11.4	6.0	-3.8	-5.1	-18.1	-26.1	-27.2	-31.5
Barley (bushels)	Baseline	310	283	296	312	342	398	400	428
	Scenario	324	285	293	309	314	358	375	363
	% Change	4.8	0.8	-1.1	-1.0	-8.4	-10.1	-6.2	-15.2

USDA analysis based on FASOM simulations provided by EPA.

Table 8. Crop Price Impacts

		2015	2020	2025	2030	2035	2040	2045	2050
	$2004 per unit								
Cotton ($/bale)	Baseline	273.45	241.60	241.60	258.62	249.79	263.67	267.94	278.53
	Scenario	267.71	259.38	260.11	264.20	264.20	287.80	339.60	347.10
	% Change	-2.1	7.4	7.7	2.1	5.8	9.2	26.8	24.6
Corn ($/bu)	Baseline	4.03	4.03	3.63	3.26	2.97	2.72	2.61	2.50
	Scenario	4.32	4.50	4.05	3.77	3.53	3.19	3.14	3.21
	% Change	7.2	11.5	11.4	15.4	19.0	17.3	20.6	28.1
Soybeans ($/bu)	Baseline	9.04	9.03	9.01	9.00	8.85	8.83	8.71	8.79
	Scenario	9.04	9.03	9.02	9.06	9.07	9.06	9.81	10.63
	% Change	0.0	0.0	0.1	0.7	2.5	2.6	12.7	20.9
Wheat ($/bu)	Baseline	5.40	5.10	5.03	4.80	4.59	4.50	4.31	4.11
	Scenario	5.35	4.85	4.95	4.94	4.76	4.94	4.78	4.66
	% Change	-0.9	-4.9	-1.6	3.0	3.7	9.8	10.9	13.4
Sorghum ($/bu)	Baseline	7.73	5.99	6.27	5.98	5.92	7.39	7.97	8.12
	Scenario	7.77	5.96	6.01	6.17	6.02	8.13	9.68	11.35
	% Change	0.5	-0.5	-4.2	3.2	1.6	10.0	21.4	39.8
Rice ($/cwt)	Baseline	7.30	6.87	6.51	6.24	5.97	5.80	5.57	5.29
	Scenario	7.42	6.97	6.77	6.58	6.29	6.14	5.89	5.72
	% Change	1.6	1.5	4.0	5.5	5.3	5.9	5.8	8.1
Oats ($/bu)	Baseline	1.35	1.96	1.41	1.01	0.47	1.15	0.47	0.72
	Scenario	1.42	1.43	1.49	1.10	0.95	1.44	1.04	1.04
	% Change	5.5	-27.1	5.9	8.9	100.5	25.3	120.0	45.1
Barley ($/bu)	Baseline	2.92	3.24	3.32	3.53	3.76	3.36	4.78	5.50
	Scenario	2.99	2.80	3.28	3.53	4.33	4.51	5.32	8.61
	% Change	2.5	-13.6	-1.1	0.0	15.0	34.2	11.3	56.5

USDA analysis based on FASOM simulations provided by EPA.

Table 9. Livestock Production Impacts

		2015	2020	2025	2030	2035	2040	2045	2050
	Million cwt except eggs (million dozen)								
Fed Beef	Baseline	510	525	547	555	560	614	640	649
	Scenario	508	507	523	536	546	576	591	587
	% Change	-0.4	-3.5	-4.4	-3.4	-2.6	-6.1	-7.7	-9.6
Hogs	Baseline	453	474	518	555	615	647	674	699
	Scenario	427	437	481	500	525	547	557	541
	% Change	-5.7	-7.9	-7.2	-9.9	-14.6	-15.3	-17.3	-22.7
Milk	Baseline	2,017	2,153	2,243	2,420	2,547	2,654	2,773	2,911
	Scenario	2,005	2,095	2,181	2,255	2,329	2,427	2,410	2,418
	% Change	-0.6	-2.7	-2.8	-6.8	-8.6	-8.6	-13.1	-16.9
Eggs	Baseline	7,506	7,749	8,000	8,259	8,615	8,803	9,088	9,480
	Scenario	7,467	7,629	7,945	8,212	8,483	8,696	8,994	9,285
	% Change	-0.5	-1.6	-0.7	-0.6	-1.5	-1.2	-1.0	-2.1
Broilers	Baseline	471	484	514	540	568	596	618	643
	Scenario	466	481	506	531	557	579	593	596
	% Change	-1.0	-0.7	-1.6	-1.6	-1.8	-2.8	-4.1	-7.3
Turkeys	Baseline	92	105	111	124	130	137	146	154
	Scenario	92	102	109	114	122	133	136	142
	% Change	0.1	-3.1	-2.1	-8.2	-6.3	-2.7	-6.9	-7.6

USDA analysis based on FASOM simulations provided by EPA.

Table 10. Livestock Price Impacts

Product		2015	2020	2025	2030	2035	2040	2045	2050
	$2004 per unit								
Fed Beef ($/cwt)	Baseline	57.60	58.57	57.91	60.24	62.07	58.12	58.10	60.17
	Scenario	58.29	61.07	61.53	62.58	64.30	63.45	65.04	68.79
	% Change	1.2	4.3	6.3	3.9	3.6	9.2	11.9	14.3
Hogs ($/cwt)	Baseline	41.77	40.42	38.73	37.43	36.44	36.97	35.29	36.19
	Scenario	43.60	44.08	42.38	41.96	41.64	41.29	43.13	45.94
	% Change	4.4	9.0	9.4	12.1	14.3	14.8	22.2	26.9
Milk ($/cwt)	Baseline	15.51	14.78	14.65	13.90	13.45	13.41	12.98	12.98
	Scenario	15.72	15.49	15.44	15.51	15.68	15.58	16.21	17.27
	% Change	1.4	4.8	5.4	11.5	16.6	16.2	24.9	33.1
Eggs ($/dz)	Baseline	0.92	0.96	0.90	0.94	0.88	0.92	0.89	0.87
	Scenario	0.96	1.02	1.01	0.97	0.97	1.03	1.03	1.05
	% Change	4.2	6.3	12.1	2.6	10.8	12.5	15.3	19.9
Broilers ($/cwt)	Baseline	49.01	49.23	47.63	46.56	45.16	44.56	44.65	44.06
	Scenario	49.65	50.30	48.88	47.79	47.05	46.77	48.54	51.09
	% Change	1.3	2.2	2.6	2.6	4.2	5.0	8.7	16.0
Turkeys ($/cwt)	Baseline	46.03	39.21	38.96	33.40	32.56	31.00	31.00	28.96
	Scenario	46.03	41.28	39.25	38.21	36.14	33.46	33.85	33.29
	% Change	0.0	5.3	3.4	14.4	11.0	8.0	9.2	14.9

USDA analysis based on FASOM simulations provided by EPA.

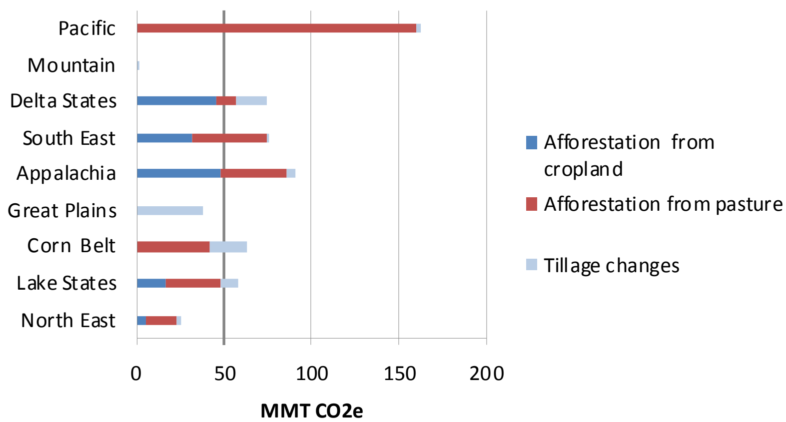
Table 11. Annuity Impacts on Producer Surplus/Farm Income, by Region.

	$2004 billion annualized annuity value	% of total
Corn Belt	6.4	29.3
Great Plains (no forestry)	2.9	13.3
Lake States	1.6	7.3
Northeast	0.4	1.8
Rocky Mountains	1.5	6.7
Pacific Southwest	0.7	3.3
Pacific Northwest	0.7	3.3
South Central	2.3	10.4
Southeast	3.4	15.6
South West (no forestry)	1.9	8.9
U.S. Total	22	100

USDA analysis based on FASOM simulations provided by EPA.

Figure 1a--Regional Potential

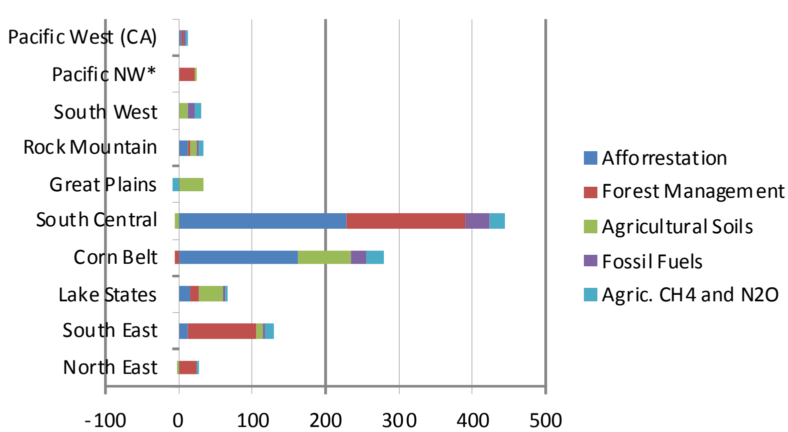
(carbon price of $34/MT CO2e)



Source: USDA, ERS. 2004

Figure 1b--Regional Potential

(carbon price of $30/MT CO2e)



Source: EPA 2005

Figure 2. FASOM Regional Map