4.2. METHANE AND NITROUS OXIDE EMISSIONS FROM AGRICULTURE

4.2.1 ADVANCED AGRICULTURAL SYSTEMS FOR N_2O EMISSION REDUCTION

Technology Description

No-tillage cropping system in irrigated agriculture to reduce Net global warming potential (A.D. Halvorson, USDA-ARS, Fort Collins, Colorado)

Low fertilizer nitrogen-use efficiency in agricultural systems is primarily caused by large nitrogen losses due to leaching and gaseous emissions (ammonia, nitrous oxide, nitric oxide, nitrogen). It is axiomatic then that most strategies that increase the efficiency use of fertilizer nitrogen will reduce emissions of N_2O and probably NO. In general, nitrogen oxide emissions from mineral and organic nitrogen can be decreased by management practices that optimize the crop's natural ability to compete with processes where plant-available nitrogen is lost from the soil-plant system, and/or by directly lowering the rate and duration of the loss processes. Strategies to increase the overall efficiency of nitrogen are therefore necessary to decrease nitrogen oxide emissions. Advanced agricultural systems are a group of technologies that can be applied to this goal. These systems enable a process of collecting and using increasingly detailed, site-specific information in conjunction with traditional farm-management tools, and applying the best available information to better manage individual farming operations. These systems conceptually provide for improved understanding, control, and manipulation of the soil/plant/atmosphere environment to match nutrient, water, pesticide, and other inputs for crop production demand, which will increase efficiency of nutrients and decrease gaseous and leaching losses. These systems provide an integrated capability to improve environmental quality while enhancing economic productivity by increasing energy efficiency, optimizing fertilizer and other chemical applications, and conserving soil and water resources. Most system concepts for reduction of GHG emissions are, however, theoretical and remain untested.

System Concepts

- Precision agriculture – global-positioning infrastructure and remote and *in situ* sensors for soil, crop, and microclimate characterization; this practice includes variable rate water, fertilizer, and pesticide application in space and time.
- Cropping system models, data and information analysis, and management tools.
- Control-release fertilizer and pesticide delivery to match crop demand and timing of pest infestation.
- Biological and chemical methods for manipulating soil microbial processes to increase efficiency of nutrient uptake, suppress N_2O emissions, and reduce leaching.
- Best-management practices to limit nitrogen gas emissions, soil erosion, and leaching.
- Soil-conservation practices utilizing buffers and conservation reserves.
- Recycling of livestock manure.
- Plant breeding to increase nutrient-use efficiency and decrease demand for pesticides and energy consumption.

Representative Technologies

- Global-positioning satellites and ground systems, satellite- and aircraft-based remote and *in situ* electrical, magnetic, optical, chemical, and biological sensors.
- Advanced artificial intelligence and information networking technologies; autonomous control and robotics systems; soil/ crop moisture, pest and microclimate responsive (smart) materials.
- Control-release fertilizers and pesticides.
- Nitrogen transformation inhibitors.
- Livestock waste delivery systems.
- Best-management practices.
- Genetically engineered plants that are resistant to herbicides or specific pests.

Technology Status/Applications

- Many first-generation precision agriculture technologies are available; in 1998, used on about 14% of farms.
- Information management and networking tools; rapid soil-characterization sensors; selected crop stress, yield, and quality sensors; and a systematic integration of all technologies for all major cropping systems are not yet at technical performance levels and require field testing.
- Strong understanding of soil microbiology and soil processes and relationships exist in the agriculture, energy, and university research community.
- Capability exists for the development of control-release materials and biological process inhibitors.
- Best-management practices are in place in many production sectors.

Current Research, Development, and Demonstration

RD&D Goals

- Precision agriculture technologies that improve production efficiencies and reduce energy consumption.
- Remote and field-deployed sensors/monitors and information-management systems for accurate, real-time monitoring and analysis of crops, soils, water, fertilizer, and agricultural chemicals use/efficiency to meet the fertilizer and energy reduction goals.
- Smart materials for prescription release utilized in major crops.
- Advanced fertilizers and technologies to improve fertilizer efficiency and reduce nitrogen inputs.
- Methods of manipulating soil microbial processes to increase efficiency of nitrogen use.
- Deployment of first-generation integrated system models, technology, and supporting education and extension infrastructure.
- Genetically designed major crop plants to utilize fertilizer more efficiently.
- First generation integrated system models, technology and supporting education and extension infrastructure need to be implemented, and research on using these techniques to improve management expanded.
- Full utilization of best-management practices.

RD&D Challenges

- Precision agriculture in general requires advances in rapid, low-cost, and accurate soil nutrient and physical property characterization; real-time crop water need characterization; real-time crop yield and quality characterization; real-time insect and pest infestation characterization; autonomous control systems; and integrated physiological model and massive data/information management systems. All of these require a full understanding of the spatial and temporal dynamics that occur within a field.
- Smart materials that will release chemicals based on soil and crop status depend on modest breakthroughs in materials technology.
- Improved understanding of specific soil microbial processes is required to support development of methods for manipulation and how manipulation impacts greenhouse gas emissions.
- Models that represent accurate understanding of plant physiology must be coupled with models that represent soil processes such as decomposition, nutrient cycling, gaseous diffusion, water flow, and storage to understand how ecosystems respond to environmental and management change.
- Detailed and simultaneous examination of biogeochemical reactions that occur in near-surface ground water is required to improve understanding of nutrient cycling, GHG emissions, and degradation of contaminants.
- Improved understanding of agro-ecosystem management on nitrogen cycling and GHG emissions.
- Development of plant varieties that increase nutrient use efficiency.
- Conduct direct basic and applied research effort on sensors, information sciences, materials, and microbial processes.
- Apply whole-systems engineering and integration to effectively develop and guide program formulation and implementation to include the concept of whole system net GHG emissions.

RD&D Activities

- Complementary efforts are underway in both public and private sectors.
- Sponsors include USDA, DOE, NASA, universities, state agencies, commodity groups, and sensor and satellite developers – the principal funding comes from USDA.

- Life-cycle analysis of tractor and irrigation pump emissions.
- Use of cover crops or mulch that would reduce or delay emissions.

Recent Progress

- High-resolution satellite imagery can identify stress and disease in some crops at 1-to-2-m resolution.
- Research programs have related reflectance spectra to disease or nutrient status.
- Control-release formulations for fertilizers and pesticides are in use.
- Rf-link deployable field sensors exist for ground moisture monitoring.
- On-farm use of yield-monitoring equipment is increasing.
- Commercial sensors for sensitive, precise, and rapid analysis of GHGs are now marketed.
- Best-management practices are in place for many crops and regions of the country.
- Genetically modified crop varieties are being used that are resistant to specific herbicides or pests.

Commercialization and Deployment Activities

- Global-positioning systems, geographic information system software for parameter mapping, remotely sensed imagery, selected field monitors, and selected variable rate control systems for seed, fertilizer, and chemical applications are commercialized and in application in the United States, Canada, Australia, and Europe.
- Slow-bleed release pesticides are available commercially.
- Nitrogen transformation inhibitors are available commercially, and were applied to approximately 10% of corn acres in 1996. Inhibitor application increased net revenue $8-$20/acre.
- Control-release fertilizers are produced and used mainly in horticultural and ornamental crops.

Market Context

- Market for technologies exists not only in the United States but worldwide. In developing countries dependent on agriculture, the market for improved agricultural systems is substantial.