2022 USAFRI Research Project Objectives

Carbon Footprint of High-Yielding Irrigated Alfalfa Production in California
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Project Award: $98,200

Justification:

- Agriculture is a major contributor to global greenhouse gas (GHG) emissions and climate change. Food systems are estimated to account for more than one-third of total GHG emissions from human activity, which includes all phases of crop and animal production, food processing and transport, and direct and indirect land use change. Across the world, governments and the private sector are developing ambitious plans to decrease the carbon footprint of crop and livestock production systems. For example, the USDA Agricultural Innovation Agenda seeks to cut the environmental footprint of US agriculture in half by 2050 while increasing production by 40%, including a net reduction in current GHG emissions. Alfalfa production systems play a critical role in the economic and environmental sustainability of US agriculture. Alfalfa is the most important high-quality forage which supports the dairy and livestock sectors and generates the third or fourth highest direct farm-gate revenue after corn, soybean, and (sometimes) wheat. As a perennial legume, alfalfa also provides multiple ecosystem services related to soil quality, wildlife habitat, pest control, reduced nutrient losses, erosion protection, and lower GHG emissions (Guyader et al, 2016). However, few studies have directly quantified the carbon footprint of alfalfa production. The scope of prior work has often included an analysis of many feed components for dairy or meat production over large regions (Thoma et al, 2013; Adom et al, 2012; Eshel et al, 2014; Hawkins et al, 2015; Veltman et al, 2018), limiting the ability transfer research findings into practical use on livestock or forage operations.

  To help meet new climate-smart agriculture goals for the US, there is an urgent need to understand the management factors contributing to GHG emissions from alfalfa production and how soil carbon storage may offset these emissions. Alfalfa has the potential to provide key climate benefits compared to other forage or row crops due to differences in carbon and nitrogen (N) cycling (Little et al, 2017). In the long-term, identifying alfalfa's comparative advantages could help increase revenue for growers through on-farm payments for GHG mitigation, supporting the financial viability of perennial forages which provide important ecosystem services that are currently not valued in livestock value chains.

  Alfalfa has been shown to have a lower carbon footprint than grain, silage, or oilseed crops because it greatly reduces nitrogen (N) fertilizer inputs (Camargo et al, 2013). Addition of N fertilizer represents the single greatest contributor to GHG emissions in crop production, reaching up to 64% in maize systems (Kim et al, 2014). Thus, decreasing fertilizer use not only for alfalfa but also the N requirements for subsequent crops could further reduce GHG emissions, but this benefit is often overlooked in previous studies (Costa et al, 2020). Another advantage is the combination of reduced tillage and deep rooting systems providing high carbon inputs throughout the year, which can significantly increase soil carbon stocks (Liu et al, 2016). Unlike frequently-planted annuals, alfalfa is likely to build carbon and N reserves over time (Putnam, 2016), yet prior work has not always considered this mitigation potential. Hence, new research is required to account for these systems-level effects in a holistic analysis. The net impact of different GHG sources including fuel and energy use, external inputs, and soil nitrous oxide (N2O) emissions can be determined using lifecycle analysis (LCA), an increasingly common tool to quantify agricultural sustainability.

  New programs are emerging to financially support farmers for sequestering carbon or avoiding GHG emissions, but these require a foundation of science-based evidence for different cropping systems in different regions. There is a current USDA-funded project to conduct an LCA for primarily rainfed alfalfa production in the US Midwest. However, we are not aware of any work investigating these issues for irrigated systems in the Western US, despite irrigated alfalfa accounting for roughly half of total US production. Irrigation has strong impacts on carbon footprint because it influences both energy use and crop productivity. For instance, irrigation energy accounted for approximately 42% of total GHG emissions for corn in Nebraska (Grassini and Cassman, 2012). This percentage is likely to differ depending upon whether the irrigation system is pressurized (as in Nebraska) vs. gravity-fed (as in many western systems). Additionally, due to the large yield increases achieved with irrigation, a key question is whether the increased productivity is worth the additional GHG emissions. A recent study for alfalfa in Italy reported net benefits of irrigation, with yields increasing to a greater degree than energy use (Bacenetti et al, 2018). In contrast, irrigation combined with fertilization resulted in higher GHG emissions in an arid region of China, representing a tradeoff with yield (Wang et al, 2021).

California consistently ranks among the top states in total forage and total alfalfa production. Alfalfa acreage is almost entirely irrigated, producing among the highest US yields due to favorable soils, climate, management, and genetics. The $7 billion dairy industry is highly dependent upon alfalfa production in the state. However, variation in rainfall and increasing frequency of drought are limiting water availability, causing a decline in alfalfa acreage throughout much of the Western U.S. Meanwhile, production costs for land, labor, and inputs continue to increase, putting pressure on growers to maximize economic returns to available irrigation water. Considering these constraints to on-farm profitability, one opportunity for increasing revenue is to quantify the ecosystem services alfalfa provides and link these to new market opportunities.

California represents the best-case study for this example because of its strong state-based efforts to decrease GHG emissions from agriculture and other sectors. Under the Healthy Soils Program, California growers can receive an incentive of $100-400 per acre to convert annual cropland to an irrigated forage such as alfalfa to achieve the goal of reducing GHG emissions and increasing soil carbon. Recently, USDA has invested $1 billion to jumpstart the development of markets for climate-smart commodities at the national level, indicating that such programs could be expanded to other regions. Importantly, alfalfa's potential for soil carbon storage is estimated to be 2-3 times higher than no-till or cover crops, two of the main regenerative agriculture practices to participate in carbon markets for commodity grain crops.

Objectives:

- The objectives of this project are to 1) Quantify the carbon footprint of alfalfa production for three main growing regions in California (Intermountain, Central Valley, and Low Desert). These represent a 3-4 cut system, 5-9 cut system, and 8-12 cut system with distinct varieties, management practices, and environments relevant to the much larger regions of Intermountain West and Southwestern US; 2)Identify the major drivers of GHG emissions and construct mitigation scenarios to explore opportunities for further decreasing carbon footprint without lowering crop productivity. This could include reducing fuel use, increasing irrigation efficiency, changing cutting systems or varieties, or applying soil amendments to build soil carbon. Scenarios will leverage results from previous and ongoing field research in California, emphasizing changes in management with the biggest impact; and 3) Perform extension and outreach with alfalfa growers and industry to raise awareness about management practices influencing GHG emissions in California, and explore the feasibility of participating in ecosystem service markets due to the anticipated low carbon footprint.