Adaptation Resources for Agriculture
Case Study: Full Belly Farm, Guinda, CA

California is one of the most important agricultural producing locations in the world; the state has a critical role in food production to meet domestic and global demand. Climate change is already impacting growers, and future changes will force vast elements of the industry to adapt. The USDA Climate Hubs, in partnership with NRCS, have developed a suite of case studies to demonstrate how farmers and ranchers can use an adaptation planning framework to address the impacts of a changing climate. The framework consists of a five-step process laid out in the USDA Adaptation Resources for Agriculture Workbook. The USDA California Climate Hub has partnered with Full Belly Farm in Yolo County, CA to illustrate how a grower can adapt their operation to changing climate conditions, ameliorate impacts, and maintain productivity. The five-step process aims to (1) define specific operational goals of a producer, (2) assess how climate change may impact their ability to meet those goals, (3) evaluate opportunities for adaptation, (4) identify adaptation practices, and (5) consider metrics for monitoring for success.

Full Belly Farm and the Capay Valley

Full Belly Farm is a diverse 400-acre farm in the Capay Valley of Yolo County, northwest of Sacramento. The farm was founded in 1985 by four partners and for this case study we worked with two of the founding and current partners, Judith Redmond and Paul Muller. The farm is certified organic by California Certified Organic Farmers and USDA National Organic Program and produces over 80 different crops including almonds, walnuts, tomatoes, cut flowers, grains, potatoes, and other specialty crops.

Image: Diana Rothery, courtesy of Full Belly Farm

1. Define operational goals

Full Belly's goals as an operation are to farm the land sustainably, promote biodiversity, have a low impact on water resources, provide stable work for employees, and foster an operation that successfully continues into the future. For the purposes of the case study, we focused on their goals of **ecological sustainability**, **economic profitability**, and providing year-round **stable employment** for workers. For an in-depth look at how Full Belly is meeting their goals given challenges from climate change, see the full adaptation exercise.

2. Assess climate impacts

Climate change creates concerns for meeting all three of Full Belly's overarching goals. Redmond speaks about the increasing variability in climate conditions, "You have to stop planning for each year to be the same. You have to start planning for each year to be different, to almost expect that you're going to have to change from year to year." Top climate impact concerns for Full Belly are extreme heat, extended drought, and flooding and erosion from heavy rains. The table to the right shows historical climate data alongside future short-term and long-term projections. The table below outlines regional climate change impacts and site-specific concerns for Full Belly.

Climate variable (annual avg)	Historical 1950-2005	Short term projections 2021-2050	Long term projections 2050-2075
Maximum temp. (F)	73.8°	77.2°	79.9°
Extreme heat days over 95°F	38	70	89
Heat waves (4 days above 95°F)	6	13	18

Climate Change Impacts and Vulnerabilities	Concerns for Full Belly
Warmer temperatures: Temperatures are expected to rise 5-6°F and the number of extreme heat days over 95°F will rise sharply	• Crop heat stress • Worker health and safety at risk • Failed crop pollination during extreme heat
Extended drought: Increased climate variability and changes in precipitation patterns may mean longer periods of drought	• Water availability • Decreased soil moisture
Heavy rains: Variability in precipitation patterns is expected, with an increase in large storms and periods of heavy rains	• Parts of the farm close to Cache Creek may flood • Soil erosion as a result of flooding

Above: Historic annual averages and climate projections for Capay Valley, CA. Source: Cal Adapt, 2020 (please note historical data is only available up to 2005). Left: Regional climate impacts and priority concerns for Full Belly.

3. Evaluate adaptation opportunities

Full Belly sees soil health as an opportunity to mitigate the impacts of climate change and make their farm more resilient. **Building soil organic matter** not only provides fertility for crops, but improves the water holding capacity and retention in soil. **Covering bare ground** is important to retain soil moisture, reduce erosion, and maintain a more stable soil temperature for crops that reduces crop stress and helps crop productivity. For Full Belly, feeding a **diverse soil ecology** is a way to reduce risk and prepare for the lack of predictability. They take a holistic approach to managing the land that supports diversity within the ecosystem and focuses on soil ecology, not just soil chemistry.

4. Identify practices

Increasingly over the past several years, Full Belly has focused on reducing bare ground, keeping living roots in the soil, and avoiding disturbance. The aim of their soil health efforts is to allow the soil to function up to its potential. The building blocks of their efforts to maintain and improve soil health include the use of **cover crops** on every field every season, application of **compost** before each planting, and incorporating rotational **sheep grazing** on approximately 230 acres of the farm. Efforts to maintain or build soil organic matter promote healthy crops, store carbon in the soil, promote microbial activity, and make the soil more resilient to impacts from drought or floods. Although Full Belly has engaged in long-term efforts to maintain and build soil organic matter and to enhance soil health, these same practices have climate adaptation benefits by increasing resilience to climate-related impacts. The table below highlights Full Belly's adaptation practices related to soil health and lists benefits for each practice.

Full Belly has also experimented with **no till** and minimum till practices. The primary objective of no till practices is improving soil health – enhancing soil structure, supporting healthy soil microbial communities and maintaining high soil moisture – yet the opportunity to store more carbon in the soil and mitigate climate change is an additional benefit. Although they see benefits to implementing these practices, there are challenges including how to manage weed pressure using methods that minimize soil disturbance. The image above shows one of Full Belly's minimum till fields where they planted winter squash into cover crop residue that was rolled down earlier this season.

Goal: Ecological sustainability	
Objective: Maintain soil health and function	
Challenges given climate change: Erosion from heavy winds or rain, reduced water availability	
Practice	**Benefits**
Cover crops	• Reduction of bare soil • Reduction of windborne soil particles / better air quality • Increase in soil organic matter and soil carbon • Enhanced soil fertility and nitrogen fixation
Compost application	• Increase in water holding capacity and water retention in soil • Enhanced soil fertility • Reduction of runoff from fertilizer / enhanced water quality • Supports healthy soil microbial communities • Increase in soil organic matter and soil carbon
Sheep grazing	• Light manure and urine deposition adds fertility to soil • Reduces need for tillage by mowing down crop residue and weeds • Can consume reject vegetables that would otherwise be wasted and turn them into protein
No till / reduced till	• Enhanced soil structure / improved aggregation • Reduces soil disturbance • Supports healthy soil microbial communities • Increase in water holding capacity and water retention in soil • Reduction of risk to flooding impacts • Less soil compaction

5. Monitoring and Evaluation

Redmond says, "Each year is a new set of variables. There's no formula." For Full Belly, the process of observation is as important as any management practice. One way they continue to monitor success is having multiple owners and supervisors engaged in evaluation, which spurs discussion about whether new practices are contributing to productivity and sustainability. Each year, they review sales records and examine yield and pricing of crops for each field, and then compare to previous years. They also evaluate practices by looking at variations in labor cost. For example, they look at time spent weeding when evaluating no till or minimum till practices. They weigh any added costs against perceived soil health benefits and benefits to yield or pricing. Muller notes it is a patient process, "It takes longer than [1-3 years] to see systems that are more ecologically intact."

This case study was developed by the USDA California Climate Hub in partnership with NRCS. The lead author is Emilie Winfield, a graduate student researcher at the USDA California Climate Hub and UC Davis, with input from Steven Ostoja and Lauren Parker of the USDA California Climate Hub. Thank you to Judith Redmond and Paul Muller of Full Belly Farm for providing information about their operation.