3.2.3 IMPROVED MEASUREMENT AND MONITORING
3.2.3.1 TERRESTRIAL SENSORS, MEASUREMENTS, AND MODELING

Technology Description

Agricultural lands (cropland, pasture, rangeland) represent potentially large and cost-effective sinks for atmospheric carbon, if management technologies can be applied in the right place at the right time. Management to increase carbon sequestration requires the development of more sophisticated, lower-cost measurement systems and models for integrating multiple data sources into a decision-making context.

System Concepts

- In the past, management of soil carbon and greenhouse gas (GHG) emissions has not been a primary management goal in agriculture. Consequently, efforts to develop rigorous quantification systems at multiple scales (local, regional national) are relatively recent, but are rapidly developing.
- Methods exist to accurately and precisely measure soil carbon and GHG concentrations and fluxes. However, most conventional methods were developed for local measurements. Plot and field applications and numerous samples must be analyzed for accurate and precise values.
- Models (particularly computer simulations) of soil carbon and GHG dynamics exist and several are in widespread use and have been extensively tested against research data. Their development and use in inventories, policy assessment, and decision-support environments is only recent.
- Emergence of new sensing technologies (i.e. laser, infrared, multispectral video) and computing power capable of handling large amounts of information has spawned a new generation of instruments, databases, and computer models.
- There is a rich collection of resource data on factors determining soil carbon and GHG dynamics in croplands, e.g., survey data on management practices, crop areas and yields, soil maps, land cover, and irrigation. Much of the data is spatially referenced and can be used to drive stimulation models and interpolate/extrapolate measurements. Similar data exists for grazing lands, with the exception of type, distribution, and extent of different management practices for which information is currently sparse.

Representative Technologies

- Instruments to measure GHG fluxes among soils, plants, animals, and the atmosphere.
- Models to integrate spatial and temporal variability into a decision context.
- Easily accessible, interactive distribution systems of quantification technologies that integrate measurement and modeling approaches.

Technology Status/Applications

- New sensors, instruments, measurement systems, models, and distribution systems are emerging, but integrated systems of information collection, retrieval, management, manipulation, and processing to aid decision making in complex and diverse agricultural environments have yet to be developed.
- Integrated information management and the physical sciences now have the capacity to provide vastly improved information to land managers and policy makers to improve the amount of carbon stored in grazing land soils.

Current Research, Development, and Demonstration

RD&D Goals

- Develop a new generation of sensors and instruments to measure GHGs and their fluxes in situ across a wide variety of agricultural ecosystems.
- Develop cost-effective soil carbon probes for in situ measurement of soil carbon content (as opposed to fluxes) that can be made both before and after implementation of management changes to validate impacts on sequestration.
- Determine time and cost-efficient sampling and monitoring designs to support national inventories and project level GHG mitigation activities.
- Combine measurement technologies and ecological process models to make reliable predictions (and verify them) regarding the impact of management on GHG dynamics.
- Integrate near real-time climate information into process models as a driver.

- Distribute site-specific information to farmers, ranchers, and technical assistance providers to aid in making more realistic decisions.

RD&D Challenges

- High spatial and temporal variability results in very complex situations that must be measured and modeled. Data sources will be multisource and large.
- Successful implementation will require substantial improvements in the ability of field staff and land managers (farmers and ranchers) to use complex information.

Recent Progress

- Laser-induced breakdown spectroscopy instrument to measure soil carbon in situ for less than 10% of the lab costs of other methods with comparable reliability.
- Mid-range infrared spectroscopy to measure soil carbon and forms.
- Near-infrared spectroscopy technology and Nutritional Balancer software to accurately predict livestock diet quality based on fecal analysis.
- Biophysical models have been developed to integrate spatial and temporal variability in soils into a predictive framework for making estimates of changes in soil carbon in response to climate and management.
- Satellite and low-altitude remote-sensing technologies have been developed that can quantify cropland and grassland features at a spatial resolution of less than 0.5 m^2.
- Internet distributed site-specific information systems that integrate near real-time weather predictions, land condition, and land-cover classes have been developed. Such tools provide ready access to information used in developing decision tools and in dynamic models as inputs.
- Decision-support systems are being developed that can integrate information to evaluate implications of various management decisions.

Commercialization and Deployment Activities

- Markets in precision agriculture and decision-support consultation are potentially large.
- Technical basis of instruments, models, and information systems is proven, but their systematic deployment to solve complex problems remains unexplored.