3.2.2 BIOTECHNOLOGY

3.2.2.1 BIOTECHNOLOGY AND SOIL CARBON

Technology Description

Biotechnology can be used to affect soil carbon by altering the chemical composition of plants and that of microorganisms that control plant decomposition. Plant chemical composition affects the amount of carbon transformed into more stable organic matter (such as humus) when plant biomass decomposes in the soil. Soil microorganisms determine the soil carbon compounds that are formed during residue decomposition.

System Concepts

- Roots and wood that have relatively high lignin content are more readily converted into stable soil organic matter than are plant components with high cellulose and hemicellulose content. Cellulose and hemicellulose are more readily decomposed by soil microbial respiration and released to the atmosphere as CO_2.
- Soil microorganisms that control plant decomposition also produce chemical precursors to stable organic compounds. Thus, genetic modifications that increase soil microorganism production of these chemical precursors could potentially affect soil carbon content.
- Use of genetically modified crops to enhance yields and reduce fertilizer.

Representative Technologies

- Plants already have been modified using biotechnological methods for herbicide resistance, to produce an insecticide, and to produce vitamin A precursors.
- Microorganisms have been bioengineered to produce novel compounds (e.g., insulin) and to biodegrade recalitrant compounds present in hazardous wastes.
- Herbicide tolerant crops that advance conservation tillage.
- Genetically modified crops that increase utilization of soil nutrients and/or fertilizer.
- Technologies that increase agricultural productivity (e.g., by increasing yields or minimizing spoilage and increasing shelf life, because each would minimize area under cultivation).

Technology Status/Applications

- Biotechnology has successfully produced modified plants and microorganisms, but it has not been used to modify plants or microorganisms to enhance soil carbon sequestration.
- This technology may be better suited for biomass/bioenergy crops than traditional food and feed crops because of the close compatibility between plant characteristics and desired biomass/bioenergy crop properties.

Current Research, Development, and Demonstration

RD&D Goals

- Identify the traits needed in plants and microorganisms to increase soil carbon sequestration capacity.
- Determine the feasibility of using biotechnology to modify the traits of plants and microorganisms that can affect soil carbon sequestration.
- Develop systems for monitoring nontarget environmental affects associated with plant modifications.
- Develop methods to incorporate genetically modified plant and microorganisms into cropland and conservation reserve and buffers systems.
- Develop guidance for farmers, other land managers, and policy makers for using carbon sequestration biotechnology products.

RD&D Challenges

- Because biotechnology has not yet been used to enhance soil carbon sequestration, the feasibility of this approach is unknown. In particular, specific genetic traits affecting carbon sequestration capacity need to be evaluated to determine whether few or many genes are involved and how modifications to these traits might also impact crop yields.
- Estimate the costs of bioengineered plants and microorganism, which may be prohibitive for farmers, ranchers, and other managers.
- Determine whether modified microorganisms can compete with native microflora.
- Address the general concern of introducing genetically modified organisms into ecosystems because of their potential to disrupt natural ecosystem processes.

Recent Progress
• Biotechnology has been used to successfully modify plants and microorganisms for other purposes.
Commercialization and Deployment Activities
• Both private companies and public research agencies have biotechnology products in commercial markets. • Regulatory procedures are in place for release of genetically modified organisms. • The private sector will support the development of carbon sequestration biotechnology if the market is large enough.
Market Context
• Difficult to estimate until feasibility research is conducted.