

Climate Friendly Farming™: Executive Summary

Agriculture is an important source of greenhouse gases associated with global climate change, coming from plant and animal production, soil processes, waste management, fertilizer and machinery manufacture and use, transport, and other activities in the food system. The Climate Friendly Farming (CFF) Project conducted the most comprehensive scientific assessment to date of the greenhouse gas (GHG) emissions from representative Pacific Northwest (PNW) agricultural systems. The project identified promising management strategies and technologies that could reduce the relative GHG contribution of agriculture. These include actions to: *reduce* greenhouse gas emissions from agricultural systems, *restore* carbon to soils (coming from the atmosphere), and *replace* fossil-fuel derived products with biomass-derived products.

We focused our research primarily on understanding and managing the *direct* “on-farm” GHG emissions and carbon (C) sequestration from agricultural systems, including carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄) fluxes. However, the *indirect* or *life-cycle* emissions [upstream and downstream] from agriculture appear to be equally important for understanding comprehensive GHG mitigation. On-farm strategies that reduce *direct* GHG emissions or increase C sequestration may also positively or negatively affect GHG emissions that are “inventoried” in different economic sectors (e.g., transportation, fertilizer manufacturing), so GHG mitigation policies need to account for off-farm “leakage”.

Several promising technologies and practices are currently (or nearly) available for use, including conservation tillage (the suite of practices that reduce soil disturbance), precision agriculture, improved cropping systems, and anaerobic digestion of organic wastes for methane capture and energy production. The most promising technological innovations resulting from our research, development, and evaluation include:

Anaerobic Digestion of Organic Wastes and Subsequent Recovery of Carbon and Nutrients

Anaerobic digestion (AD) of manure is a technology that is ripe for application to our modern dairy farming systems. We helped deploy the first commercial anaerobic digester on a dairy farm in the state, to provide a platform for performance evaluation and technology demonstration. We researched, developed and demonstrated novel AD system design, recovery of nitrogen and phosphorous fertilizers, use of AD fiber as a horticultural potting substrate, co-digestion of food processing waste with manure, and purification of biogas for liquid fuel applications. We expect that findings from this research will help overcome economic and technical barriers to the widespread adoption of AD technology. Using conservative assumptions regarding its deployment in the state, our study suggests that AD has significant GHG mitigation potential for the PNW’s agriculture and food industry, representing an annual reduction potential of more than 1 million metric tons CO₂e per year.

Conservation Tillage

Tillage-intensive agriculture of the past century has caused severe soil erosion and has depleted more than 50% of the native soil carbon in dryland grain cropping region of the PNW. Conservation tillage (e.g., no-till, reduced till, strip-till) reverses this trend; it reduces *direct* emissions of CO₂ from decreased on-farm fuel use, reduces *direct* emissions of CO₂ to the atmosphere caused by oxidation of soil carbon, and can increase carbon sequestration in soils (i.e., returning atmospheric carbon to soils). Numerous regional studies indicate that long-term no-till farmers have increased soil C. However, due to the extreme heterogeneity of the landscape, variability of climatic conditions, and complexity of management impacts on soils, it is difficult to accurately predict the magnitude of soil C changes expected from a shift to conservation tillage. We have developed assessment strategies and modeling capabilities to increase the confidence with which soil carbon changes can be predicted for specific, representative PNW agricultural systems. While our drier climate leads us to expect more modest potential for sequestering soil C than reported for the U.S. Midwest, widespread deployment of conservation tillage to protect the region's fragile soil resource (and the remaining C sink) is still an essential goal for future sustainability.

Managing the Carbon Cycle

Soil disturbance through tillage is only one factor that affects the carbon balance in agricultural soils. Carbon inputs (e.g. crop residues, green manures, organic amendments) and residue management (as well as the initial soil organic matter content) are important factors affecting soil carbon balance and are even more important than tillage for *increasing* soil C. Carbon inputs can be increased through the use of higher biomass crops or rotations, cover crops, perennial crops or organic amendments, and increasing C inputs tends to increase soil C. But this may affect *indirect* GHG emissions, particularly those related to the manufacture and use of nitrogen (N) fertilizers (N is required to produce carbon inputs). We evaluated several “indicator” management practices that could affect C inputs, including application of manure, perennial switchgrass production, continuous cereal vs. legume crop rotations, and residue removal for energy production. Our research indicates that each of these management practices *can* impact soil C, but may also have consequent impacts on other GHG emissions. Further evaluation of the life-cycle impacts of such practices is needed in order to more completely understand their impact on net GHG emissions.

Improving Nitrogen Use Efficiency (NUE)

Nitrogen is an essential element for crop production, and the amount of N pollution in the environment has increased with expanding agricultural production, including emissions of nitrous oxide (N₂O) from agricultural soils and emissions of CO₂ from the manufacture of N fertilizers. Improving nitrogen management is a critical need for reducing total GHG emissions from future cropping systems. The combination of *direct* N₂O emissions and *indirect* CO₂ emissions from fertilizer manufacturing represents a substantial source of GHG emissions associated with food production, often overwhelming the potential for carbon sequestration in our PNW cropping systems. Since nitrogen use (and its consequent

emissions) is essential to food production, *public policies must recognize that GHG emissions related to the agricultural use of nitrogen will always exist* – there simply is no emission-free substitute for nitrogen. Even “renewable” [biological] sources of nitrogen generate GHG emissions. Our best strategy for reducing these emissions is improving the Nitrogen Use Efficiency (NUE) of our cropping systems, meaning that we use less total N (meaning there is less reactive N to lose) to produce the same amount of biomass. Near-term strategies for improving NUE include both precision nitrogen management and the use of non-fossil based forms of nitrogen.

Research Highlights

The Climate Friendly Farming Report Summary highlights numerous scientific findings from the Project and opportunities and challenges faced by those seeking to implement Climate Friendly Farming practices and technologies in the PNW. Supporting chapters and appendices document the details of the many research findings, technologies, economic considerations, and management strategies. These include the following:

- Anaerobic digestion is the best available technology platform for capture and recovery of methane from organic wastes, generation of renewable energy, and recovery of carbon and nutrients that can substitute for other GHG intensive agricultural inputs.
- Co-digestion of food waste with dairy manure improves both the technical and economic performance of anaerobic digestion, increasing biogas output through synergistic activity – but also increases the potential for nutrient loading on dairies.
- Widespread recovery and re-use of nutrient products from organic wastes is an essential next step in developing Climate Friendly Farming systems in the region, beneficial for reducing potential on-site pollution as well as providing a substitute for manufactured and mined fertilizer products.
- Conservation tillage coupled with improved cropping systems can provide a modest, near-term GHG mitigation strategy in the region, but more importantly represents a fundamental “shift” in environmental management necessary for sustaining agricultural production in the future.
- Technology and management options for conservation tillage vary greatly across the region and across cropping systems, and incentive structures designed to encourage adoption need to be strategically applied to address site-specific barriers.
- Accurately predicting soil carbon sequestration potentials in the region is extremely challenging and the application of crop-soil models in combination with assessment of site-specific history and direct measurement can greatly increase the confidence in predicted soil C changes.
- The expected rate of soil C sequestration slows over time and mitigation projects need to account for time horizon in assessing total C sequestration.
- The use of nitrogen fertilizers is a major source of *direct* and *indirect* GHG emissions, outweighing the annual carbon sequestration potential of most cropping systems in our region on a life-cycle basis. Given the need for nitrogen inputs, improving Nitrogen Use Efficiency (NUE) is key for reducing agriculture-related GHG emissions.

- Measurements of N₂O emissions from the N fertilizer-intensive potato production system in the region are significantly lower than expected based on IPCC estimates. We hypothesize this is, in part, due to widespread use of existing, improved NUE technologies such as fertigation.
- Deployment of precision nitrogen management technology can improve NUE in dryland grain-based cropping systems, reducing nitrogen-related GHG emissions and saving farmers money.
- Management decisions directed at increasing soil carbon sequestration may have consequent effects, positive or negative, on *direct* and / or *indirect* nitrogen related GHG emissions. Incentives to encourage C sequestration should account for these changes.
- Conversion of organic residuals (e.g. manures, food waste) to energy can be the most efficient and significant option for bioenergy production in the region, but sustainability and life-cycle carbon concerns must be addressed for feedstocks, particularly when considering crop residues that are also key to reducing erosion and maintaining soil C and the health of the soil microbial community.
- Dedicated energy crop production *can be* an important, but limited aspect of a sustainable bioenergy strategy in the region, if adequate consideration is given to impacts on regional nutrient demand (and emissions) and the agronomic role these crops play in rotation with primary food crops in the region.

The CFF Project findings clearly illustrate opportunities for agriculture to reduce its “carbon footprint”, while continuing to perform its primary role of feeding a large and growing human population. Many of these actions will also provide other environmental benefits, but may or may not currently be profitable choices for farmers. Policy-makers need to carefully balance these realities to achieve sustainable economic, environmental, and social outcomes from the agricultural sector.