Introduction

Agriculture is vital to the economy of California’s Central Valley. California leads the nation in the production of fruits, nuts, vegetables and dairy products. The state is also at the forefront of legislation to protect air and water quality and most recently, in policies to mitigate climate change. Concerted efforts to plan for and adapt to higher temperatures, less snowpack, and potential drought are also being initiated. As California farmers balance these objectives, they also face numerous uncertainties. Will climate change dramatically influence water availability or alter which crops can be profitably grown? How will new government policies influence their day-to-day operations? How can they protect agricultural lands from rapid urbanization? How will changes in global commodity markets affect their bottom line? Anticipating and adapting to these uncertainties will be crucial for the future viability of California agriculture (Figure 1).

Yolo County as a Case Study for Climate Change Mitigation and Adaptation

In this article we discuss how one rural community in California’s Central Valley, Yolo County, is already preparing for the future. We focus on Yolo County for several reasons. First, as a county it has many attributes typical of the Central Valley: small towns and cities with a changing mixture of urban, suburban, and farming-based livelihoods. Its agricultural landscape includes a mix of irrigated row crops and orchards grown on alluvial plains; and grazed rangelands in the
uplands along the eastern edge of California’s Coastal Range. The second reason is that Yolo is among the first rural counties in California to specifically address climate change mitigation and adaptation in their recently passed “climate action plan”. Not surprisingly, concern about the impact of both climate change as well as the new state and local policies have brought a diverse range of stakeholders into the discussion. We also focus on Yolo County because of the relative wealth of research on climate change and agriculture that has been conducted at the nearby land-grant university (University of California, Davis), through partnerships with local farmers, cooperative extension, non-profit organizations and local officials.

An essential element of the adaptation process is an understanding that the capacity of a rural community to cope with climate change and other uncertainties will be largely dependent on its collective ability to assemble and process relevant information and then act accordingly (Adger, 2003). Since the impacts of climate change on agriculture will include agronomic, ecological, and socioeconomic dimensions, useful data and knowledge will come from many sources including scientists, Cooperative Extension, public officials, NGOs as well as innovative farmers and local businesses. Here we highlight how involvement and insights from these stakeholders in Yolo County have helped to spur planning and action in response to climate change.

Figure 1. A diagram of potential agricultural vulnerabilities and responses to various change factors including climate change, population growth, markets and regulations. Adapted from Jackson et al., 2011.
Government Initiatives at the State and Local Level

Much of the recent impetus for both research and action on climate change stems from the passing of California’s Global Warming Solutions Act in 2006 (Assembly Bill 32; AB32). For example, AB32 now requires local governments to address climate change mitigation in any update to their general plan or to submit a separate climate action plan that does so in detail (CAGO, 2009). The climate action plan recently completed by Yolo County’s local government is an early example of what other counties and municipalities will carry out in the not so distant future (Yolo CAP, 2010). Yolo County’s climate action plan consists of three main components; 1) an inventory of greenhouse gas emissions (GHG) for 1990 and the current period; 2) a set of local policies to mitigate future emissions; and 3) a section examining possible adaptation strategies to help county stakeholders cope with the local impacts of climate change.

Since the jurisdiction of Yolo County’s government is limited to the mostly rural “unincorporated” parts of the county, insights and feedback from the agricultural community were crucial to the planning process. To facilitate this dialog, Yolo’s Planning Department held a series of rural stakeholder meetings where available data on agricultural emissions sources and mitigation strategies were discussed with local farmers, the county’s agricultural commissioner, cooperative extension, university scientists and others. Table 1 shows the range of GHG mitigation strategies addressed during these meetings and highlights some of the tradeoffs and co-benefits articulated by the participants.

While examining the county’s data on GHG emissions, perhaps the most important observation made by local stakeholders was that electricity use and transportation in neighboring urban areas leads to emissions rates that are roughly 100 times higher per acre than agricultural land uses (Yolo CAP, 2010). The intent here was not to shift the emphasis away from the mitigation opportunities within agriculture, but rather to highlight how local policies to promote “smart growth” and protect prime farmland from urbanization may actually help stabilize and reduce future emissions from other sectors. This is particularly relevant in regions of the Central Valley which face mounting pressure to convert farmland to urban land uses. More importantly the concept seemed to...
Table 1. Stakeholder generated trade-offs and co-benefits of various agricultural GHG mitigation strategies in Yolo County.

<table>
<thead>
<tr>
<th>Emissions Category</th>
<th>Strategy</th>
<th>Trade-offs</th>
<th>Co-benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct and Indirect Nitrous Oxide</td>
<td>N fertilizer rate reduction</td>
<td>- yield loss for some crops; already optimized for some crops</td>
<td>- lower input costs; water quality</td>
</tr>
<tr>
<td>from Agricultural Soil (N₂O)</td>
<td>organic farming methods</td>
<td>- organic fertilizer costs; labor costs; limited pest control options</td>
<td>- price premium; local or direct marketing; environmental quality; agrobiodiversity</td>
</tr>
<tr>
<td>Mobile Farm Equipment (CO₂, N₂O, CH₄)</td>
<td>cover cropping</td>
<td>- cost of crop establishment; additional fuel use; not compatible with all crop rotations; spring incorporation constraints</td>
<td>- erosion and runoff control; better soil water quality; agrobiodiversity</td>
</tr>
<tr>
<td></td>
<td>equipment maintenance</td>
<td>- maintenance cost; generally done already</td>
<td>- lower fuel costs</td>
</tr>
<tr>
<td></td>
<td>optimize draw-bar load</td>
<td>- generally done already</td>
<td>- lower fuel costs</td>
</tr>
<tr>
<td></td>
<td>conservation tillage</td>
<td>- not compatible with all crop rotations</td>
<td>- lower fuel costs and less labor; less wear on tractors; soil carbon sequestration; water conservation</td>
</tr>
<tr>
<td></td>
<td>engine upgrades or retrofits</td>
<td>- cost of new equipment</td>
<td>- lower fuel costs</td>
</tr>
<tr>
<td>Irrigation Pumping (CO₂, N₂O, CH₄)</td>
<td>Maintain pump bowl assembly</td>
<td>- maintenance cost; generally done already</td>
<td>- lower fuel or electricity costs</td>
</tr>
<tr>
<td></td>
<td>solar-powered pumps</td>
<td>- cost of photovoltaic cell; limited to low horsepower engines; limited to daytime use</td>
<td>- lower fuel or electricity costs</td>
</tr>
<tr>
<td>Livestock (CH₄)</td>
<td>biogas control systems</td>
<td>- cost of building the system; engines subject to air quality rules.</td>
<td>- energy generation (gas or electricity); sale of carbon credits</td>
</tr>
<tr>
<td>Rice Cultivation (CH₄)</td>
<td>baling and removal of straw</td>
<td>- baling costs; limited market for rice straw; impacts quality of waterfowl habitat</td>
<td>- sale of rice straw; feed and bedding for livestock; feedstock for biomass power generation</td>
</tr>
<tr>
<td></td>
<td>reduce winter flooding</td>
<td>- poor decomposition of straw; impacts quality of waterfowl habitat</td>
<td>- lower pumping costs, fuel savings</td>
</tr>
<tr>
<td></td>
<td>mid-season drainage</td>
<td>- crop water stress; yield loss</td>
<td>- control of aquatic weeds; water conservation</td>
</tr>
<tr>
<td>Residue Burning (CO₂, N₂O, CH₄)</td>
<td>minimize burning</td>
<td>- low overall mitigation potential; already regulated</td>
<td>- air quality</td>
</tr>
<tr>
<td>Carbon Sequestration (CO₂)</td>
<td>reforest rangelands, riparian zones and hedgerows</td>
<td>- cost of establishment; require irrigation in early years</td>
<td>- water quality; erosion control; biodiversity</td>
</tr>
</tbody>
</table>

establish valuable common ground with those in the agricultural community. Unlike California’s industrial sector, AB32 does not require agricultural producers to report their emissions or to implement mandatory mitigation measures (CARB, 2008). The state is however encouraging farmers to institute voluntary mitigation strategies through various public and private incentive programs (Niemeier and Rowan, 2009). That said, some in the agricultural community are still concerned that the policy for agriculture could shift from voluntary to mandatory mitigation at some point in the future, which could make it more difficult for farmers to stay in business. Given that this hypothetical shift in climate policy might inadvertently accelerate farmland conversion and further boost urban emissions, there appears to be a sound case for maintaining and protecting agriculture’s voluntary mitigation status.

Tapping into Farmers’ Ideas on Mitigation and Adaptation

Protecting farmland from conversion is an important first step, because it expands the opportunities to mitigate future emissions, and perhaps more importantly helps to maintain our economic and ecological resilience to the impacts of climate change. But for these goals to be fully realized local farmers and land managers must be part of the process. Farmers have a key role to play since they have vast practical knowledge on how to optimize farm management to reduce agricultural emissions, conserve water or store carbon in the agricultural landscape. Almond orchards in Yolo County are a prime example; reports from some local growers indicate that innovations in drip irrigation have allowed some to reduce N fertilizer applications by up to 30%, while also boosting yield and water use efficiency. Since
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N₂O emissions from fertilizer use are the single largest source of emissions from agriculture, efforts by growers and commodity boards (e.g. California Almond Board) to expand the use of these technologies have already begun to yield mitigation benefits.

Given that local (and global) temperatures are expected to rise even if the state’s mitigation targets are met, it is equally important for rural communities to consider ways to adapt local agricultural systems to the possible impacts. With this in mind, understanding how farmers have adapted to past extreme events (e.g. heat-waves, droughts, floods) can often give insight about what strategies might be effective in the future. For example, during previous droughts Yolo farmers reduced rice and alfalfa acreage (both of which require a lot of water) but increased the cultivation of rain-fed winter wheat. Another planning strategy is to simply look at what farmers are growing just a few hundred miles to the south. By the end of the century the climate in Yolo County is expected to resemble the current climate in Merced County (Jackson et al., 2011). Consequently, Yolo may become better suited for the more heat-tolerant crops commonly found there like olives, citrus and melons.

Bridging the Gap Through Research and Extension

To support these local efforts, an interdisciplinary group of researchers from UC Davis is working on a case study for the California Energy Commission to explore planning scenarios that support the sustainability of agriculture and its adaptation to climate change in Yolo County. The purpose of the project is to create a planning template for other California counties where knowledge on agricultural impacts and solutions are assembled and then made widely available to the public through an interactive website. A key component of this has been the development of three planning tools that will help local land managers and decision makers consider what land-use and adaptation strategies might be useful. The first is a water evaluation and planning (WEAP) model, which assesses how future climatic and economic projections will impact the local water supply and also test the efficacy of various mitigation and water conservation strategies. The second is an urban growth model called UPLAN, which will allow decision-makers to see how future urbanization scenarios might impact the county’s farmland and greenhouse gas emissions. The final element has been the development of a survey, which solicits farmers’ ideas and perspectives on proposed mitigation and adaptation strategies.

Conclusion

In addition to assembling the information and tools necessary for decision-making one of the main roles of this UC Davis research project has been to serve as a bridge between the various stakeholders. Uncertainty is an inherent part of climate change planning. However, by helping people to express their views and concerns about these uncertainties important social linkages within the community are also strengthened. Better communication in turn increases the ability to come to a consensus on the uncertainties, risks and opportunities posed by the various factors that drive change. Ultimately, communities with strong linkages among those in the social network are bound to have better adaptive capacity in response to change. While this planning process remains in its early stages, there appear to be many good reasons for optimism in Yolo County. Not the least of which is a recognition that the stakeholders mentioned above are committed to strengthening the resilience of Yolo’s agricultural landscape to the many changes that lie ahead, be they climate-driven or otherwise.

References
Yolo County, 2010. Final Yolo County Historic Greenhouse Gas Emissions Inventory Results.
Bridging the Gap in Yolo County

Researchers and local growers discussing perspectives on sustainable agriculture.

A field of newly transplanted tomatoes irrigated using traditional furrow irrigation.

Researchers and Extension Specialists interacting with local growers in the field.

Coming This Winter:
Survey of Yolo Farmers’ Views on Water Scarcity and Climate Change

Participation is a change to:
- Make your concerns heard
- Share your priorities with local and state officials
- Other ways for you to adapt

We invite Yolo farmers to share their thoughts on how California agriculture can adapt to future challenges posed by water scarcity and climate change.

See previous slide for details.