Food, Feed, Energy and Ecosystem Services (FFEE): A Role for American Agriculture

Charles W. Rice[1], Scott Staggenborg[1], and Richard Nelson[2]

Kansas State University
[1]Department of Agronomy, [2]Engineering Extension
Manhattan, KS
Contact: cwrice@ksu.edu

Agriculture: Role as Producer of Feed, Fuel, and Fiber for the U.S. and World.

Traditionally, agriculture systems produced the basic components of the food and fiber consumed by humans. In recent decades, the production and use of biofuels have expanded agriculture's role in human society. Most recently, increased production and consumption of biofuels, notably ethanol, have significantly expanded agriculture's role into the energy arena. In 2007, the US converted 17% of its corn crop into ethanol to provide 4% of its transportation fuel. Biodiesel use increased from 2 million gallons in 2000 to 240 million gallons in 2007 (DOE 2008). As these and other biobased energy systems expand, agriculture will be under increasing pressure to supply more biofuel feedstocks as well as traditional food and fiber commodities.

Because Kansas's agro-ecosystems resemble those of surrounding areas, the state represents the Great Plains region. This includes the northern Great Plains, the Cornbelt, and the High Plains. As a result of this unique characteristic, several plant subgroups used for ethanol feedstock and numerous crops used to produce biodiesel can be grown in Kansas as well as the region (Table 1).

Table 1. Food, fiber, and fuel crops grown in Kansas and the surrounding regions.

Crops to be used for ethanol, thermochemical, gasification or direct combustion energy production	**Crops for biodiesel production**
Feed grains corn, grain sorghum and wheat	Warm season crops soybean, cotton, sunflower, milkweed, okra, niger and sesame
Annual forages forage corn, forage sorghum, sweet sorghum	Cool season crops canola, camelina, crambe, cuphea, flax, and safflower
Perennial grasses switchgrass, big bluestem, and Miscanthus	Algae
Perennial plants Hybrid poplars	

Food, fiber, and fuel production from agricultural fields is currently undergoing tremendous pressure to meet world-wide demands for feedstocks for each of these groups. This coupled with record demands for food by developing economies in Asia, primarily China and India, has resulted in high crop commodity prices and even higher energy prices. Increasing energy prices have led to higher food prices and feedstock production costs. As pressure is placed on ever-shrinking agricultural acres, societies around the world must be certain the current policies adequately protect their natural resources. Of primary concern are losses of soil carbon and losses from soil erosion if biomass is removed from no-till fields to produce biofuels.

Competition for water between agriculture, manufacturing, and human use is another developing issue worldwide. Currently Kansas is in litigation with Colorado and Nebraska over water access rights.

This conflict at the regional scale is likely to spread throughout the world. Water use by crop producers is under constant scrutiny in the Great Plains region as it overlies the largest aquifer in the world, the High Plains Aquifer or, as it is commonly known, the Ogallala Aquifer. Producers are constantly searching for more efficient methods of applying water and nitrogen fertilizer, two of the highest input costs in the region. One potential solution is the use of forage crops to produce biofuel feedstocks. Annual forage crops such as photoperiod sensitive sorghum and sweet sorghum may provide more biomass per unit of input compared with corn. Also, perennial grass species have the capability to produce biomass with lower annual inputs once the grass is established.

Energy

President Bush, in his 2007 State of the Union message, set a goal of reducing America's gasoline consumption by 20 % over the next 10 years; and in early 2008, the Congress passed the Energy Independence and Security Act (EISA) which mandated production of 36 billion gallons of renewable fuel in 2022. The majority of this target is expected to come from ethanol and biodiesel derived from conventional grains and oilseeds (corn, sorghum, soybeans), agricultural crop residues (corn stover, small-grain straws), and/or dedicated energy crops (switchgrass, poplar). The increase to 36 billion gallons is huge, not only numerically (total gallons and energy required), but <u>more importantly</u>, in the expansion of crops (conventional and dedicated), residues, and waste resources, needed to meet this goal. Issues such as potential expansion onto marginal lands, markets and prices, cropping systems and production, climate, and environmental quality with respect to air, water, and soil resources, will need to be considered and analyzed with an emphasis on energy, environmental, and economic sustainability.

The agricultural sector definitely has a large role to play in helping meet this nation's energy and economic security goals and maintaining or enhancing environmental quality. However, accurate assessment of the agricultural biomass resource base will be extremely important in determining the sustainability with respect to energy inputs and outputs, environmental impacts, and economic feasibilities of biomass-related production and utilization scenarios. Quantitative <u>and qualitative</u> (e.g., net energy returns; air, water, and soil impacts, etc.) assessment and cost of production and/or disposal associated with each individual biomass resource at the sub-county (soil type) level is critical to optimize and maximize energy returns, potential environmental enhancement, and economic feasibility.

Ecosystem Services

<u>The Role of Agriculture in Combating Climate Change and Greenhouse Gas Emissions</u>

While agriculture contributes to greenhouse gas (GHG) emissions, agriculture currently helps to reduce a portion of total U.S. GHG emissions. Land use, land use change, and forestry represent a small but significant sink of 780 Metric Tons CO_2 eq. (USEPA, 2006). Agriculture and forestry thus *reduce* U.S. GHG emissions by 11% of the total emissions (USEPA, 2006).

Agricultural soils alone currently sequester or store about 46 metric tons CO_2 eq. per year (USEPA, 2006). With increased use of practices that enhance soil carbon sequestration, such as conservation tillage and targeted crop rotations, that total could be increased to about 200 million metric tons per year. This reduction in GHG emissions provided by agriculture can be enhanced by CH_4 capture from animal production, energy savings from reduced tillage, and the use of agricultural feedstocks for bioenergy. Thus production agriculture has the potential to reduce its own emissions and significantly offset the net U.S. GHG emissions from other sectors of the economy while maintaining food production.

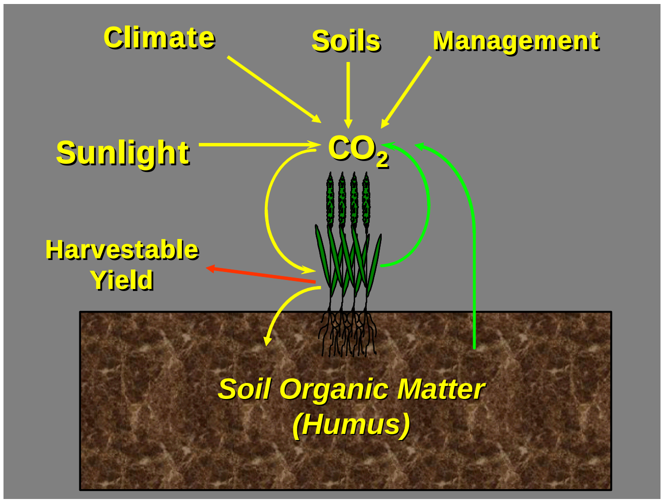
Economic analyses suggest that soil carbon sequestration is among the most beneficial and cost effective options available for reducing GHG, particularly over the next 30 years (IPCC, 2007). Soil carbon sequestration offers the potential to reduce U.S. emissions and slow the increase in atmospheric GHG as other technologies are developed to reduce those emissions.

While agriculture as a mitigation option contributes to reducing emissions, the practices also have long-term and permanent benefits for improving agricultural sustainability and other societal impacts, such as improved air and water quality, flood protection, reduced soil erosion, enhanced water retention, and improved wildlife habitat. Few, if any other means of reducing atmospheric carbon emissions, have so many co-benefits.

Agricultural Practices that Combat Climate Change

Agricultural land use options can play an important role in mitigating the increase of GHG emissions. Agriculture's mitigation contributions can (1) decrease emissions; (2) sequester carbon derived from atmospheric CO_2; and (3) avoid or displace emissions.

Decreasing emissions: GHG emissions can be reduced by efficiently managing carbon and nitrogen in agricultural systems. More efficient use of N fertilizer can reduce N_2O emissions. Greater N efficiency is achieved by lowering amounts, placement and application timing which will also reduce losses to water (another environmental benefit) and increase profitability, especially in light of high N prices. Increasing the efficient use of feeds for livestock may reduce CH_4 emissions. The capture and destruction or use of methane emissions from animal waste management may decrease agricultural emissions. Switching from intensive tillage scenarios to no-till may also reduce GHG emissions due to less consumption of in-field diesel fuel. The approaches that best reduce emissions in any geographic area, farm, or even field, depend on existing management practices and local conditions.



Enhancing sinks: Agricultural systems hold large reserves of carbon, mostly in the form of soil organic matter and inorganic carbon. Agricultural soil carbon sequestration involves the net accumulation and storage of carbon in the soil, known as the "soil sink." The effect of this storage capacity is to reduce the CO_2 in the atmosphere while improving soil quality and productivity. In crop production and grassland agriculture, plants absorb CO_2 from the atmosphere through the process of photosynthesis. Some CO_2 is released back to the air through soil microbial respiration and plant root respiration. In all plant-based systems, carbon is constantly being cycled between the atmosphere, living tissue, soil organic matter, and soil microbes. It is the net result of this cycle that is of interest for climate change mitigation.

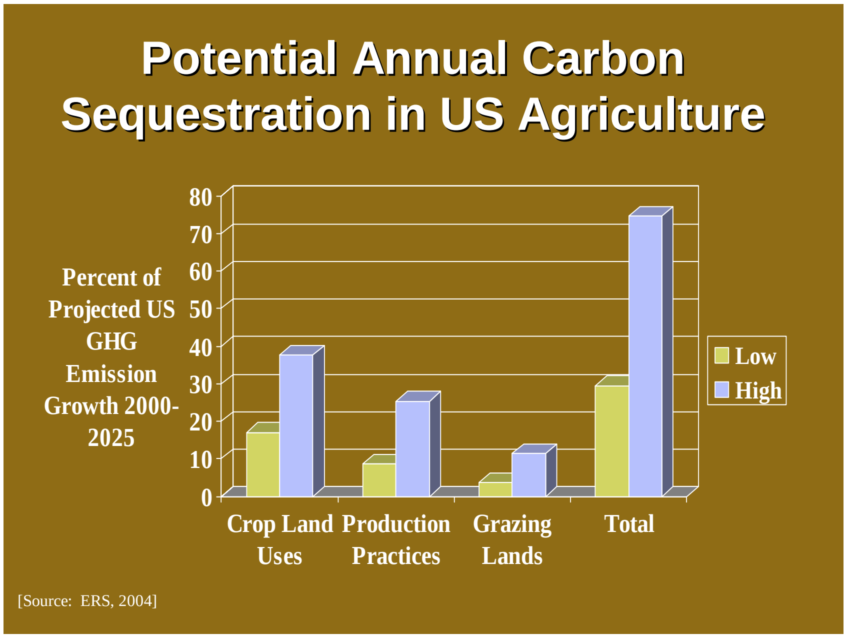
During the first half of the 20th century, much of the U.S. cropland was tilled resulting in soil C losses up to 50% of the original uncultivated soil C content. Much of this lost C can be recovered through improved agricultural management activities. Replacement of some of the lost soil organic carbon levels over the next 50 years would represent a net gain of carbon in the soil sink and a significant reduction in the rate of CO_2 increase in the atmosphere.

Table 2.

Estimates of Potential Carbon Sequestration of Agricultural Practices			
Agricultural practice	Tons C/acre/yr	MT CO_2/acre/yr	MT C/hectare/year
No-till	0.15-0.30	0.45-1.05	0.30-0.70
Summer fallow elimination	0.05-0.15	0.15-0.5	0.10-0.35
Use of cover crops	0.05-0.15	0.15-0.5	0.10-0.35
Grazing land management	0.015-0.03	0.06-0.1	0.03-0.07

The table above shows a range of estimated annual potentials for carbon sequestration on agricultural and grazing lands. However, the potential to achieve these reductions will be governed by the extent to which these practices are adopted by the producer, which in turn will be governed by markets and policy forces, including the rules that will determine whether and how much agricultural emissions reductions will be credited (McCarl and Schneider, 2001). Smith et al (2007) estimated that approximately 30% of this technical potential would be realized at a price of $20 per ton of CO_2-eq. and increases to 75% at a price around $100 ton CO_2-eq. In other words, in a functioning carbon market, the higher the price per ton of CO_2, the greater participation by farmers and the greater reductions in atmospheric GHG.

The potential for agricultural practices to sequester carbon relative to the predicted growth in U.S. GHG emissions out to the year 2025 is shown in the graphic, below. The bars represent low and high estimates of reductions from agricultural sequestration, and show that agricultural sequestration can offset from 30 to over 70 % of the growth in U.S. emissions until 2025.
Source: Environmental Defense, 2007.



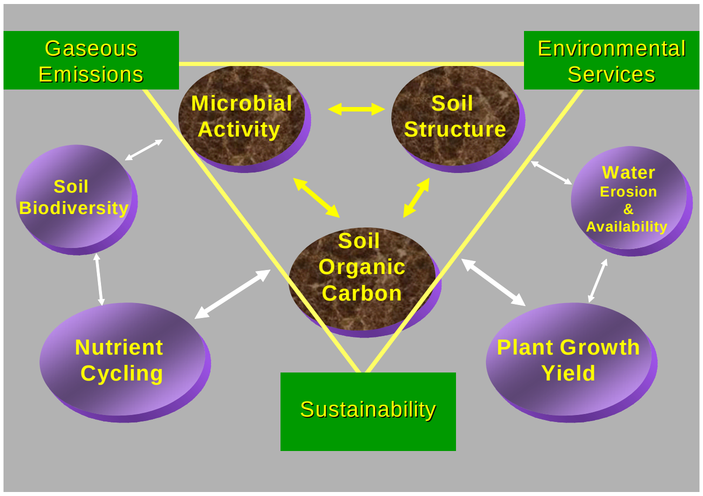
Economic Benefits of Conservation Tillage and No-Till Systems

Often no-till systems have higher net returns than conventional tillage systems due to lower overall costs. This is illustrated in an analysis comparing no-till corn production to tilled corn production systems in northeast Kansas (Pendell et al., 2006). One of the major benefits of adopting less intensive tillage systems is the reduction in fuel use. Emissions from direct energy use in the Kansas study were nearly 40% lower for no-till compared to tilled systems due to reduced trips over the field. Fewer trips over the field in no-till systems also reduce labor requirements and wear-and-tear on machinery, which can reduce equipment maintenance costs.

Co-benefits of Soil Carbon Sequestration:

Several of the agricultural GHG mitigation options provide ancillary co-benefits to the agricultural sector and to society, making them somewhat unique in their ability to address climate change simultaneously with other pressing social and environmental issues

Increased soil C content improves soil structure (McVay et al., 2006), increases soil fertility, soil biodiversity (Schnürer et al., 1985; Hooper et al., 2000), and water availability (Peterson and Westfall, 1997), all of which are beneficial to agriculture and to society. In addition, retention of residues on the soil



surface reduces soil erosion, thus improving air and water quality. Better N management in agriculture and forestry has the potential to improve water quality and N use efficiency.

Increasing soil C also increases available plant nutrients; considering the nutrient supplying capacity of just N, P, S, A 1% increase on soil organic matter content (21 Tons of CO_2) would translate to 75 lb N, 8 lb P and 8 lb of S per acre (Table x) (Rice et al., 2007). Given current prices this is equivalent to a fertilizer value of $101 per acre per % organic matter or value of nearly $5/metric ton of CO_2 sequestered which does not include savings from application costs (Table 3).

Table 3. Plant nutrients supplied by soil organic matter (SOM) (adapted from Rice et al., 2007).

Nutrient	Value	Supplied by SOM	Savings
	$ lb^{-1}	*lb (% SOM)$^{-1}$ ac^{-1}*	*$ (% SOM)$^{-1}$ ac^{-1}*
Nitrogen (N)	1.1	25-75	28-68
Phosphorus (P)	3.3	2.5-8	8-26
Sulfur (S)	0.9	2.5-8	2-7
Total	**5.3**		**38-101**

Additionally, adoption of conservation tillage in lieu of traditional tillage is associated with reduced use of fuels and fertilizers, and reduced labor, resulting in cost-savings as well as additional reductions to GHG, as discussed earlier.

Displacing emissions: Bioenergy development, utilization, and expansion (e.g., EISA RFS) encompasses many areas concerned with energy, environment, economics, and natural resources including conventional grain and oilseed crops and residues, dedicated herbaceous and woody energy crops, perennial oilseed crops, and processing by-products and wastes. These resources can serve as feedstocks for energy to displace solid and liquid fossil fuels through production of ethanol or biodiesel. These fuels release CO_2 when burned, displacing CO_2 which otherwise would have come from fossil C and is recycled into new plant growth. The net benefit to atmospheric CO_2, however, depends on the type and amount of energy used in growing, transporting, and processing the bioenergy feedstock (Spatari et al., 2005). Production of each potential bioenergy crop should be tailored to individual land bases to maximize energy, environmental, and economic returns to society. One accepted way to accomplish this is to perform full life-cycle analyses of net GHG impacts with respect to potential bioenergy crop production and incorporating land use effects/displacement. Crops and residues from agricultural lands can be used as a fuel source, either directly or after conversion to liquid fuels such as ethanol or diesel.

An example of a policy that can help displace GHG emissions from transportation fuels is the recently announced Low Carbon Fuel Standard (LCFS) in the state of California. The California LCFS is the worlds' first global warming standard for transportation fuels, and establishes an initial goal of reducing the carbon intensity of passenger fuels in the state at least 10 % by 2020. The standard requires in-state fuel providers to reduce the average emissions of GHG associated with the fuels they sell, beginning at the end of 2008. The standard will decline over time, and is expected to reduce GHG emissions and triple the size of California's renewable fuel market. The agricultural sector can help meet this mandate by providing low-carbon fuels. Fuel producers can reduce the average GHG emissions of fuels by blending or selling more low-carbon fuels, such as E10 and E85 ethanol.

The 21st Century Farm

The 21st Century Farm can deliver substantial benefits for mitigation offsets and farm income. Based on a farm of 1000 acres with a diversified land use under a cap and trade system, the operation could generate $20,600 based on a $20/ton value in soil carbon credits alone; that is an additional income of over $2,000 per acre. Nearly 40% of the income comes from soil C credits generated from no-till crop production which also is generating food and income. Additional income would be derived from energy offset credits for the energy crops, offset credits in wood, and methane destruction from the animal waste lagoon. This scenario does not include offset credits for reduced fuel use. All these extras could double or triple the income from the farm. In addition the farm would have diversified income form wind farms and biomass incomes for biofuel feedstock.

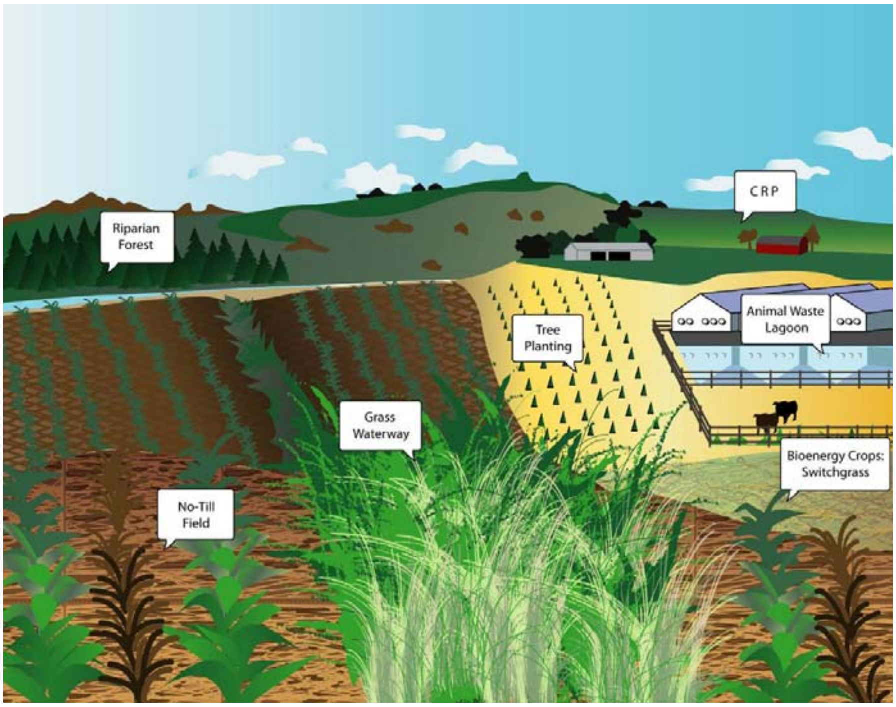


Table 4. 21st Century Farm. Potential income generated from carbon offset credits with a 1000 acre farm

Practice	Soil Mt CO_2/a/y	Area (acres)	Total Soil Credit	Value $4/ton	Value $10/ton	Value $20/ton	Other Offset[1] Mt CO_2/a/y	Value $10/ton
Riparian Forest	NA	40					0.70?	
Grass Waterway	3.00	50	150	600	1500	3000		
Tree Planting[2]	0.45	100	45	180	450	900	0.70	700
CRP	3.00	100	300	1200	3000	6000		
Bioenergy grass crop	0.20	200	40	160	1600	3200	5.0	10000
No-till Field	0.75	500	375	1500	3750	7500		
Animal Waste Lagoon	NA	10					18.25	
Total		1000		3640	10300	20600		

[1] Other credit generated from carbon accumulation in woody biomass (Heath et al., 2003a) and offset from perennial grass use to cellulosic ethanol production to substitute for fossil fuels (Nelson pers. Comm.) and methane credit from animal waste lagoon

[2] (Heath et al., 2003b)

Challenge for Land Grant Institutions

All of these issues point to the importance of training the next generation of agricultural scientists to understand global trends impacting agriculture while adapting more efficient production practices at the local level. A more comprehensive training program is needed for post-secondary agricultural students to address the demands of the 21st century. Students need to comprehend the complexity and degree of inter-relation of sustainable production of fuels from biomass and the production of foods. This complexity can only be learned through interdisciplinary programs outside the bounds of traditional disciplinary departments.

In addition extension must expand beyond it traditional role of serving producers and consultants. Integrated programs involving the biofuel and food processing industries along with the traditional audiences are needed to successfully develop the bioeconomies of rural America.

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