SUBCOMMITTEE ON PRODUCTION AND PRICE COMPETITIVENESS HEARING ON CARBON CYCLE RESEARCH AND AGRICULTURE'S ROLE IN REDUCING CLIMATE CHANGE

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Thank you Mr. Chairman and members of the Senate Subcommittee on Production and Price Competitiveness of the Committee on Agriculture, Nutrition, and Forestry. I am Dr. Charles W. Rice, Professor of Soil Microbiology in the Department of Agronomy at Kansas State University. I am a member of the Soil Science Society of America and a Fellow of the American Society of Agronomy. I hold membership in several other professional organizations including Ecological Society of America and American Association for the Advancement of Sciences. I personally have been involved in soil organic matter and no-tillage research during my Ph.D. training starting in 1980.

I am please to be invited to testify on the role agricultural soils in carbon cycling and mitigating greenhouse gases.

INTRODUCTION

Since the late 1800's fossil fuel use, expansion of cultivated agriculture, and forest clearing have led to an increase in atmospheric CO_2 from 260 ppm to current levels >370 ppm (IPPC, 1995) (Fig. 1). This increase in atmospheric CO_2 potentially impacts climate, as it is a greenhouse gas.

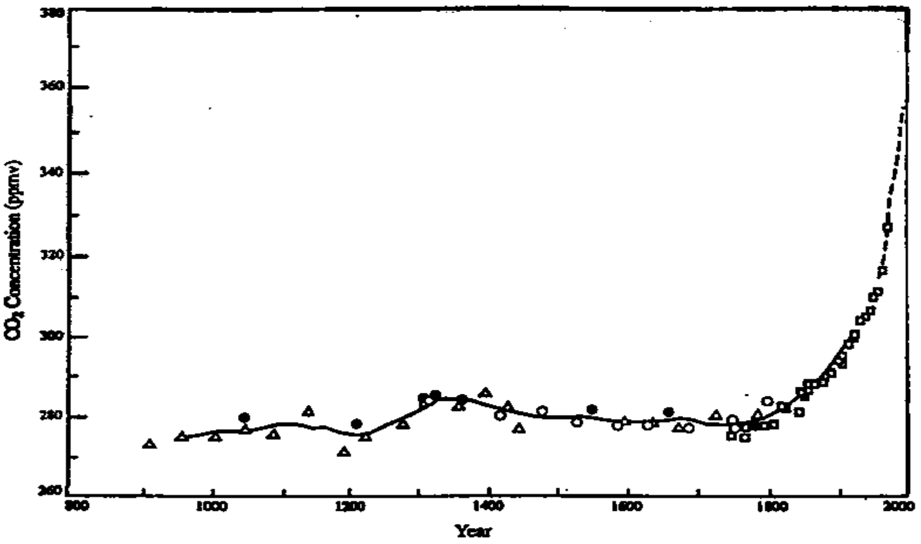


Figure 1. Temporal changes in atmospheric concentration of CO_2 (IPCC, 1995).

Most of the recent increase in CO_2 has been attributed to combustion of fossil fuels for energy and transportation, but changes in land use also contribute to atmospheric CO_2. Land use contributes to CO_2 by 1) combustion of biomass (forest clearing), and 2) release of soil organic carbon (C) following cultivation.

Recent models of land use suggest terrestrial systems can mitigate the increase of atmospheric CO_2 by sequestering C into vegetation and soils. The estimated amount of C stored in world soils is about 1100 to 1600 Pg, more than twice the C in living vegetation (560 Pg) or in the atmosphere (750 Pg) (Sundquist, 1993). Hence, even relatively small changes in soil C storage per unit area could have a significant impact on the global C balance. Approximately 50% of the soil organic carbon (soil organic matter) has been lost from the soil over a period of 50 to 100 years of cultivation. However, this loss of soil carbon also represents the potential for storage of C in agricultural soils. Carbon sequestration by soils occurs primarily through plants (Fig. 2). Plants convert CO_2 into tissue through photosynthesis. Upon their death, plant tissues decompose, primarily by soil microorganisms, and the carbon in the plant material is eventually released back into the atmosphere as CO_2. However some of the C in plant material forms soil organic matter sometimes referred to as “humus.” Some of this carbon in the soil can persist in soils for hundreds and even thousands of years.

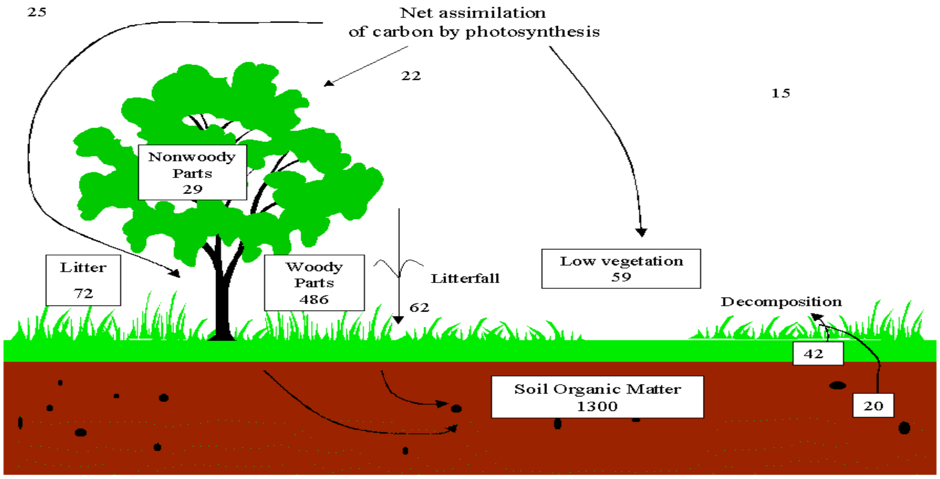


Figure 2. Terrestrial carbon cycle. Values in boxes represent Gt C and those assicated with arrows represent Gt/yr.

Agriculture's Role

The amount of carbon soils can sequester is dependent on several factors. Inherent factors include climate variables (temperature and rainfall) and clay content. Much of the central United States and Canada, which was once prairie, is now in cultivated agriculture. The grasses of prairies store much of their C belowground, which is eventually converted to soil organic carbon. Previous cultivated agricultural practices have decreased soil C, but advancement in crop and soil management practices have the potential to increase soil C. Table 1 lists several practices affecting the soil's ability to sequester C (Lal et al., 1998).

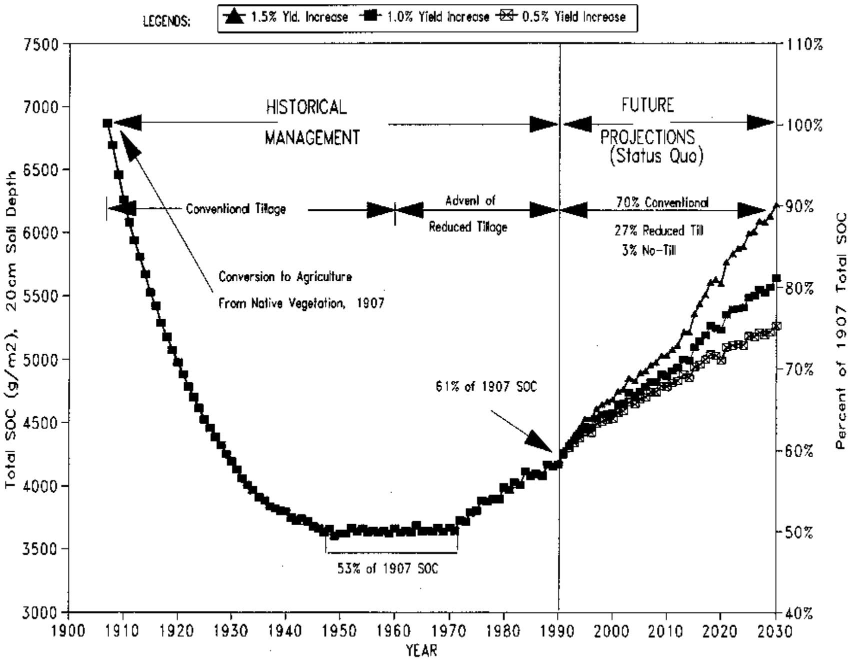
Table 1. Land Use for C Sequestration (Lal et al., 1998)

Management Strategies

Land Use	Soil Management	Crop Management
• Cultivation • Forestry • Rangeland	• Tillage • Residue Management • Fertility • Water Management • Erosion Control	• Varieties • Crop Rotations • Cover Crops • CRP

(Table 1)

The impact of soil and crop management is illustrated in Fig. 3. As noted earlier, agriculture in the 1800 and early 1900's relied upon the plowing the soil with low crop yields and crop residues were often removed. This combination of agricultural practices resulted in reducing the replenishment of organic material (carbon) to the soil. As a result soil C



content decreased by as much as 50% over a 50 to 70 year period. In recent decades, higher yields, return of crop residues, and development of conservation tillage practices have begun to increase soil carbon. Simulated soil C levels are projected to increase due to improved crop yields. A projected 1.5% annual increase in yields (the current annual rate is 1.8% per year) will result in 1.8 Gt of soil C over a 40 y period in the central U.S. (Flach et al., 1997). Flach et al. (1997) suggested if a 1% annual increase in productivity were achieved globally, then 15% of the C emissions could be sequestered in soil due to increased crop productivity.

Additional gains in soil C in agricultural soils could be achieved by a reduction in tillage and better management of residues Table 2.

Table 2. Estimates of C sequestration potential through improved management of U.S. cropland (Lal et al., 1999)

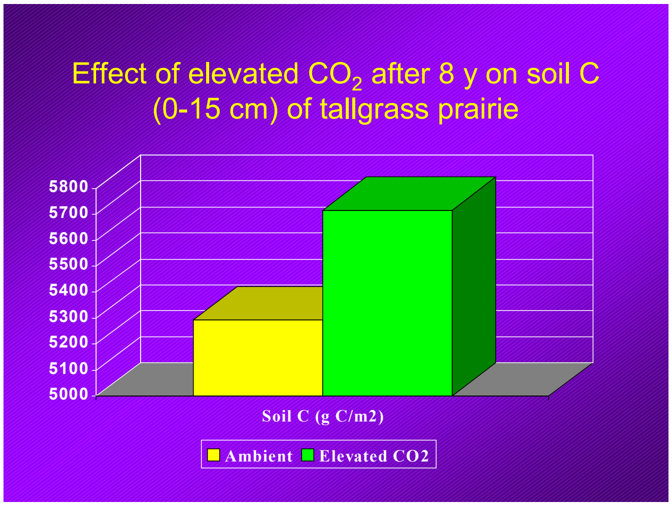
Agricultural practice	(MTC/ha/y)
Conservation Reserve Program	0.3 – 0.7
Conservation tillage	0.24 – 0.40
Fertilizer management	0.05 – 0.15
Rotation with winter cover crops	0.1 – 0.3
Summer fallow elimination	0.1 – 0.3

Comparisons of no-tillage with spring plow have projected 20 to 80% higher soil C with no-tillage after 40 years (Donnigian et al., 1994). Others have reported field studies with approximately 30% increases in soil C due to no-tillage when compared with conventional tillage (Kern and Johnson, 1993). At Kansas State University, we have shown an increase in soil C of approximately 0.2 MT C/ha/y. This is equivalent to an increase of 1 ton C/acre over a 10-year period. The amount of carbon sequestered is on the lower end of the range given by Lal et al. (1998). Cropping sequences can also affect soil C. In Kansas, intensifying cropping systems by conversion from wheat-fallow rotation to wheat-grain sorghum-fallow rotation in western Kansas increased soil C levels (Havlin et al., 1990). Combinations of high intensity cropping with no-tillage gave maximum benefits modeled for several locations in the North American prairies (Paustian et al., 1998) (Table 3).

Table 3. Change in soil C due to cropping intensity and tillage (g C m^{-2}) (Adapted from Paustain et al., 1998)

Cropping intensity/tillage				
	-----High----		-------Low------	
Site	CT	NT	CT	NT
Wisconsin	1300	1400	-30	260
Kansas	2000	2300	980	1100
Canada	290	450	-90	100
Nebraska	1170	1320	140	230
Colorado	810	970	-80	30

Grassland systems also can contribute to C sequestration when properly managed. Research at Kansas State University has shown that under elevated atmospheric CO_2 the soil contained 6% more C to a depth of 15 cm compared with ambient conditions (Rice et al., 1999). The increased in soil C was due to increased plant production followed by incorporation into the soil. The amount of C sequestered over the 8-year experimental period was equivalent to 2 tons C/acre. Proper fire management also increases soil C. We have reported a 5 % increase with annual burning compared to unburned tallgrass prairie (Rice et al., 1999).

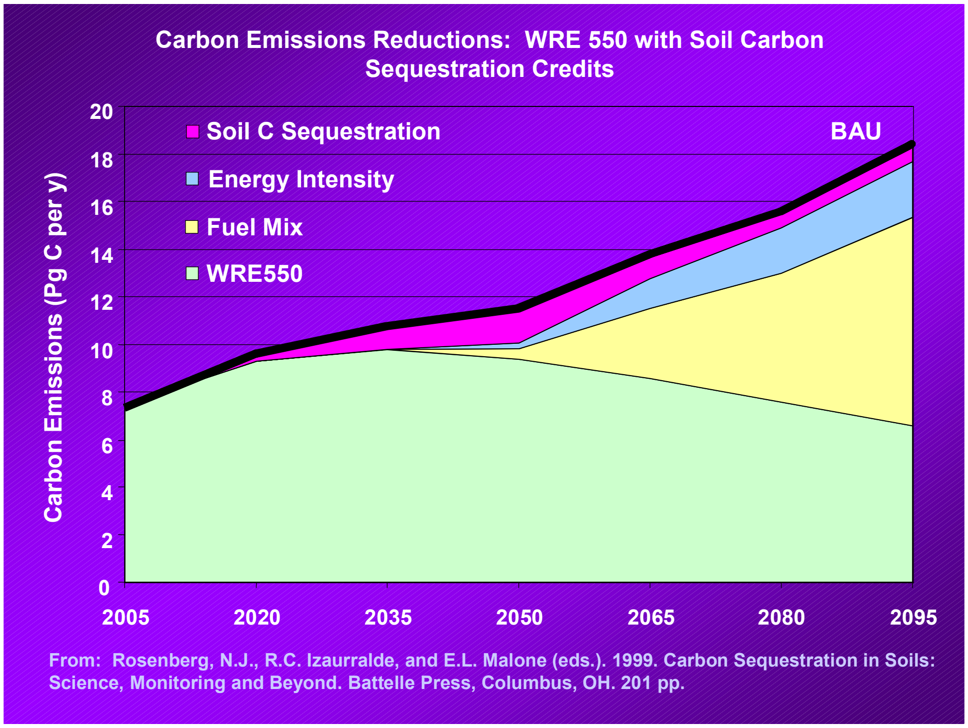

Effect of elevated CO_2 after 8 y on soil C (0-15 cm) of tallgrass prairie

While much of the discussion of carbon sequestration has been directed to forests, global estimates for C sequestration for different ecosystems indicate the agricultural lands are 45 to 90 % of forests (Metting et al., 1999) (Table 3). If grasslands and rangelands are considered, then managed lands contributions to carbon sequestration are greater than forests. Thus all ecosystems must be considered in any plan to increase C sequestration.

Table 3. Global terrestrial C sequestration potential (adapted from Metting et al., 1999)

Ecosystems	Potential (Gt C/y)^2
Agricultural lands	0.85 – 0.90
Biomass crops for biofuel	0.5 – 0.8
Grasslands	0.5
Rangelands	1.2
Forests	1 – 2

Economic analysis suggest that soil carbon sequestration is among the most beneficial and cost effective options available for reducing greenhouse gases, particularly over the next 30 years until alternative energy sources are developed and become economic feasible. Recent estimates of the potential for U.S. agriculture, using existing technologies, are on the order of 75-200 MMT C per year (Lal et al., 1998; Bruce et al., 1998). The figure below illustrates a scenario in which carbon sequestration is allowed. Under this scenario, soils achieve the necessary net carbon emissions until 2050. After 2050 reductions in carbon emissions must come from changes in energy technologies.

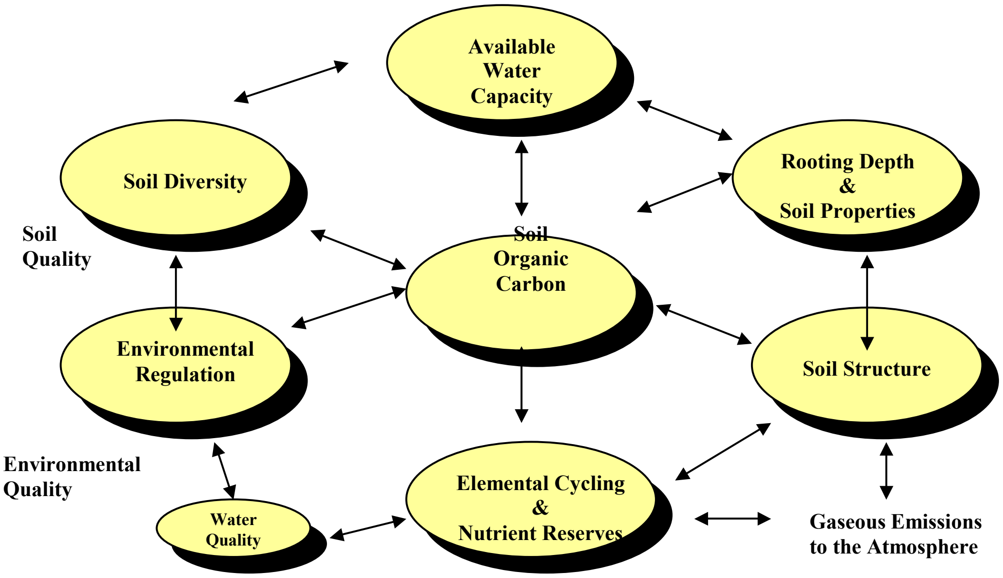


Carbon Emissions Reductions: WRE 550 with Soil Carbon Sequestration Credits

From: Rosenberg, N.J., R.C. Izaurralde, and E.L. Malone (eds.). 1999. Carbon Sequestration in Soils: Science, Monitoring and Beyond. Battelle Press, Columbus, OH. 201 pp.

Additional benefits

Managing agricultural soils for sequestering C will result in additional benefits.



Increasing soil organic C include increased crop productivity and enhanced soil, water, and air quality. In addition, management practices that increase soil C also tend to reduce soil erosion, reduce anthropogenic energy inputs into the soil, and improve soil resources.

Research Consortium (CASMGS)

The Consortium for Agricultural Soil Mitigation of Greenhouse Gases (CASMGS-pronounced like chasms) will provide the information and technology necessary to develop, analyze, and implement carbon sequestration strategies. CASMGS is a multi-year, collaborative effort to improve the scientific basis of using land management practices to increase soil carbon sequestration and to provide the tools needed for policy assessment, quantification, and verification. The CASMGS team is made of internationally recognized researchers and institutions in the fields of soil carbon dynamics, soil-derived greenhouse gases, soil erosion, water quality and computer modeling, land resource data analysis, agricultural resource economics and integrated assessments. The scientists are from major land-grant universities and a national laboratory. Participant institutions are: Colorado State University, Iowa State University, Kansas State University, Michigan State University, Montana State University, Texas A & M University, the University of Nebraska, and the Pacific Northwest National Laboratory.

The overall goal of CASMGS is ***to provide the tools and information needed to successfully implement soil carbon sequestration programs so that we may lower the accumulation of greenhouse gases in the atmosphere, while providing income and incentives to producers and improving soil quality. Such benefits include an increased and stable agricultural production and an overall reduction of soil erosion and pollutions by agricultural chemicals and fertilizers.***

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