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Mr. Chairman and Members of the Subcommittee. Thank you for the opportunity to appear today to discuss soil carbon measurement processes, methods used to measure soil carbon changes, and the research related to such measurements. I am a research soil scientist with the Natural Resources Conservation Service in Lincoln, NE. The work on soil carbon has been going on for many years. In fact, much of the early work in soils dealt with soil organic matter, which is primarily made up of soil organic carbon. The importance of soil carbon to the farming community has long been recognized. In the 1938 USDA Yearbook of Agriculture *Soil and Men,* William Albrech wrote a chapter entitled “Loss of Soil Organic Matter and its Restoration.”. The opening to the chapter says, “This article tells why organic matter in the soil may be considered our most important natural resource.” Other questions raised in this chapter included whether levels of soil organic matter should be maintained or raised to maintain fertility. The answer even then was that the levels, at a minimum, should to be maintained. The discouraging thing is that for years, even though many understood the importance of maintaining soil carbon, management practices continue to deplete soil carbon. We have now renewed our appreciation for soil organic carbon and are looking at ways to reverse its decline. Increasing soil carbon has many farm benefits (improved productivity and sustainability) and off-farm benefits (improved water and air quality).

I have been working with colleagues for the last 12 years on issues related to soil carbon changes and its measurement and verification. NRCS has been investigating the role that agriculture can play in the sequestration of carbon in the soil both as soil organic carbon (SOC) and soil inorganic carbon (SIC). We have published 10 books related to the issue of soils, greenhouse gasses, and carbon sequestration. A recent one is directly related to the topic of this hearing: *Assessment Methods for Soil Carbon* edited by R. Lal, J. M. Kimble, R. F. Follett, and B.A. Stewart.

Soils vary widely over the landscape. Their spatial variability has led to the critique that it is too costly to accurately measure its properties. In fact, we have well-developed tools (including models and soil survey maps) to measure properties at points and to scale up from those point measurements to large areas. Our National Soil Survey Program inventories soils in the landscape into described units. This inventory is pivotal in this scaling.

Data acquired from long-term (5+ years) no-till fields clearly shows that the level of carbon in soil has increased over time. One long-term no-till farmer in Illinois has doubled his SOC in a period of about 15 years. He did this not on research plots but on agriculture fields using good conservation practices. A special publication of the Soil Science Society of America *Soil Carbon Sequestration and the Greenhouse Effect* provides numerous examples of measurable rates of change of soil organic carbon.

Based on sampled data, ARS senior scientist Dr. R. Follett and several co-authors reported an average rate of change of 910 kg SOC ha^{-1} in the top 20 cm of soil that was taken out of production and put in the Conservation Reserve Program (CRP). This land was in the 13 state-region of the historic grasslands. Using soil maps we can estimate the amount of carbon in the entire region. A total of 5.14 million metric tons carbon per year was accumulating in the top 20 centimeters of CRP land in this region. The rates would vary along the temperature gradient form the south to the north and along the moisture gradient from the east to the west. This variability can be explained and understood when such data is scaled to larger areas. In the same publication Keith Paustain and his co-authors describe how carbon cycle models can be used to make regional assessments of soil carbon. They have completed assessments in Iowa using the Century model and are working on similar projects in several other states.

The book *Assessment Methods for Soil Carbon* provides papers from United States and international scientists on all aspects of soil carbon measurement and estimation. The areas of sampling, sample preparation, spatial variability, the use of soil surveys, methods to determine carbon in the laboratory, (carbon) pool sizes and turn over rates, effects of soil erosion, procedures to model and scale data as well as numerous other related topics are addressed. These papers along with numerous others in the scientific literature provide a large database of information to develop rates of soil carbon accumulation and change associated with site-specific agricultural management practices.

There remain a number of research areas that need continued work. We need to continue to improve our analytical methodology both in the laboratory and in our field sampling techniques. We need to develop better statistical techniques to scale data from single point data to larger areas. Scaling can be improved as we increase the use of remote sensing and other techniques.

We need to develop and improve sampling protocols to reduce variability. We need to build on the data needed to understand soil carbon conditions at the site, regional, and national levels. Soil surveys provide essential information for sampling and could be refined to improve their use for this purpose.

The Century model has been used to take point data and scale it up to make regional assessments. Other models, named CQESTR (pronounced sequester), are under development and being testing by the USDA Agricultural Research Service, the Natural Resources Conservation Service, and others. CQESTR will allow farmers and land managers to estimate the effects of alternative management systems and practices on rates of carbon sequestration. These models also help us look at changes and make predictions about rates of fluxes of greenhouse gases.

The various models need to be validated against ground plots where actual measurements are made. This validation has been done in a major project in Canada called the “Prairie Soil Carbon Balance Project.” In this study a large group of farmers got together and showed that with a combination of models and field trials, changes can be predicted. The study found that carbon gains in the 0-30 cm soil layer averaged 1.21 tons/ha with direct seeding. The carbon gains ranged from 1.56 tons C/hectare in the humid direct seeded fields to 0.82 tons C/hectare in the semiarid areas. The gains were also found to vary with clay content. The rates were measured on actual plots in fields that were farmed as a part of normal farming operations. The study showed that the amount of both above- and below-ground biomass increases with direct seeding (no-till).

As we continue to increase the amount of above-ground biomass, we can expect more carbon to be returned to the field and converted to soil organic carbon. The system will build upon itself.

The use of remote sensing coupled with modeling has great potential to improve our measurement and estimation capacity. We know that soil carbon is not randomly distributed over the landscape. It is highly correlated with clay content and other soil properties that we can map. Therefore, it is important to integrate mapping and monitoring techniques with predictive models for different soils and ecoregions.

The understanding of soil carbon dynamics is advancing. We now know we must look at more than the total carbon pool in the soil. We need to look at each of three carbon pools that are found in soil. These are the labile pool, which has a turn over rate of less than a year; the intermediate pool, which has a turn over rate of 10 to 100 years; and the stable pool, which has a turn over rate of 100 to 1000+ years. If we are to create and maintain a sustainable environment, our goal for soil carbon should be to increase the intermediate and stable pools. Management strategies need to be developed and applied to reach this goal. Farm policy that encourages conservation and no-till systems, crop rotations, particularly with grass or small grains, cover crops, and appropriate use of organic amendments such as manure and compost will help. Plant breeding may also help with varieties that will put more carbon into plant root systems and in forms that are more resistant to microbial breakdown

In conclusion, the bottom line is that we know how to measure soil carbon changes over time. We have been measuring it as part of our research for a long time. The scientific process of measurement is now verifiable, and the point data can now be scaled to larger areas with models. We can also couple remote sensing data with the models to improve their output. We can measure, estimate, and predict changes in carbon with the tools at hand, which include field sampling, models, and statistics. Our focus should be to get the conservation practices on the ground that will lead to increases in soil carbon. This will simultaneously advance our goals of sustainable farming systems and improved water and air quality.

Mr. Chairman, that completes my statement. I would be happy to answer any questions.