

Greenhouse Gas Mitigation Through Energy Crops in the U.S.
With Implications for Asian-Pacific Countries

Uwe A. Schneider

Research Associate

Department of Economics

Center for Rural and Agricultural Development

Iowa State University

Bruce A. McCarl

Professor

Department of Agricultural Economics

Texas A&M University

Seniority of authorship is shared

November 2001

Greenhouse Gas Mitigation Through Energy Crops in the U.S.

With Implications for Asian-Pacific Countries

Demand for agricultural participation in greenhouse gas (GHG) emission mitigation efforts has increased in recent years. While the original text of the Kyoto Protocol only considered carbon changes from deforestation, reforestation, and afforestation, subsequent efforts were made to determine agriculture's contribution in a broader spectrum (Intergovernmental Panel of Climate Change meetings in Buenos Aires, Bonn). Discussion has now focused on how to involve agriculture rather than if to involve agriculture.

Planting energy crops is one of many agricultural options under consideration. Crops such as switchgrass, short rotation woody trees, eucalyptus, and a variety of ethanol generating plants can generate alternative biomass based energy and thus reduce the amount of fossil fuel based, GHG emission intensive energy. While other agricultural GHG mitigation options such as switching tillage systems or planting permanent trees saturate over time, GHG emission offsets from energy crops can be supplied continuously. Furthermore, emission offsets from energy crops are generally easier to implement than other agricultural emission abatement strategies. For example, if a carbon market or a government institution prices one ton of carbon emissions to be worth \$50, all fossil fuel input going into energy crop production will most likely carry this price through increased purchasing cost and all energy output will receive revenue based on the amount of fossil fuel energy offset. The net effect to the energy producer is the difference between increased revenue and increased cost.

Substantial research has been conducted in the U.S. and Canada on energy crops (Walsh et al., Mann and Spath, Wang, Saricks, and Santini, Samson and Duxbury). These studies, however did not account for tradeoffs between the production of energy crops and other agricultural mitigation strategies. This analysis estimates the economic feasibility of energy crops in the U.S. in an environment where all major agricultural mitigation strategies are incorporated simultaneously.

Greenhouse gas emissions constitute a global problem, which is not limited to the U.S. but also involves countries in Asian Pacific. In contrast to the U.S. and Canada however, research on energy crops has been very limited in many Asian-Pacific countries. Here, the authors try to extrapolate results from the U.S. model to these countries. To reflect Asian Pacific characteristics, a sensitivity analysis is conducted on key parameters of the U.S. model, which might differ between the U.S. and Asian Pacific countries.

Background

Energy crops have been explored in the U.S. since 1978 (U.S. DOE, 2001) about 20 years before the Kyoto Protocol was established. Major initial objectives involved reducing the dependency on foreign petroleum reserves and providing cleanly burning fuels. The potential to mitigate emissions of clean gases such as carbon dioxide was not emphasized until the 1990s when countries started to seriously negotiate greenhouse gas emission reduction programs.

Almost all energy crops produced in the U.S. today are still subsidized. Ethanol suppliers receive, on average, a \$0.54 per gallon subsidy, which is even greater than the 1998/1999 wholesale price of gasoline of \$0.46 per gallon (Yacobucci and Womach).

Governmental incentives to promote biomass power include project co-funding; various tax credits, deductions and exemptions, as well as direct subsidy payments (Badin and Kirschner).

Greenhouse gas emission mitigation efforts could improve the economics of energy crop production. If a market or governmental institution values carbon emission savings, energy crops would yield additional revenues equal to carbon price times net emission savings relative to an energy equivalent amount of fossil fuel. The question then becomes what carbon price level is needed to make energy crops economically feasible? In answering this question one must analyze both energy crop possibilities and traditional agricultural production (Schneider) because:

- 1) Large-scale production of energy crops would substantially reduce the amount of land devoted to traditional food and fiber crops. As a consequence, aggregate food and fiber production would most likely fall, causing commodity prices and land values to rise. The increased opportunity cost as reflected by higher land values may cause a strong negative feedback to large-scale efforts on promotion of energy crops.
- 2) General mitigation incentives will encourage a variety of agricultural strategies. McCarl and Schneider (1999 and 2000) grouped agricultural GHG mitigation options into three broad categories: a) reductions in agricultural based emissions for example through diminished use of fossil fuels, fossil fuel intensive inputs, or livestock herd size reductions; b) enlargements of agricultural based sinks for example through afforestation or tillage changes,

and c) increased production of commodities such as energy crops which offset emissions in other sectors of the economy.

Some agriculture mitigation strategies are mutually exclusive, some are complementary, and most interfere with traditional agricultural production. Hence, an independent analysis of a large-scale production of energy crops would most likely overestimate the economic potential.

The U.S. Agricultural Sector Model

For this analysis we used a new version of the U.S. Agricultural Sector Model (ASM, McCarl et al.). ASM was first developed in the mid-1970s and has been used in many economic appraisals regarding environmental policies in the U.S. (see Chang et al. for references). Schneider modified ASM to include GHG emission accounting and mitigation possibilities. This GHG augmented version is employed for this analysis and will hereafter be referred to as ASMGHG.

Scope of ASMGHG

ASMGHG depicts production in 63 U.S. agricultural sub-regions endogenizing crop choice, irrigation choice, livestock numbers, and livestock management. Commodity coverage is broad with more than 30 commodities considered including the major U.S. feed and food grains, oilseeds, fiber, hay, silage, sweetener, cattle, sheep, poultry, dairy and hog commodities. Production of eight major internationally traded commodities in 28 rest-of-the-world regions is included with detailed international trade depiction for those commodities. Trade and consumption of more than 50 other commodities are modeled at a more aggregate level. Production is gathered together into

ten U.S. marketing regions and in turn shipped on to processing, consumption, or international markets.

ASMGHG solutions provide projections of land use and commodity production within the 63 U.S. areas, commodity production in the rest of the world, international trade, crop and livestock commodity prices, processed commodity prices, agricultural commodity consumption, producer income effects, consumer welfare effects, and various environmental impacts.

Greenhouse Gas Features in ASMGHG

ASMGHG jointly incorporates all major GHG emission mitigation options available to agriculture (McCarl and Schneider, 2001). For this study we considered only potential strategies, which are currently feasible. There are other strategies, which may become practical in the near future as technology advances. However, we did not want to speculate as to when this might happen. Engineers are often overly optimistic about new technologies not taking into account economics. Currently included strategies are listed below. Schneider provides a detailed technical description of how these strategies are implemented in ASMGHG.

ASMGHG mitigation strategies through the agricultural sector:

- Afforestation,
- Production of energy crops for use in electrical power plants,
- Production of ethanol to replace fossil fuel based gasoline,
- Soil carbon sequestration through crop, tillage, irrigation, and fertilization choice or through conversion of arable land into permanent grassland,

- Reduction in crop management emissions through alternative crop mix, fertilizer, irrigation, tillage intensities,
- Methane reductions through livestock herd size reduction, livestock, manure system improvements, enteric fermentation changes, and rice acreage reduction, and
- Reduction in nitrous oxide emissions from livestock herd size reductions, and alternative fertilization, crop and tillage choice.

Each individual emission and emission reduction category is individually accounted for but also aggregated into a measure of total carbon equivalents. To place different gases on an equal footing, methane and nitrous oxide are converted to carbon equivalents based on the IPCC 100-year global warming potentials (GWP), which are 21 for methane, 310 for nitrous oxide, and 44/12 for carbon.

ASMGHG can examine the impact of various mitigation policies on the agricultural sector. At each incentive level, it identifies the optimal choice of mitigation strategy. In addition, impacts on the traditional agricultural sector are reported.

Economic Feasibility of Energy Crops in the United States

Competitive feasibility of major GHG emission mitigation strategies was simulated by running ASMGHG under a wide range of carbon equivalent prices imposed on net emissions from agriculture. For emissions of non-carbon GHGs, prices were adjusted based on the GWP of the affected GHG relative to carbon. In addition, carbon credits from soil carbon sequestration and afforestation were value-discounted to reflect the saturating nature of these carbon sinks. McCarl and Murray provide a detailed description along with examination of many alternative setups. We chose an average

setup leading to a 25 percent value discount for sequestered tree carbon and a 50 percent value discount for sequestered soil carbon (Schneider and McCarl). Thus, at a hypothetical carbon price of \$20 per TCE, land owners would receive \$20 for each ton of offset carbon emissions, \$10 for each ton of sequestered soil carbon, and \$15 for each ton of carbon sequestered through afforestation and they would pay each ton emitted with \$20 for carbon, \$114.55 for methane, and \$1690.91 for nitrous oxide.

Major Impacts of Agricultural GHG Emission Mitigation Incentives

Figure 1 displays the resultant levels of emission abatement from agricultural mitigation strategies (see also Table 1). Unsubsidized energy crops as identified by current technologies are not competitive at zero carbon prices. Economic feasibility of biofuel crops begins at carbon prices around \$40 per ton of carbon equivalent.

Furthermore, energy crops used as electrical power plant feedstock are more competitive than crops processed into gasoline substitutes such as ethanol.

Under low carbon prices, agricultural management changes, i.e. tillage changes, are the preferred option. Above carbon incentives of \$70 per ton of carbon equivalent, emission offsets from bioelectricity generating crops dominate all agricultural mitigation strategies. For prices above \$250 per TCE, the afforestation share increases partially at the expense of bioelectricity generation. For extremely high carbon prices the model favors mitigation options with the highest carbon saving potential per acre, outweighing high operation and implementation costs of these strategies. However, the highest carbon net emission reduction may involve different strategies in different regions.

The results (Table 1) also show that large-scale agricultural mitigation efforts divert farmland, reduce traditional crop and livestock production and exports, increase

prices, and changes agricultural welfare distribution with producers likely to gain and consumers likely to lose. In addition, GHG mitigation efforts have a mostly positive impact on other environmental externalities related to agriculture such as erosion and water pollution.

Economic versus Technical Potential

An important concept when regarding biofuel production involves potential to mitigate GHG emissions. Physical scientists often quote very large estimates of potential but these estimates typically neglect the cost of achieving that potential. We used ASMGHG under three settings to derive alternative measures of potential. The first represents technical potential, the second economic potential when considering biofuels as the only mitigation option, and the third competitive economic potential when considering all mitigation options simultaneously.

The technical potential estimate was obtained by changing ASMGHG's objective function from maximizing total economic surplus to maximizing bioelectricity based emission offsets thereby disregarding economics. This yields substantial emission offsets in the amount of 212 MMTCE annually (Figure 2). The single strategy economic potential takes into account all cost of bioelectricity generation except for the opportunity cost related to other possible agricultural mitigation strategies. Under such setting, a relatively high carbon price of \$100 per TCE would only achieve 129 MMTCE emission reduction or 61 percent of the technical potential. Finally, all agricultural mitigation options were incorporated to find the competitive economic potential. This method yields fewest emission offsets because implementation of other mitigation strategies limits the extent to which biofuel crops can be grown. At \$100 per TCE, biofuels would

reduce carbon emissions by 115 MMTCE, about 54 percent of biofuels' technical potential.

The gap in the results between single strategy and competitive economic potential is reflective of inter-strategy competition and relative advantage. Some strategies are superior in some price ranges. The differences between the two economic measures of potential are most notable for high carbon prices (Figure 2).

Sensitivity Analysis on Key Parameters of the U.S. Model

Agriculture in the U.S. is certainly very different from agriculture in Asian-Pacific countries. Differences exist with respect to soil, climate, culture-based preferences, per capita land availability, technology, and international market competition (FAO). To illustrate these differences we conducted a sensitivity analysis on a few decisive model parameters of the U.S. agricultural sector model.

Biomass Yield

The competitiveness of energy crops depends on many technological parameters. We chose to examine alternative energy crop yields, ranging from 50 to 200 percent of current U.S. yield estimates. Asian Pacific biomass producers in moist tropical regions may benefit from generally higher plant productivity compared to the U.S. but could also experience lower productivity due to production conditions and altered input mixes. Duke, for example, reports U.S. comparable or higher biomass yields in Asian-Pacific countries for eucalyptus and guineagrass (hamilgrass).

Results show a strong impact of energy crop yields on supply of emission offsets (Figure 3). In most cases, increased (decreased) yields lead to more than proportional

increases (decreases) in biomass emission offsets. For example, at a carbon price of \$100 per TCE, energy crops offset about 115 MMTCE per year. A 50 percent yield increase leads to a 145 percent increase in emission offsets. In interpreting Figure 3 one should keep in mind that all yield increases were implemented without changing crop input parameters. If higher yields were based on higher input use the effects would be less significant.

The results from yield scenarios are not limited to crop yield differences. They can be applied to all technological improvement from farming to generation of bio-energy which increase the emission input / energy output ratio.

Energy Price

There are two sources of revenues for producers of energy crops: a) revenue from selling energy, i.e. electricity and b) potential revenue from carbon emission offsets associated with biomass energy. The potential carbon revenue could be a governmental subsidy or an emissions market based income source. If the country is a major energy importer, then its electricity price is determined by the international energy market price. Many Asian Pacific countries, i.e., Japan, South Korea, the Philippines, Taiwan, and Thailand import substantial amounts of energy (U.S. DOE). Because currency values differ between countries, the international market price may cause different incentives to grow biomass. For example, agricultural producers in energy importing countries with a relatively low domestic currency value would earn a higher relative revenue from selling electricity than would U.S. biomass producers. Similarly, revenues would be low if conventional energy is cheap (energy exporting countries or countries with high currency

value). In this study we examined alternative prices for conventional electricity ranging from 50 to 200 percent of the current U.S. market price.

The effect of energy price changes on the amount of bioelectricity emission offsets is depicted in Figure 4. Note that a 100 percent energy price increase results in much less additional emission offsets than does a 100 percent yield increase. This occurs because selling electricity is only one profit source besides revenues from supplying carbon offsets. If, for example, selling electricity contributes 25 percent to total profits, then a 20 percent energy price increase results only in a 5 percent total profit gain¹. As the carbon price increases, the electricity revenue becomes relatively less important and energy price changes have less effect on the amount of emission offsets supplied. For example, a doubling of the energy price increases carbon offsets by 54 percent at \$100 per TCE but only by 6 percent at \$150 per TCE (Figure 4).

The results on energy price sensitivity are useful beyond extrapolation of U.S. results to foreign countries. They indicate how energy crop's competitiveness changes as fossil fuel prices fluctuate in general. If the recent trend of increased fossil fuel prices continues, energy crop farming may soon be on the rise in the U.S. Furthermore, the results also indicate how higher or lower costs of energy crop strategies would affect their

¹ Suppose $p=e+c$, where p represents total profit, e represents energy revenue and c represents carbon offset revenue. Suppose further that the ratio of carbon revenue to energy revenue is known, i.e. $c/e=r$. Substitution yields the following identity: $p=e+er=(1+r)e$. If the energy revenue is increased by a factor f , the new profit (np) can be calculated as $np=te+c=te+er=(t+r)e$. Thus, $np/p=(t+r)/(1+r)$. Setting $r=3$, a 20 percent energy revenue increase ($t=2$) implies a total profit increase of 5 percent.

competitiveness because higher energy prices are equivalent to lower production and processing costs.

Demand Elasticities

Energy crop production on agricultural land takes away land from traditional agricultural operations. As discussed above, traditional agricultural food and fiber production will decrease raising prices. The extent to which prices increase may depend on the elasticity of demand for traditional agricultural commodities. ASMGHG explicitly defines demand curves for 48 primary agricultural products and more than 50 processed products. Each demand curve is specified as constant elasticity function. To assess the effect of higher or lower elasticities we increased and decreased demand elasticities across all primary agricultural products by a constant fraction ranging from 50 to 200 percent.

As Figure 5 shows, modifications of ASMGHG's demand elasticities have almost no impact on the amount of emission offsets supplied from energy crops. Similar results were obtained when altering export and import elasticities for traded agricultural commodities. Note that elasticities were equally modified across all commodities. In reality, elasticities in foreign countries may be higher or lower depending on the commodity in question.

Land Availability

The U.S. has a relatively large agricultural land base relative to its population (FAO). Taking food and fiber cropland away for the production of energy crops may thus be cheaper in the U.S. but more expensive in densely populated countries, which

heavily depend on domestic food production. To illustrate such differences we modified the available agricultural land base in the U.S. between 50 to 200 percent of its original value.

Figure 6 shows supply of bioelectricity emission offsets for different assumptions about the amount of available agricultural land. Not surprisingly, we find energy crops to be very sensitive to land availability. If the U.S. agricultural land base were cut in half, energy crops would not become profitable below carbon prices of \$200 per TCE (Figure 6). Less land implies less production, higher commodity prices, and thus higher revenues in the traditional agricultural sector. Consequently, farmers have to give up more by growing energy crops. Limited availability of agricultural land may be a major obstacle to grow energy crops in the Asian-Pacific area.

Conclusions

Energy crops supply fossil fuel alternatives and thereby have the potential to reduce greenhouse gas emissions. Economic feasibility implies that the energy output has to be greater than the energy input; otherwise growers could –in absence of subsidies– not yield a profit. The attractiveness of energy crops relative to fossil fuels depends on the overall net emission balance and the value of carbon offsets. In addition, growing energy crops must be economically superior to other possible GHG mitigation strategies.

Assessments of energy crops in the U.S. agricultural sector show that biomass based electricity (based on switchgrass or short rotation woody crops), while expensive, has considerable potential to offset carbon emissions. Emission offsets range between 1 to 2 metric tons per acre and year. However, a financial support of at least \$40 per ton

carbon equivalent (about \$20 per dry ton) is needed to make them economically feasible. Paying less than \$40 per ton of carbon offset induces other agricultural mitigation options, i.e. changes in tillage or afforestation. Ethanol generating energy crops turned out to be an inferior strategy over the whole range of analyzed carbon prices.

We also tried to generalize U.S. results through a sensitivity analysis on key parameters and to infer to Asian-Pacific countries. Results indicate that implementation of energy crops in the U.S. is highly sensitive to yields and land availability, sensitive to the price of energy under low and medium carbon prices, but relatively insensitive to demand elasticities of traditional agricultural commodities. With exception of Australia, and Russia, most of the Asian-Pacific countries have far less arable land per capita than has the U.S. (FAO). Allocation of currently cultivated land to energy crops in those countries would imply less land available to produce food. Shortages in domestic food supply, however, could only be offset through increased food imports. Thus, energy crops in most Asian-Pacific countries may not be economically feasible unless food imports are cheaper than energy imports.

Bibliography

- Badin, J. and J. Kirschner. "Biomass Greens U.S. Power Production." *Renewable Energy World* 1,3(November 1998):40-45.
- Chang, C.C., B.A. McCarl, J.W. Mjelde, and J.W. Richardson. "Sectoral Implications of Farm Program Modifications." *American Journal of Agricultural Economics*. 74(1992):38-49.
- Duke, J.A. "Handbook of Energy Crops.", unpublished, [Online]. Available at http://www.hort.purdue.edu/newcrop/duke_energy/dukeindex.html, 1983.
- FAO (Food and Agriculture Organization of the United Nations). FAOSTAT Statistics Database, [Online]. Available at <http://apps.fao.org>., 2000.
- IPCC. *Land Use, Land-use Change, and Forestry*. Special Report of the Intergovernmental Panel on Climate Change, Geneva Switzerland, Robert T. Watson, Ian R. Noble, Bert Bolin, N. H. Ravindranath, David J. Verardo and David J. Dokken (Eds.) Cambridge University Press, UK. pp 375, 2000.
- Mann, M.K. and P.L. Spath. *Life Cycle Assessment of a Biomass Gasification Combined-Cycle Power System*. National Renewable Energy Laboratory, Golden, CO, TP-430-23076. (1997).
- McCarl, B.A., C.C. Chang, J.D. Atwood, and W.I. Nayda, 'Documentation of ASM: The U.S. Agricultural Sector Model.' Unpublished Report, Texas A&M University, [Online]. Available at <http://ageco.tamu.edu/faculty/mccarl/asm.htm>, 2001.

- McCarl, B.A. and B.C. Murray. "Harvesting the Greenhouse: Comparing Biological Sequestration with Emissions Offsets", Department of Agricultural Economics, Texas A&M University, College Station, TX, 2001, [Online]. Available HTTP: ageco.tamu.edu/faculty/mccarl/papers/885.pdf.
- McCarl, B.A. and U.A. Schneider. "Curbing Greenhouse Gases: Agriculture's Role." *Choices*, First Quarter 1999:9-12.
- McCarl, B.A. and U.A. Schneider. "U.S. Agriculture's Role in a Greenhouse Gas Mitigation World: An Economic Perspective." *Review of Agricultural Economics* 22, No.1(2000):134-159.
- McCarl, B.A. and U.A. Schneider. "The Cost of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry." Forthcoming in *Science* (2001).
- Samson, R. and P. Duxbury. "Assessment of Pelletized Biofuels.", Resource Efficient Agricultural Production – Canada, Quebec, [Online]. Available HTTP: www.reap.ca/Reports/pelletaug2000.html, April 2000.
- Schneider, U.A. *Agricultural Sector Analysis on Greenhouse Gas Emission Mitigation in the U.S.*, PhD Dissertation, Department of Agricultural Economics, Texas A&M University, December 2000.
- Schneider, U.A. and B.A. McCarl. "Economic Potential of Biomass Based Fuels for Greenhouse Gas Emission Mitigation." Forthcoming in Special Issue of *Environmental and Resource Economics*.
- United Nations, Framework Convention on Climate Change. *Kyoto Protocol*. Climate Change Secretariat (UNFCCC). [Online]. Available at <http://www.unfccc.de/resource/convkp.html> (March 1998).

U.S. Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels. "Renewable Energy 2000: Issues and Trends."

[Online]. Available at http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/, February 2001.

U.S. Department of Energy, Energy Information Administration. Annual Energy Review 1999. [Online]. Available at <http://www.eia.doe.gov/emeu/aer/>, September 2000.

Walsh, M.E., D. de la Torre Ugarte, S. Slinsky, R.L. Graham, H. Shapouri, and D. Ray. "Economic Analysis of Energy Crop Production in the U.S. - Location, Quantities, Price and Impacts on the Traditional Agricultural Crops." *Bioenergy 98: Expanding Bioenergy Partnerships*, Madison Wisconsin, October 4-8, vol. 2 (1998):1302-1310.

Wang, W., C. Saricks, and D. Santini. *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions*. Center for Transportation Research, Argonne National Laboratory, ANL/ESD-38, January(1999).

Yacobucci, B.D. and J. Womach. "RL30369: Fuel Ethanol: Background and Public Policy Issues", The National Council for Science and the Environment, Washington, D.C., [Online]. Available at: <http://www.cnie.org/nle/eng-59.html>, March 2000.

Table 1 GHG Mitigation Policy Impact Summary from U.S. Agricultural Sector

Category	Carbon Price in \$ per TCE					
	10	20	50	100	200	500
Net GHG Emission Reductions from Major Agricultural Mitigation Accounts (1,000 TCE)						
Soil Carbon Sequestration	31,540	46,316	59,945	57,105	47,520	50,291
Afforestation	4,028	13,445	20,619	59,407	59,407	121,278
Electricity from Energy Crops	0	0	27,037	118,979	198,591	172,093
Subsidized Corn-Ethanol	2,893	2,893	2,893	2,893	2,893	2,893
Agricultural Inputs	2,303	3,608	5,687	7,116	9,105	12,977
Livestock CH ₄ + N ₂ O	417	875	4,428	9,826	11,301	22,330
Crop CH ₄ + N ₂ O	1,385	1,579	1,981	3,248	4,380	5,350
Total Net GHG Emission Reductions from U.S. Agriculture (MMTCE)						
Carbon Dioxide	37.9	63.4	112.2	237.7	306.5	349.7
Methane	0.5	0.8	5.0	13.3	17.9	24.7
Nitrous Oxide	1.4	1.6	2.5	4.7	5.9	9.9
Total Carbon Equivalents	39.7	65.8	119.7	255.7	330.3	384.3
U.S. Farmland Use (Million Acres)						
Traditional Crops	325.06	324.18	313.78	276.6	240.48	229.3
Pasture	395.95	393.22	388.85	373.77	374.24	322.58
Energy Crops	0	0	12.58	57.01	92.66	78.37
Afforestation	0	3.61	5.81	13.63	13.63	37.42
U.S. Agricultural Market Effects (Fisher Index)						
Crop Production	99.43	98.94	96.46	86.23	74.88	69.31
Crop Prices	100.52	101.02	106.36	129.18	162.07	211.84
Crop Net Exports	98.08	96.03	88.60	59.86	31.36	23.69
Livestock Production	99.92	99.62	97.19	91.80	88.47	75.71
Livestock Prices	100.18	100.19	103.77	119.86	142.10	182.87
Agricultural Welfare Changes (Billion \$)						
U.S. Farmers' Welfare	0.43	0.6	3.65	13.83	26.59	52.89
U.S. Ag-Consumers' Welfare	-0.39	-0.68	-4.39	-19.46	-41.23	-75.09
Foreign Ag-Sector Welfare	-0.14	-0.25	-1.05	-3.36	-4.81	-5.69
U.S. Ag-Sector Welfare	-0.11	-0.32	-1.8	-8.99	-19.45	-27.89
Other Agricultural Externalities from Traditional Crop Production (% Change per Acre)						
Erosion	-13.1	-25.5	-37.8	-44.3	-49.5	-48.2
Nitrogen Percolation	-8.1	-9.6	-17.0	-18.4	-21.1	-26.3
Nitrogen Subsurface Flow	-10.9	-11.4	-12.7	-11.2	-9.7	-12.3
Phosphorous Loss in Sediment	-23.0	-33.9	-45.2	-50.2	-54.3	-50.1

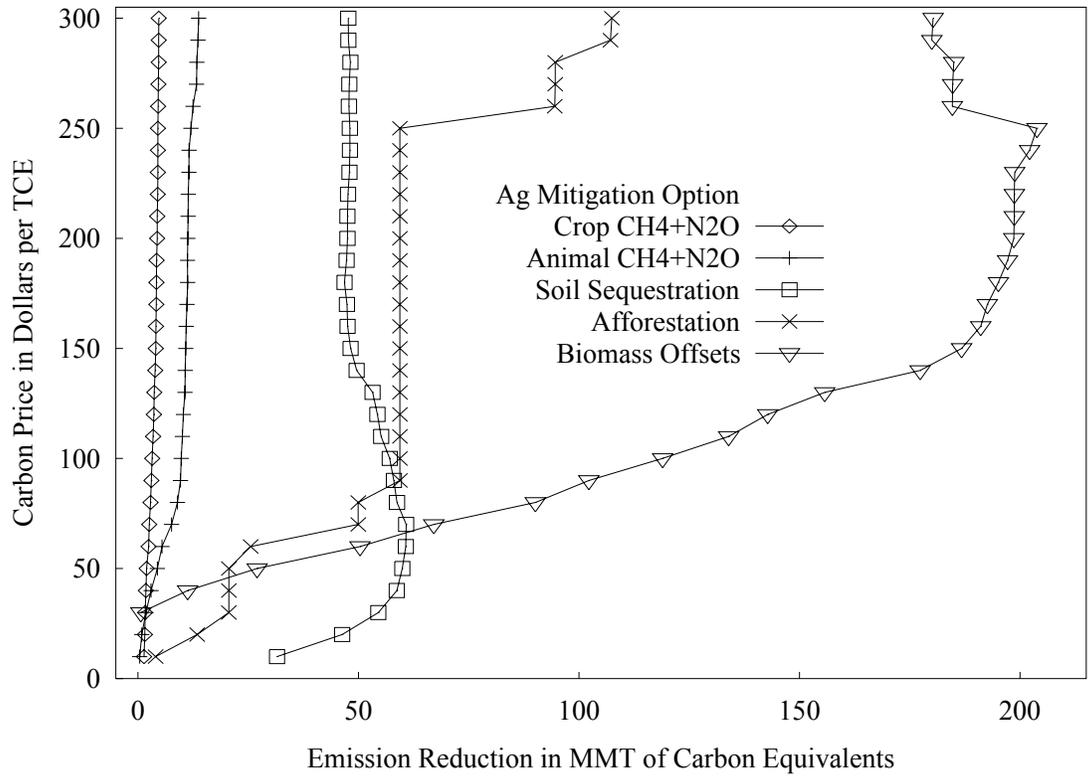


Figure 1 Role of Major Agricultural Strategies to Greenhouse Gas Mitigation at Selected Carbon Equivalent Prices

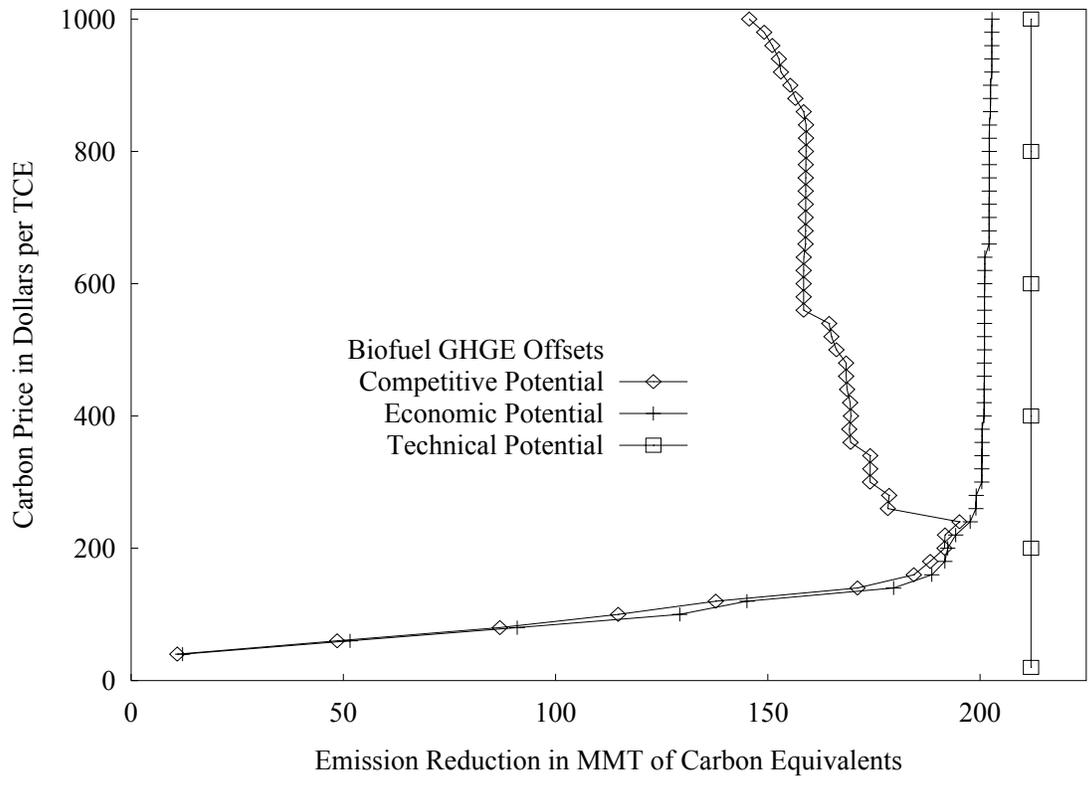


Figure 2 Comparison of Various Measures of Carbon Emission Mitigation Potential from Energy Crops

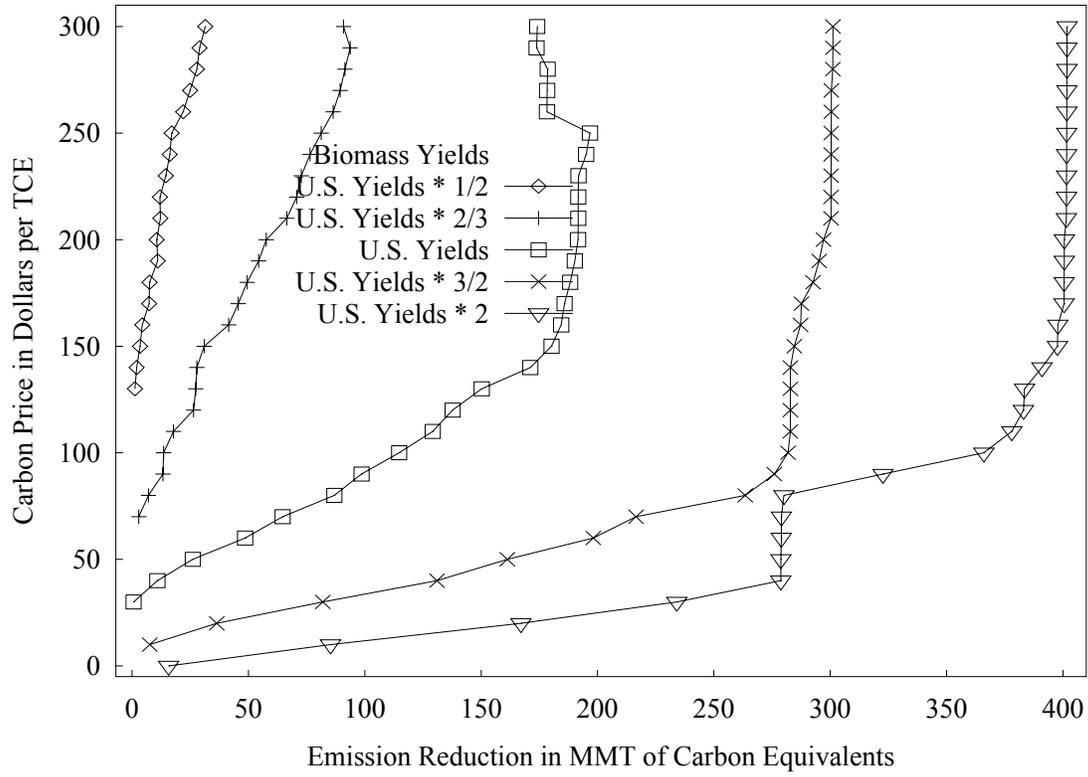


Figure 3 Changes in Amount of Emission Offsets Generated by Energy Crops When Energy Crop Yields are Altered

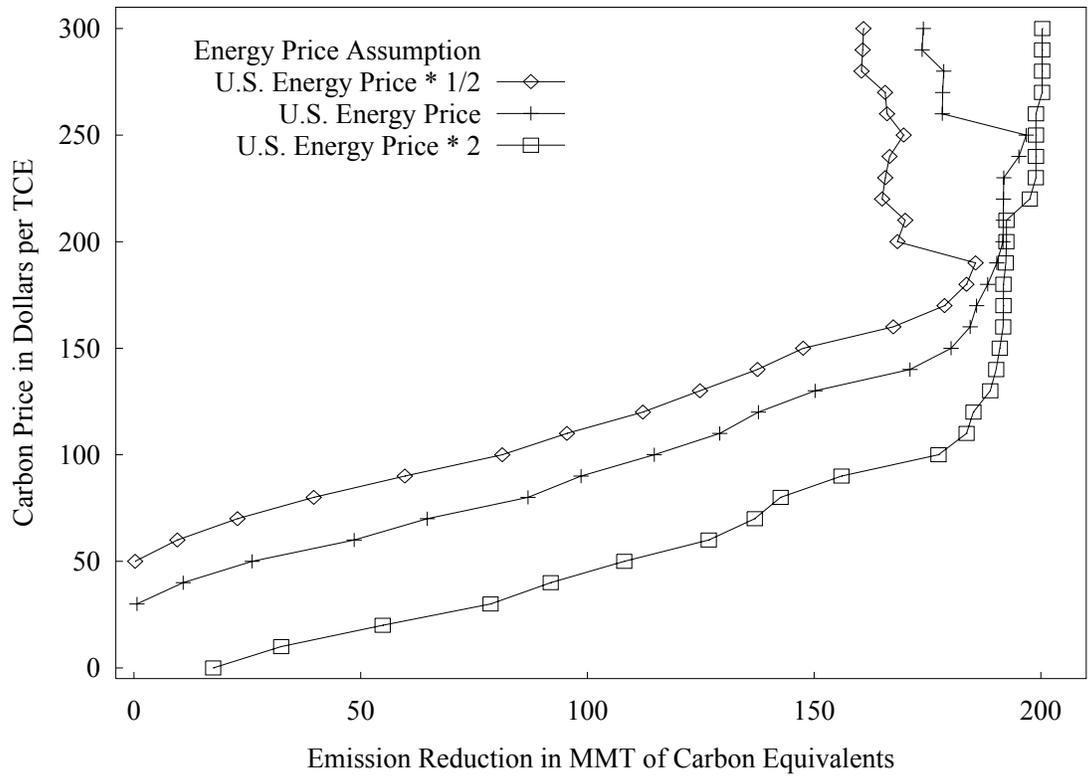


Figure 4 Changes in Amount of Emission Offsets Generated by Energy Crops When Electricity Prices are Altered

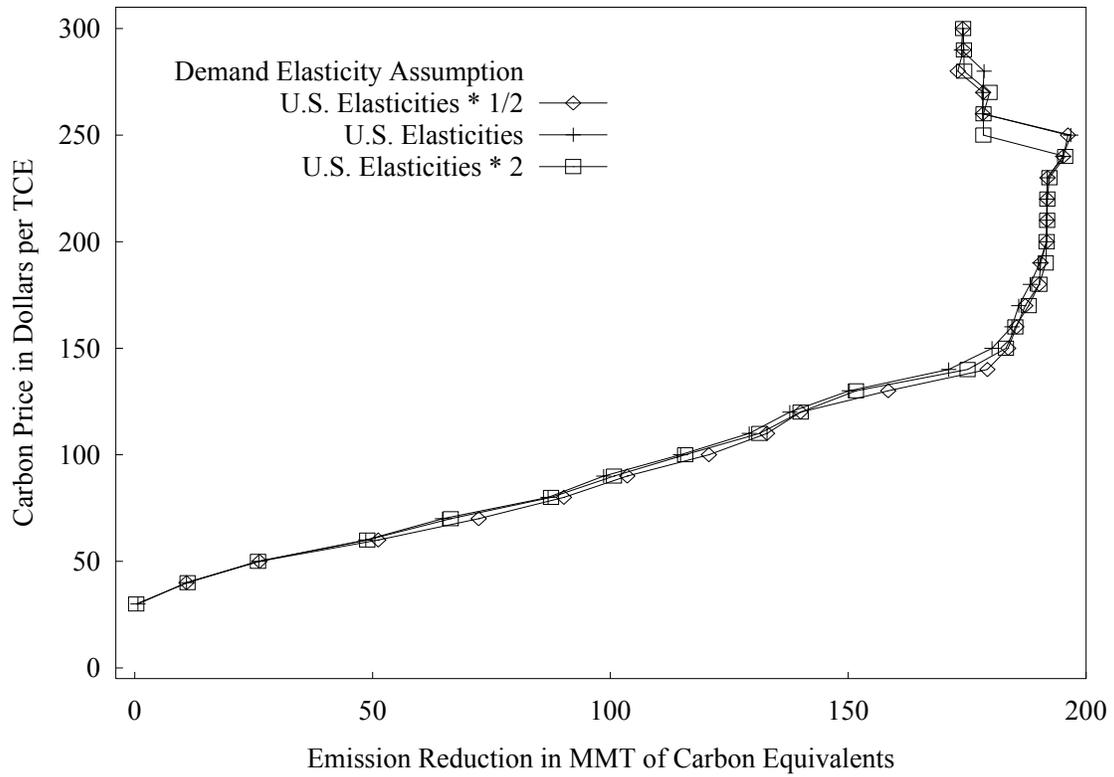


Figure 5 Changes in Amount of Emission Offsets Generated by Energy Crops When Domestic Agricultural Demand Elasticities are Altered

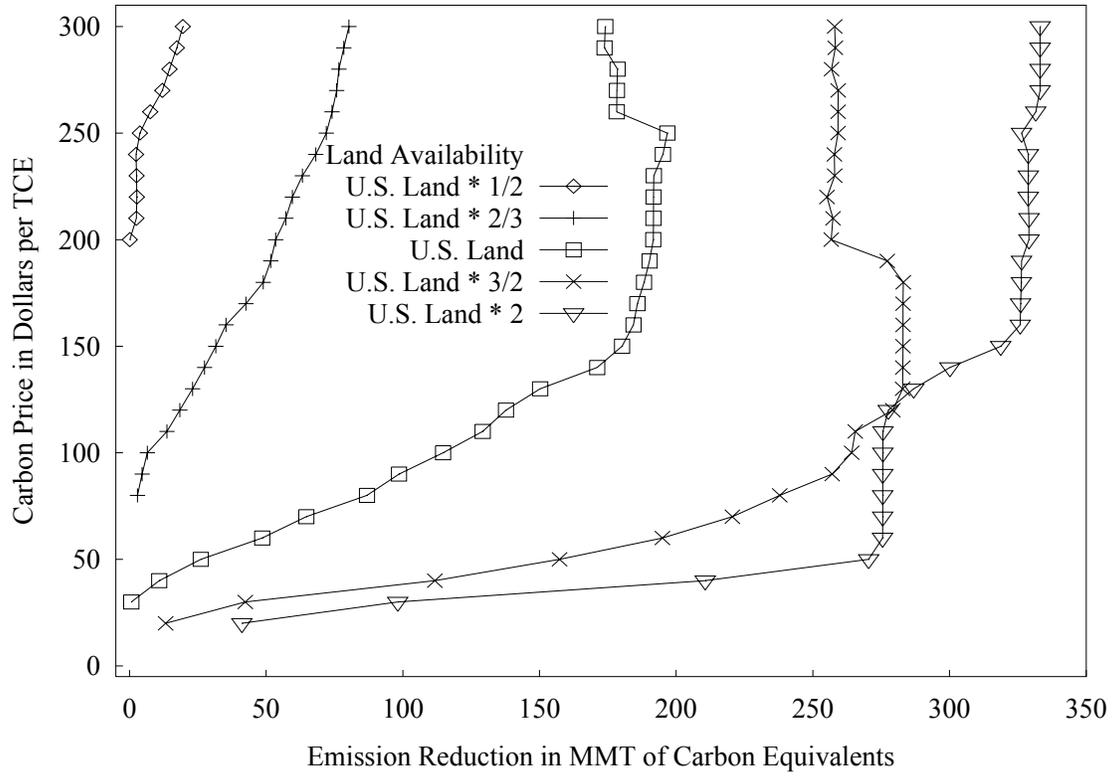


Figure 6 Changes in Amount of Emission Offsets Generated by Energy Crops when Land Availability is Altered