Climate Solutions in California Agriculture

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California agriculture is particularly vulnerable to the impacts of climate change. Climate scientists report that state water supplies will become increasingly limited, threatening a fundamental resource for the agriculture industry.[1] Also predicted is greater pressure from weeds and pests, increased animal diseases, reduced winter chill hours, and changing intensity and number of storms.[a]

The significance of the impacts of climate change on California's important agriculture industry cannot be overstated. California's nearly 78,000 farms and ranches generated over $42.6 billion in 2012.[2] Producing over 400 food and fiber products, California agriculture represents nearly every crop produced in the U.S.[3] Thus, the future of California agriculture in the face of a changing climate is important not just for the state's economy but also for the nation's food security.

To protect California agriculture in the coming decades, greenhouse gas (GHG) emissions must be reduced and the worst impacts of climate change must be averted. Agriculture can make significant, unique and profound contributions to meet this challenge.

Here we summarize the current peer-reviewed scientific literature on agriculture and climate mitigation, with a focus on studies specific to California conditions, and in consultation with several academic experts in the field.

While the focus of this review is on methods for reducing GHG emissions and sequestering carbon in agriculture, it is important to note that many of the climate-focused measures also prepare agriculture to better cope with the impacts of climate change and provide additional environmental and health benefits both on and off the farm.

Finally, as California considers GHG emissions issues in agriculture, it is important to take a whole-farm system approach rather than a practice-by-practice approach. Altering one agricultural practice to reduce GHG emissions may lead to the unintended consequence of increasing GHG emissions elsewhere in the farm system. Considering agricultural practices as integrated parts of the whole farming system will provide a more complete picture of the opportunities to reduce GHG emissions and provide multiple benefits. Sustainable agricultural systems, based on ecological principles, offer this holistic approach.[4]

Water & Energy Efficiency, Renewable Energy Production

There is no "one size fits all" set of best practices for achieving on-farm water use efficiency and reduced dependence on fossil fuel-based energy. Instead, such activities must take into consideration the operation's production, soils, water sources, and other regional variables. Growers must also consider the value of gains in on-farm water efficiency, balanced against potential trade-offs in diminished groundwater recharge or increased energy demand, described in more detail below.

Improving water use efficiency can deliver energy savings for farmers and reduce energy-related GHG emissions. Each year, California agricultural irrigation consumes over 10 billion kilowatt hours (kWh) of electricity—nearly enough energy to power 1.5 million residences.[5,6] Furthermore, the vast majority of that power consumption occurs between the months of May and October, when the state's energy demand is at its highest. During the summer months,

energy used for groundwater pumping in California exceeds the amount of energy required to run the State Water Project, the Colorado River Aqueduct and the Central Valley Project combined.[7] However, optimizing on-farm irrigation efficiency through close monitoring and evaluation can achieve significant water and energy savings.[8]

The most widely used on-farm water use efficiency methods are drip and micro-sprinkler systems. These technologies can produce the highest crop yield per unit of water applied and can achieve irrigation efficiencies as high as 90 percent compared to flood irrigation at 60 to 85 percent.[9] Studies have also found that subsurface drip irrigation—particularly when combined with reduced tillage practices and fertigation (the application of fertilizers through irrigation systems)—can significantly reduce nitrous oxide emissions.[10,11]

The benefits of drip and micro-irrigation systems must be weighed against the potential for reduced groundwater recharge compared to flood or furrow irrigation, an important consideration as the state faces the diminished water availability predicted with climate change. The low energy requirements of flood irrigation should also be considered.[12]

Additional management practices can improve water use efficiency and offer other benefits. For example, cover crops, reduced tillage practices, and organic soil amendments that can decrease evapotranspiration by 30 to 50 percent[13] also help build soil organic matter, promoting water infiltration and storage.[14] Dry farming techniques can improve soil moisture retention and reduce or eliminate the need for irrigation, instead relying on seasonal rainfall.[15] On-farm ponds can reduce runoff, recharge groundwater, store rainfall, and contribute to regional flood management efforts.[16]

Energy efficiency measures and on-farm renewable energy production can provide energy and cost savings to farms and ranches while reducing GHG emissions. Before investing in renewable energy production, growers should maximize energy efficiency on their farms and in packing, cooling, and shipping operations to avoid oversizing their renewable energy systems. Energy audits, available through California's electric utilities and the Natural Resources Conservation Service (NRCS), can identify opportunities to increase efficiency.[17]

In terms of renewable energy, wind turbines, solar panels, geothermal and bioenergy projects on agricultural land can increase the state's production of renewable energy and also generate income for farmers and ranchers through the sale of excess energy.[18,19,20] By 2012, the number of California farms reporting the installation of on-farm renewable energy systems nearly tripled to 5,845, up from the nearly 2,000 systems reported in 2009.[21,22] There is considerable potential for growth with continued financing and outreach.

Soil Building

Agriculture and forestry can serve as terrestrial "sinks" of carbon dioxide, removing our most ubiquitous greenhouse gas from the atmosphere and storing it in soils, trees, and other plant biomass. This process is known as carbon sequestration.[23] The ability of farm and rangeland to sequester carbon depends on soil type, regional climate, crop systems, and management practices.[24]

Among the agricultural soil management practices that have significant potential to sequester carbon are conservation tillage, cover cropping, agroforestry techniques, improving rangeland and pasture management, adding organic amendments like compost, and reducing and properly timing the application of nitrogen fertilizer inputs.[25,26,27]

Conservation tillage can stabilize soil carbon by decreasing the mechanical disturbance to soil aggregates and minimizing the conversion of carbon in soil and crops to atmospheric carbon dioxide.[28] Also, replacing synthetic fertilizers with nitrogen-fixing cover crops can halve carbon dioxide emissions.[29] Soil management practices used in combination, such as cover cropping and applying composted manure or plant material, show the greatest potential for building soil organic matter, sequestering carbon, and reducing emissions of carbon dioxide and the potent GHG, nitrous oxide.[30,31,32,33]

Many of the soil management practices that increase carbon sequestration also reduce nitrogen inputs and therefore can lower nitrous oxide emissions. These practices include conservation tillage and the application of composted manure and green waste as an alternative to synthetic nitrogen fertilizers.[34,35,36] These sources of nitrogen have the added benefit of releasing nitrogen slowly over time to better suit plant nutritional needs, rather than in periodic large applications that leach through soils more quickly. For example, the use of cover crops can reduce nitrate contamination in groundwater by as much as 83 percent.[37]

Organic Farming

Organic systems integrate ecologically based practices to boost fertility, build soil organic matter, conserve natural resources, and mitigate GHG emissions.[38,39,40] Organic farming operations provide multiple opportunities to reduce agricultural GHG emissions and sequester carbon.[41,42] Many of the techniques used by organic producers are incorporated on conventional farms.

A critical distinction between conventional and organic systems is that organic farmers are prohibited from using the fossil fuel-based synthetic fertilizers, herbicides, and pesticides that can increase a farm's carbon footprint.[43] Instead, organic systems use inputs with up to 30 percent less embedded energy than conventionally managed systems, resulting in lower net GHG emissions.[44,45] Although organic producers may use more fuel (because increased tillage may be necessary to deal with weeds in place of synthetic herbicides), organic systems often have smaller carbon footprints per acre than their conventional counterparts when all energy inputs are taken into account.[46,47]

While there is considerable variability between farms, seasons, soils, and other conditions, studies have found that soils under organic management—including use of animal manures, compost and cover crops—exhibit significantly more carbon sequestration than soils managed conventionally using synthetic fertilizers.[48,49,50,51,52]

In an eight-year study in California, soil organic carbon increased 19 percent in organic and low-input systems, compared to an increase of only 10 percent in conventional agriculture.[53] A twelve-year study in California showed a 36 percent increase in carbon sequestration with the use of organic practices like green manures and animal manures, despite increased tillage compared to the conventional system.[54] USDA research shows that organic agriculture, even when using tillage, can sequester more carbon than no-till conventional agricultural systems.[55]

Rangeland Management

Rangelands cover approximately half of California's total land area and approximately 34 million acres are actively grazed.[56] The conservation and management of both grazed and ungrazed rangeland can be critical for addressing climate change because, while most rangeland has limited potential for carbon sequestration in soils and woodlands, over this vast acreage the combined potential for sequestering atmospheric carbon is significant.[57,58]

While there is great variability in the soil carbon storage potential across California's diverse rangelands and climate conditions,[59,60] management practices can improve carbon storage,[61,62,63,64] particularly in the wetter areas of California.[65]

The Many Benefits of Climate-Friendly Farming

Many of the agricultural practices that reduce GHG emissions and sequester carbon can also provide numerous environmental and public health benefits. They can also enhance the resilience of California farms and ranches to climate impacts such as drought, flooding, new pests and diseases, and extreme weather events. For example:

- On-farm water conservation reduces agriculture's vulnerability to California's cycles of drought and water scarcity.
- Improved air quality results from the use of renewable energy and reduced fossil fuel-based inputs.
- Cover crops and tailwater ponds can reduce nitrate pollution in groundwater.
- Farmscaping provides habitat for beneficial insects, pollinators and wildlife.
- Increasing soil organic matter improves soil water retention, reduces soil erosion and provides flood control.

Restoring woody vegetation (e.g., oak trees) and riparian habitats can increase carbon sequestration on rangelands, and there is evidence that increasing the population of native perennial grasses also stores more carbon.[66,67]

Managing the timing, duration and intensity of livestock grazing can bolster aboveground species richness and productivity, which is correlated with increased soil carbon.[68,69,70,71,72] Increasing forage quantity with fertilization and organic amendments has been shown to increase soil carbon.[73] Whereas uncomposted manure additions have been correlated to increased GHG emissions,[74] a model based on two field sites found that the application of compost to rangelands can lead to soil carbon sequestration that is expected to persist for many years.[75] Carbon sequestration in rangeland soils has many benefits, including reduced erosion and increased water infiltration and storage in soils.[76]

Livestock Production

Livestock-related methane emissions account for more than half of California agriculture's GHG emissions and over three percent of the state total,[77,78,79] the majority from dairy and beef cattle manure management and the digestive processes (enteric fermentation) of the animals. Importantly, there are promising opportunities to reduce this impact by altering livestock diets, manure management techniques, breeding strategies, and managed grazing practices.[80]

Improving the digestibility and nutrient composition of animal feed can reduce methane emissions generated by enteric fermentation,[81,82] as can grazing that provides livestock with high quality forage.[83,84] Furthermore, grassfed livestock may require less fossil fuel energy inputs compared to conventional feedlot livestock. One study found half the energy demand in grassfed systems.[85]

Another source of GHG emissions in conventional livestock rearing systems is manure management. Stockpiling manure in ponds and lagoons leads to anaerobic decomposition, which emits methane and nitrous oxide.[86] Capture of methane from manure storage lagoons and conversion to electricity via biodigestion offers a significant opportunity for both emissions reductions and emissions avoidance by offsetting fossil fuel use.[87] The application of anaerobic digestate or composted manure to soils can add organic matter and likely reduce net GHG emissions.[88] Alternatively, when animals are grazed, their manure is applied directly to rangelands, thereby avoiding anaerobic decomposition and the associated methane and nitrous oxide emissions of confined livestock systems.[89]

Farmscaping

Farmscaping describes a broad range of land management practices that incorporate perennial and annual flora into agricultural production to achieve a variety of agronomic and environmental benefits.[90] Reforesting rangelands, planting hedgerows along field margins, and installing tailwater ponds to capture irrigation runoff are common farmscaping techniques.[91] The most important climate benefits of farmscaping include carbon storage in plants and soil and reduced nitrous oxide emissions.[92,93,94]

Incorporating trees, shrubs, or other types of woody vegetation into rangeland or cropland can increase carbon sequestration.[95,96] Studies on organic farms found that riparian and hedgerow habitats with woody vegetation stored up to 20 percent of the farm's total carbon, despite occupying less than six percent of the total area.[97,98]

Planting hedgerows along the margins of farms, establishing woody biomass in riparian zones, and replanting oak woodlands on rangeland offer some of the best opportunities to sequester atmospheric carbon.[99,100] Riparian areas can store nearly twice as much carbon per acre as adjacent rangeland and 25 percent more carbon compared to cropland.[101]

Establishing riparian buffer zones and planting hedgerows also allow for the uptake of excess nitrogen that otherwise would have been lost, decreasing by 28 to 42 percent the nitrate that can pollute streams and groundwater.[102] Tailwater ponds can reduce nitrate contamination in groundwater by as much as 97 percent.[103]

Winter cover crops improve nitrogen use efficiency by scavenging for residual soil nitrogen and increasing its availability for target crops, which reduces the amount of fertilizer needed.[104,105,106]

Farmscaping provides habitat for beneficial insects and pollinators,[107,108,109,110] assisting with pest control and helping offset the recent decline in pollinator populations.

Conserving California Farm and Rangeland

California loses an average of over 50,000 acres of agricultural land annually, which has a negative impact on climate change mitigation and adaptation opportunities in the state.[111,112,113] Due to the potential of rangelands to sequester small amounts of carbon over vast acreages, the ongoing loss of rangelands from urban development and the conversion to more intensive forms of agriculture have implications for climate mitigation.[114]

Farmland conservation offers a multitude of climate benefits, such as carbon sequestration, reduced GHG emissions, renewable energy production, and greater resilience to climate change impacts for both cities and rural areas.[115] An acre of urban land was found to emit 70 times more GHG emissions compared to an acre of irrigated, conventionally managed cropland.[116,117]

Research suggests that conserving farmland at the urban edge slows the spread of sprawl and reduces transportation-related GHG emissions.[118] Furthermore, agricultural land around urban areas may help cool the "hot spots" created by cities through the albedo effect (the tendency of urban areas to absorb more solar radiation). Such cooling will help offset the impacts of increased temperatures.[119,120] Farmland preservation provides an array of additional benefits, such as maintaining local food sources for Californians, enhancing biodiversity and wildlife habitat, and aiding in water filtration and groundwater recharge.[121,122]

Supporting Climate-Friendly Agriculture

Farmers and ranchers can be part of a climate solution for California and the nation as a whole. Encouraging sustainable agricultural practices can reduce GHG emissions, enhance on-farm capacity for carbon sequestration, and provide numerous environmental and health co-benefits.

More California-specific research on climate change and agriculture is needed. Technical assistance is required to translate those research findings into real opportunities for GHG emission reductions on California's farms and ranches. When there are costs or perceived risks of making the transition to climate-friendly practices, financial incentives for farmers and ranchers are essential.

Researchers at UC Davis find that California producers will adopt practices to mitigate climate change if they are given realistic payments and assistance.[123] Increased funding from USDA conservation programs, as well as investments at the state and national levels from carbon pricing policies, are needed to support agriculture's role in climate protection.

California agriculture can be a leader in mitigating and adapting to climate change. With additional research, technical assistance and financial incentives, we can ensure that agriculture remains a viable, innovative, and ecologically and economically sustainable industry for years to come.

About CalCAN

The California Climate and Agriculture Network (CalCAN) is a coalition of the state's leading sustainable agriculture organizations and farmer allies. We came together out of concerns for climate change impacts on California agriculture and to advance sustainable agricultural solutions to a changing climate. Since 2009, we have cultivated farmer leadership to serve as the sustainable agriculture voice on climate change policy in California.

CalCAN
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