Appendix C - Focus Group Working Papers

Agriculture Working Paper

Introduction

Agriculture is an important resource for California, providing a safe, reliable, and affordable food source to support growing local, national, and global populations. It is also a key economic driver in the state. California has a range of climatic regions that allow for the production of a diverse variety of annual crops, such as vegetables and grains, perennial crops such as fruits and nuts, as well as livestock and dairy products. One tradeoff from agricultural food production is the release of greenhouse gases (GHGs) into the atmosphere. On a national scale, agriculture contributes approximately 6 percent of total GHG emissions (USDA 2011; Olander et al., 2011). The same levels apply for California - agriculture is responsible for approximately 6 percent of total inventory according to the California Air Resources Board. The primary GHG emissions from agriculture include methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O). The global warming potential of CH_4 and N_2O is 21 and 310 times that of CO_2, respectively.

According to a recent report titled "Solutions from the Land: Developing a New Vision for U.S. Agriculture, Forestry, and Conservation", in 2050, U.S. farmers and ranchers will need to manage land to produce the food, fiber, and energy needed to support a growing population while simultaneously protecting and improving biodiversity and the health of the environment. The report goes on to note that land management must take into account a wide range of goals that address both food production and environmental sustainability. Environmental sustainability includes mitigating any GHGs from agriculture and also using agriculture to offset climate change through methods such as biological carbon sequestration – the natural process of plants absorbing CO_2 from the atmosphere and storing it in soil and plants.

It is in the best-interest of California's agricultural sector to identify and implement opportunities to mitigate GHGs since several documents, reports, and scientific publications have found that the impacts to agriculture from climate change and associated extreme events could impact both food production capacity and economics (Boicourt and Johnson, 2010; Maximilian et al., 2006; Medellin-Azuara et al., 2011; Jackson et al., 2011). In the 2009 Adaptation Strategy report for the State, rising temperatures, a reduction in water resources, and increased plant pests and disease pressures are among the impacts that threaten California agriculture in the future. Further, research has shown that as atmospheric CO_2 concentrations increase, nitrate (a key plant nutrient) assimilation may decline, consequently impacting protein content and food quality (Bloom, 2009). In addition, recent research has shown that certain regions of California will have potentially significant effects or changes to crop production (Sato et al., 2000; Ziska et al., 1997; deJong 2005; Hayhoe et al. 2004) as temperatures increase 1.3-2.0℃ by 2050, depending on the level of carbon in the atmosphere (Cayan et al., 2009). Therefore, addressing GHGs from various sources, including agriculture is critical to the future sustainability of agriculture as a food production and key economic sector in California. There are opportunities for the agriculture sector in California to limit its GHG emissions in the future through mitigation efforts. In addition, agriculture can play a critical role with enormous opportunities to increase biological carbon sequestration in both vegetation and soils (i.e., rangelands), thereby reducing GHG concentrations in the atmosphere. Like the natural and working lands sector, optimizing carbon storage opportunities in the agricultural sector will be a key strategy to help California achieve its aggressive 2050 carbon reduction goal of reducing GHGs 80 percent below 1990 levels.

This paper discusses the potential for the agricultural sector to reduce GHGs in the future through 2050. To understand the GHG reduction potential and strategies for the agricultural sector for this time period, a baseline for the sector must be established. Analysis of the current California agriculture facts and figures will provide guidance. This baseline can be used to project a “mid-term and long-term “vision”. Identifying how climate change mitigation measures fit into the vision is the purpose of this document. A similar approach has been adopted by Sumner (2013) in a document titled “Agricultural outlook for California to 2030.”

Establishing a baseline – California’s agriculture sector in 2011

According to national statistics on California agriculture, the State’s 81,500 farms and ranches received a record $43.5 billion for their output in 2011. The revenue was led by the dairy industry. Other large revenue producers include almonds, grapes, cattle, plant nursery, berries, hay, lettuce, walnuts and tomatoes followed by numerous other crops. The state produces about half of the fruits, nuts, and vegetables grown in the U.S. The top 5 counties for agricultural production in the State are Fresno, Tulare, Kern, Merced, and Monterey (USDA NAAS, 2012). Additional baseline information on California agriculture is provided by Sumner (2013).

Agricultural production acreage in California accounts for 25 percent of its landmass: a little over 25 million acres. Approximately 75 percent of farms in the State are less than 100 acres while another 15 percent are farms that range between 100 and 500 acres. Almost half of all farms had sales less than $10,000 while about 70 percent of total farms had sales of less than $50,000. Close to 80 percent of all farms in California are family-owned and operated (USDA ERS, 2013). A 3.5 percent decrease in farmland was observed from 1997 to 2007.

The population of the state continues to increase and has doubled in size since 1980. The population in 1980 and 2012 were 23.6 and 37 million people, respectively. Much of the population growth has occurred in urban areas of California and is expected to continue to grow in the future (USDA ERS, 2013). This upward trend in population growth is expected to continue from the current 37 million to between 42 and 48 million by 2025 (PPIC, 2008).

Agricultural efficiency, in terms of food production per unit animal or crop acre, continues to increase through methods such as precision agriculture. The fundamental question is how and what will agriculture look like in the future and how does GHG mitigation fit into an agricultural vision through 2050.

California's Agricultural Sector in 2050

Agriculture in California is and has been a foundational sector of the social and economic aspects of the state and must continue to play an important role through 2050. Several documents and reports have established a framework of agricultural sustainability for the 21st century. California Agricultural Vision or Ag Vision was conceived by the California Department of Food and Agriculture and the State Board of Food and Agriculture to address future sustainability challenges including climate change impacts and mitigation (Ag Vision, 2010). This report recognizes that, "The central challenge to agriculture in the 21st century is to achieve and sustain the capacity to feed a growing global population that is expected to reach nine billion people by 2050. As one of only five Mediterranean growing regions on Earth, California is a major contributor to the global food supply, particularly of nutritious fruits, nuts, vegetables and dairy products". Ag Vision identifies fundamental features of present-day agricultural systems that need to be maintained or enhanced into 2050. Strategy 9 of Ag Vision discusses climate change and the fact that mitigation of GHG is important to the sector's sustainability in the future.

This update report provides a discussion, focused on agriculture in the future, and explores potential mitigation solutions for GHGs as well as increases for biological carbon sequestration. The discussion is divided into three primary topics: crop production, animal production, and other considerations. The potential reductions of GHG from each topic are discussed along with specific methods of achieving GHG reductions in the future. In general, a range of on-farm management practices can help to reduce GHG emissions and sequester carbon. The adoption of these management practices primarily depends on agro-economic and on-farm feasibility as well as a host of other issues discussed (e.g., agricultural support services, incentives for management practice adoption, research activities). Incentivizing the implementation and long term maintenance of the management practices to reduce GHGs in agriculture will facilitate adoption by growers.

Crop Production

California has extensive annual row crops (e.g., lettuce, tomatoes, broccoli) and perennial crops (e.g., almonds, pistachios, citrus) which demonstrate the diversity of crops grown in the state.

Within crop production, several important aspects of the sector should be maintained or enhanced into through 2050. The USDA compiles ten-year agricultural projections for production, value, and acreage on a national basis for several crops. These projections provide a general overview, and should be used cautiously, since they are based on national data. However, some information is applicable to California agriculture since it is the dominant producer of certain crops. A good example is tree nut production which is expected to increase by 20 percent as prices also are projected to increase. A more detailed summary of future projections and a snapshot of agriculture crops in California at present is provided by Sumner (2013).

There are several other strategies for the agricultural sector in California that should also be maintained (e.g., food safety) in the future and are referenced in documents such as Ag Vision but are not discussed in this report since they do not directly contribute to GHG emissions and mitigation measures.

1. Soil quality and heath

Soil quality and health is a fundamental component of California agriculture. The numerous benefits of soil with sufficient levels of organic matter are well understood. Ag Vision recognizes the importance of preserving farmland for agricultural food production. A list of potential mitigation measures for croplands in California is provided by Culman et al (2013). Considering the management activities in recent reports, such as Culman et al (2013) and those described below, will ensure the sector reduces GHG while maintaining its economic and social benefits into 2050.

Agricultural Land Conservation

Recent research has shown that GHG emissions are approximately 70 times greater from urban regions than agricultural lands (Jackson et al., 2012). Therefore, protecting and conserving agricultural lands from residential, commercial, and industrial use offers climate change mitigation benefits. Since agricultural lands also emit GHGs, efforts to reduce GHGs from managing these lands are critical. As population increases in the state from the current 37 million to between 42 and 48 million in year 2025 (PPIC, 2008), maintaining agricultural lands as a GHG carbon mitigation sink will be important through 2050. A summary report on GHG reduction opportunities in croplands in California by Culman et al (2013) notes that “recent reports highlight the importance of farmland preservation as a key strategy for stabilizing and reducing California’s future greenhouse emissions across multiple economic sectors”.

Tillage

Historically, tilling (loosening and turning) of soil has been a fundamental agricultural practice since there are numerous agronomic benefits such as: suppression of weeds and loosening of compacted clay soils. However, soil tillage also releases large quantities of carbon dioxide (CO_2) into the atmosphere. Several alternative methods, including changing tillage or cropping patterns, have shown to reduce the release of GHGs while maintaining crop yields. These specific methods are summarized in a recent report by Culman et al (2013). There is more research information needed on tillage practices for California (Suddick et al., 2010). Presently, a concentrated research effort is underway to identify which conservation tillage methods can be practically applied to California’s diverse crop systems since tillage management practices were developed for non-specialty crops grown in other U.S. States. Recent research has shown that the use of conservation tillage practices is growing in California but adoption is relatively slow in annual crops (Culman et al., 2013). Built-in incentives and operational cost savings are required for wider adoption (Meadows, 2006; Gryze et al., 2009; Mitchell et al., 2009). Recent research has shown that conservation tillage offers numerous co-benefits in addition to GHG reduction: less tillage equates to fewer tractor passes and, therefore, cost savings in fuel, reduction of particulate (dust) emissions and further GHG reductions (Suddick et al., 2010). Cultural practices to adopt tillage must also be examined since; currently only about 10 percent of total crop acreage in California is under conservation tillage (Suddick et al., 2010).

Carbon Sequestration

Biological soil carbon sequestration or the capture of gaseous carbon from the atmosphere into soils is a process that can play a critical role reducing GHGs from agriculture to help meet our mid-term and long-term goals. There are numerous methodologies associated with building carbon in soils and some are under investigation through research efforts to quantify the benefits.

Cover crops have been shown to build biomass in fields, increasing total primary productivity and increasing soil carbon sequestration. Similar to tillage management, winter cover crops offer multiple benefits including reduced nitrogen fertilizer use and reduced N_2O emissions (Alluvione et al. 2010; Delgado et al. 2007; Gregorich et al. 2005). Recent annual crop research has shown that cover crops can provide organic matter inputs, benefiting soil health and increasing the carbon pools (Veenstra et al., 2007). Winter cover crops also offer other co-benefits, such as nitrogen fixation, leading to potentially less nitrogen use, and reduced sediment and nutrient runoff during winter months (Griffin et al., 2000). Much of the data to-date has been focused on annual row crops but perennial crops should be investigated as well.

Several other methods of carbon capture, using existing agronomic methods (e.g., organic farming), have been discussed in the literature and include building of organic matter pools by application of composted stable organic matter to farms and rangelands (Silver et al. 2010). The low decomposition rates of biochar carbon (defined as carbon-rich product from pyrolyzing biomass – Biederman and Harpole, 2013) may yield net GHG mitigation benefits. Recent studies suggest additional potential GHG benefits from biochar, including reduced N_2O emissions (Singh et al. 2010; Taghizadeh-Toosi et al. 2011), replacement of fossil fuels (Woolf et al. 2010) and reduced nitrogen fertilizer requirements (Lehmann et al. 2003). Sequestration of carbon in soils provides almost 90 percent of the global potential for agricultural mitigation (Smith et al. 2008).

Biofuels

Certain agricultural crops can be used to produce fuels (e.g., corn). Although, fuels derived from plant matter or biofuels eventually produce CO_2, there is no net addition of CO_2 to the atmosphere since it is re-captured by plants during its growth cycle. Biofuel production is a renewable energy or bioenergy resource which reduces the reliance on fossil based fuels.

Bioenergy has been identified in the 2012 Bioenergy Action Plan (California Energy Commission, 2012) which is a multiagency coordination approach to address challenges and maximizing opportunities for the development of bioenergy projects that promote economic development and provide the greatest environmental benefit. The plan outlines state agency actions that: 1) stimulate cost-effective utilization of the state's diverse biomass resources for conversion to "low-carbon" biofuels, biogas, and renewable electricity; 2) increase research, development and demonstration of bioenergy toward commercializing new technologies; 3) streamline the regulatory and permitting processes; and 4) quantify and monetize the benefits of bioenergy.

Research efforts have already been initiated to identify crops for biofuel production in California. Advanced biofuels other than corn-based ethanol include ethanol derived from cellulose, hemicellulose, or lignin, sugar or starch (other than corn starch), waste materials, including crop residues, animal and food waste, biomass-based diesel, biogas, and butanol. The UC Davis Institute of Transportation Studies (Ogden and Anderson, 2011) concluded that advanced biofuels could provide significant environmental benefits and that the first commercial-scale biorefineries are expected to produce large quantities of advanced biofuels by 2015. If these technologies prove to be viable, rapid expansion could take place in the United States to meet the 2022 requirements of the Renewable Fuel Standard.

Conversion of plant matter to biofuels is expected to have a small GHG footprint. Biofuels can be used as an effective substitute for fossil based fuels which have a large GHG footprint and is not a renewable resource. Combustion of biomass in contained biomass-to-energy facilities, or conversion of crop residue to biofuels offers environmental advantages over in-field burning of crop residue. Specifically, processing of crop residue biomass in contained facilities results in capture of lost energy, and reduces GHG emissions and air pollution caused by in-field burning. Incentives and efforts to include crop residues (e.g., tree pruning's), into such processes, in a manner which reduces transportation associated GHG emissions, would be beneficial to mitigating burning events that add CO_2 to the atmosphere. However, biofuel production must be carefully evaluated and balanced so that food production and reliability is not compromised.

2. Irrigation water supply and conservation

Irrigation of crops in California is essential to food production. Crops require sufficient amounts of water throughout the growing season. California has a water delivery system that transports water to agricultural lands where production can be maintained (as opposed to rain-fed systems). The distribution network for water in California must be maintained and enhanced to meet our mid-term and long-term goals. Adequate "supply" of water is also required to maintain and enhance agriculture in the future.

Irrigation methodologies
Effectively using and managing the water allocated to agriculture in the state is critical to the future success of the sector since water supplies and availability are directly connected to water use and management. Effective irrigation methods and technologies are needed to reduce N2O levels from agriculture fields. Several management practices have already been employed to establish effective irrigation that contribute to reducing GHGs. They include moving away from furrow or flood irrigation to precision irrigation methods such as drip and micro-sprinkler irrigation if compatible with the cropping system. These methods along with effective application of nitrogen fertilizers and compost can reduce future emission of GHGs in agriculture. Novel methods and techniques for irrigation will continue to be developed including the addition of organic matter and mulch for water retention purposes. For instance, field crops are not typically grown with drip irrigation but sub-surface drip irrigation has been used to effectively increase the yield of some field crops (e.g., tomatoes) where the economic returns and/or yield increases are sufficient to allow for a greater investment in advanced irrigation methods. Management practices that both increase yields while at the same time reducing GHGs will be more quickly adopted at the field level compared with management practices solely designed to reduce GHG without any other incentives to farmers.

Some cropping systems that require flooding contribute to CH_4 emissions (e.g., rice). Management practices are being developed to effectively reduce these GHG emissions from rice fields in California. The development of agricultural offset protocols could offer a level of quantification and verification since there are numerous components of the practice that need to be established, including research and data to support GHG mitigation benefits and measurement.

Water supply (see DWR write-up)
The California Department of Water Resources (CDWR) has predicted 25 percent reduction of the 15 million acre feet of snow pack storage in California by 2050 (CDWR, 2007). Methods such as precision agriculture and irrigation technologies to increase efficiency will play a role in maintaining adequate water supply. Additionally, methods to increase soil carbon and organic matter, through application of composted organic matter, have shown to improve the water-holding capacity of soil, helping conserve water and reducing runoff. Research from Australia (Recycled Organics Unit, The University of New South Wales, 2006) calculated potential water savings for grapes and cotton from using compost and mulch. In California, researchers at UC Riverside found that compost applications were "very effective in reducing water runoff," reducing total runoff by as much as 80 percent while improving the quality of that runoff. "Compost has the ability to absorb and store a considerable amount of water and concentrated nutrients," according to the researchers (Crohn, 2011), who also

noted compost's ability to conserve water where soils are damaged by human activity or erosion. There as numerous indirect benefits to water supply and conservation which lead to GHG mitigation (e.g., reduced fuel usage for irrigation water pumps).

3. Nitrogen management

Nitrogen is a critical nutrient central to all living systems including ensuring plant growth and food crop yields. Nitrogen is essential for many metabolic processes in plants and animals including formation of amino acids, which are the building blocks for protein. The human daily protein requirement ranges between 40 to 70 grams and is supplemented by crop and animal agriculture production. Nitrogen fertilizers are applied at sufficient quantities and under different chemical compositions to maintain economically viable food production systems in California. However, nitrogen fertilizers applied to crops also interact with soil microbes where ammonia and nitrates are transformed though nitrification and denitrification processes into N_2O. Nitrous oxide generation from crop nutrient management practices is the major GHG emission source from cropping systems. Two key factors in managing these emissions at the field level are the quantity of nitrogen (N) applied and the efficiency with which it is taken up by plants. Consequently, the nutrient management options focus on nitrogen application rates, timing, inhibitor application, and method of application (ICF International, 2013, IPNI, 2013). Effectively managing fertilizer use in the future will help mitigate this GHG from agriculture systems.

Fertilizer technologies

Slow release or polymer coated fertilizers are designed to release nitrogen at rates that are more conducive to plant uptake. Improvements in the design and application technology might contribute to reducing N_2O through 2050. Fertigation, or the application of fertilizer through drip irrigation systems, is a more controlled method of nitrogen application that is a well established management practice for specific crops. Management practices related to the method of application and timing for California's diverse crop industry will be needed in the future to limit N_2O gas emissions from agriculture.

Nitrification inhibitors

Nitrification inhibitors are chemicals that, when used with nitrogen-based fertilizers, can inhibit the conversion (or nitrification) of ammonium to nitrate, the main form of mobile nitrogen species in soils. The impact of nitrification inhibitors on N_2O emissions from agricultural soils is an active research area and there is strong and consistent scientific evidence that the use of nitrification inhibitors in some crops can reduce N_2O emissions by at least 30 percent while also increasing yields. Offset protocols have been developed by several organizations for inclusion in voluntary carbon markets. Nitrification inhibitors offer several other benefits beyond reducing N_2O emissions including increased yields and reduced offsite movement of nitrates that can impair water quality.

Animal Production

Animal production is a large component of California agriculture. The dairy and ranching industries contribute significantly to the state's animal food production supply, as do egg and poultry production. Milk and related animal food products provide a fundamental nutritional resource for local, regional, national and international populations. Dairy production leads the state as a commodity group in terms of economic value (USDA NASS, 2011). As with crop production, GHG emissions mitigation is in the best interest of animal agriculture. Climate change events such as increased temperatures are expected to cause animal stress leading to less productivity (e.g., less milk production). The primary GHG emitted from animals following anaerobic food digestion is CH_4. In general, ruminant animals such as cows and goats, and, to a lesser extent, monogastric animals such as pigs release CH_4 during digestion of grasses and feed in a process called enteric fermentation. Controlling CH_4 will be a key management strategy in the future. Methane is also produced from manure holding and storage systems such as lagoons. Research and incentives are key components to addressing GHG from animal agriculture through 2050. Recent findings show that animal agriculture production in California is highly efficient, in terms of meat and milk production per unit cow, compared to other countries and regions (Pitesky et al., 2009). Based on existing infrastructure and efficiencies, GHGs will continue to be reduced in production animal agriculture in the future using effective management strategies and new technologies. There are additional opportunities for agriculture to reduce GHGs and these are summarized by Owen et al (2013).

1. Manure management

Dairy systems generate significant amounts of CH_4 from on-site operations: primarily from manure storage lagoons. Technologies exist today for enclosing dairy lagoons to capture the CH_4 generated from anaerobic microbial decomposition of the manure in the lagoon and using the CH4 to produce energy. Use of these technologies through 2050 will contribute to reducing GHGs.

Dairy digesters

Dairy digesters (or biodigesters) are a technology that uses dairy waste to generate and capture methane-rich gas that, if cleaned of contaminants, can be burned to generate electricity or used to produce other renewable fuels. Manure biogas capture and destruction processes, such as those that produce energy, result in reduced GHG emissions from dairy systems. The Air Resources Board estimates that only eleven dairy digesters are in place in California.[1] There are a number of economic challenges limiting widespread adoption of this approach including high cost of electrical interconnection, lack of economically-viable pollution control technologies, and limited feedstock availability. These economic challenges make new projects unable to compete with other renewable resources under current rate structures. The construction of these facilities is not adequately incentivized to be widely adopted. Permitting issues were identified as a barrier, however the state has made significant efforts to improve the permitting process.

[1] http://www.arb.ca.gov/ag/manuremgmt/operating-manure-digester-site-list-1st-quarter-2013.pdf

Additionally, digesters offer non-energy benefits by providing options for increased nutrient management, reducing dairy odors, and improving overall groundwater quality. For example, biodigesters can be designed to produce an ammonia-based, stable fertilizer or fiber for animal bedding.

Organic soil amendments
Dairy manure is used as an organic plant nutrient fertilizer in some cropping systems. Ammonia (NH_4) in manure is the chemical form of nitrogen in the manure that interacts with soil microbes and is converted to nitrate (also a form of plant nutrient) and N_2O. New technologies such as nitrification inhibitors may be able to limit GHG emissions from manure but more promising methods include manure management and application practices. For instance, composting of manure before application to fields can help to stabilize the nitrogen fraction (Pratt and Castellanos, 1981), thereby reducing both N_2O emissions to the atmosphere.

Animal feed
According to a recent draft report by Moraes et al (2013), configuring the diet provided to dairy cows "has been one of the most recognized methods to mitigate methane emissions from livestock. Recent reports have been published to establish guidelines to optimize milk production through diet while at the same time, reducing enteric fermentation and methane production in the animals. Feeding practices and adding specific agents to the feed are promising long term solutions to improving GHG emissions from the animal component of agriculture.

2. Rangelands
Rangelands in California comprise approximately 30 to 50 percent of the land area in the state (Own et al., 2013). According to the California Rangeland Trust, "Rangelands are an economic, ecological and cultural resource that California cannot afford to lose. By 2040, according to an estimate of the California Department of Finance, the state's population will increase to more than 50 million people." The economic industries supported by rangelands include meat (e.g., cattle) for food production, wool (e.g., sheep) for clothing, and recreational opportunities (e.g., horses). However, increased urban population growth adds pressure on rangelands, which are often converted to housing developments. Rangelands must be maintained since they offer numerous co-benefits and opportunities to mitigate GHGs. The importance of existing grasslands (a type of rangeland) to mitigate GHGs emissions is well understood since they store one third of the world's soil carbon (Owen et al, 2013).

A promising climate change mitigation measure from rangelands is the biological sequestration of carbon. Current research shows that specific management methods can promote long-term carbon sequestration on California range lands (Ryals and Silver, 2013; Silver et al., 2010). Other methods of using rangelands to reduce existing GHG levels in the atmosphere are provided by Owen et al (2013). Incentivizing a host of methodologies, so that rangeland managers have a list of options that in turn, provide flexibility in land management, will allow for the use of an existing resource to mitigate GHGs on a scale that is significant.

Other Considerations

Reductions of GHGs in the future depend on several other aspects of agriculture in California. Historically, scientific research has been able to determine which mitigation measures will be the most effective in reducing GHGs given the state's diverse crops. Therefore, current and future research efforts are a critical component of ensuring agricultural sustainability and GHG mitigation in the future. Any incentive strategies must be supported by sound scientific research. Similarly, agricultural support services play an important role in outreach and education of GHG mitigation to the State's 81,500 farmers and ranchers. Maintaining and enhancing these key aspects of agriculture in California are essential to achieving further reductions of GHG emissions to meet our mid-term and long-term goals.

1. Research

Limited research funds have been available in the state for agricultural GHG research mitigation, despite the sector's social and economic value. For example, previous research on carbon sequestration potential in agriculture has largely focused on the Great Plains and states where corn is the primary crop (Follet, 2001). In general, the unique climatic conditions and diverse crops in California prevent direct implementation of management practices from other states. Therefore, comprehensive, near-term and long-term, California-specific research projects on management practices and incentive-based practices (e.g., offset protocol) must be initiated in California to address GHG mitigation measures.

Research should be focused on determining which specialty crops in California with the largest acreage can benefit from management practices such as tillage. Similar studies need to be completed for biochar and composted materials. Scientists generally agree that biochar application may have significant potential as a GHG mitigation tool, but research on the magnitude and life-cycle implications is needed. Research is required to understand the long term "permanent" benefits of soil carbon and sequestration management methods in California agricultural soils since the current scientific literature, at a national and international level, contains more uncertainty than certainty. Modeling might be useful to this research but the models must be calibrated using regional California-based agricultural conditions.

According to Suddick et al (2010), interdisciplinary research should also be considered as a fundamental priority to achieve GHG reductions in the future. Priority research areas should include topics related to agricultural economics, sociology, and the environment. Economic research areas could include the evaluation of management practice co-benefits, costs of carbon sequestration under different management practices, and crop productivity and yield responses to GHG management practices, such as conservation tillage. Sociological research areas may include determining the limitations to management practice adoption. Environmental research areas may include precision monitoring of GHGs from and to agricultural systems, modeling of carbon sequestration and GHG measurements from agricultural crops, water savings from compost and mulch use, and model validation/verification with collected data (Suddick et al., 2010).

2. Technological aspects
The average age of a farmer in California is approximately 58 years old. A new generation of farmers will be required to support agriculture in the State. The new generation of farmers will be technologically advanced and demand tools that will help sound decision making.

At present, many technologies are being used in agriculture (e.g., remote irrigation systems). Consequently, the application of natural resources for crop production becomes highly efficient, leading to several other co-benefits in addition to GHG reductions. Sensor technologies have also been developed and implemented at the field level or are in the process of being developed. Sensors, remote mapping, and satellite technology will all play an important role in future agricultural operations and potential GHG reductions. Other technologies including infrastructure development, such as compost production, are important with a special emphasis on controlling emissions and retaining nutrients, while providing a safe food produce that reduces GHG emissions through carbon sequestration and water conservation.

3. Modeling
Modeling will play a significant role in the future of agriculture in California and GHG mitigation. It is expensive, time consuming, and resource-intensive to measure GHG emissions under all the diverse cropping systems of California. Process-based models can be used to estimate GHG changes in soil and the atmosphere for different cropping systems, soils, climates, and in some cases management practices (Suddick et al., 2010). Some local level experimental research is always needed to calibrate models to local conditions for ensuring reliability and accuracy of the results. For example, recent research, funded by CDFA, CARB, and CEC has shown that California N_2O emissions from several major crops are less than the average N_2O emissions of 1 percent, of total nitrogen applied, proposed by the IPCC. Such information is critical for accurate model projections. Currently, regional, site specific data for N_2O from nitrogen fertilizers are being gathered to support different models for agricultural systems. The models and associated management practices are discussed extensively by Guo et al. (2011). Open source models will also benefit a wide grower audience and range of expertise in the future (Camargo et al., 2013). Models can also be used to effectively calculate the carbon sequestration potential of specific cropping systems or determine which management practices can be used to effectively reduce GHG emissions into the future.

4. Agricultural support services
Agricultural support services (e.g., university extension) have declined over the years. In order to address climate change mitigation in the future with limited public resources, coalitions of land managers, regulators, scientists, and other stakeholders will need to provide support to the agricultural food production systems. This collaborative approach should be the foundation for advancing land use and management policies

that meet economic, social, and environmental objectives through consensus-driven solutions. They should also help to set regional objectives for land management and identify the relevant voluntary and/or regulatory strategies that will meet those objectives (e.g., see Solutions from the Land for specifics).

The distribution of practical management practice information to reduce GHGs, while also providing an incentive to growers (as well as other co-benefits), will be essential for the future viability of agriculture in California. For example, the benefits of incorporating cover crops into a crop rotation have been historically recognized. However, according to Mitchell et al. (2007), there are a few constraints and disadvantages which potentially affect the slow adoption of cover crops in California. They include a lack of knowledge, economic cost, incorrect choice of cover crop, and conflicting timing that interferes with the establishment of summer crops (Suddick, 2010). To effectively communicate the multiple benefits and assist growers with technical expertise required to establish cover cropping systems, a resource network of support services will need to be developed, trained, and integrated into agriculture for the future.

There is a need to increase opportunities for dialogue and education between growers, researchers, and farm advisors to effectively implement practices that have benefits to reducing GHGs from agriculture. A good example of this effort is the UC ANR Conservation Tillage Workgroup with over 540 members from the University of California systems, farmers, United States Department of Agriculture Natrual Resources Conservation Services (USDA NRCS), private sector, environmental groups and public agencies.

5. Incentives and Ecosystem Services

A promising incentive to adopt mitigation measures to reduce GHGs from agriculture comes from agricultural offsets being introduced as part of the California carbon trading market. The development of agricultural offset protocols offers a level of compliance coupled with a high degree of scientific validity. Adoption of an offset for agriculture involves numerous details of the management practices that need to be established, including research data to support the quantification and verification of GHG mitigation benefits and mechanisms to ensure permanence. Other financial incentive-based programs could prove beneficial to the adoption of specific management practices (Howitt et al., 2009; Broekhoff and Zyla, 2008). Several incentive methodologies are discussed below.

Market-based systems

New initiatives and programs that target Ecosystem Services (CDFA, 2012) have the potential to substitute for conservation payments, but are rarely structured to adequately provide returns comparable to traditional production. Producers are concerned that these markets do not meet all stakeholder demand and/or reflect consumption pressures. Without better clarity on the value of the Ecosystem Services provided, uncertainty limits the scope for landowner/operator decisions and choices to implement management practices. Land management indices, metrics, and other measurements that are understood by land owners and operators will be important to allow the social interaction needed for market evolution. These initiatives and programs require information on the crops, management practices, and new technologies that can enhance GHG mitigation—information such as their viability in different regions, their economic costs or savings, their effect on production, and their net GHG emissions. Identification, cataloging, and providing recognition to growers for adopting existing management practices can lead to the decline in agricultural GHGs.

Regulatory Certainty
Food production in California involves numerous permits and regulatory requirements. Some policies conflict while others do not provide adequate reward for economic investment by growers and ranchers. According to the Solutions from the Land report, land owners face multiple and potentially unnecessary administrative requirements that add to the cost of managing land, regardless of the net environmental and social benefits. The report suggested that Ecosystem Service markets could help achieve some policy objectives more efficiently with sufficient incentive and reward to land owners.

Combining Practices
In many cases, multiple management activities are implemented on one parcel of land. For example, Drinkwater et al. (1998) examined three systems with different crop rotations, nitrogen fertilizer sources, and chemical application rates, with and without cover crops. Wagner-Riddle et al. (2007) compared two systems that differed in tillage, nitrogen rate, nitrogen timing, and cover crop use. Although the existing body of research is insufficient to provide estimates of net GHG potential for many combinations of practices, biogeochemical models (described in this report) can provide estimates of their GHG fluxes. The existing research that assesses combined practices is important for calibrating and testing the accuracy of these models' estimates.

Summary and Recommendations
There are significant hurdles to mitigating future GHG emissions in light of population growth, limited arable land area in California, limited water resources and on-farm economic considerations. Establishing a short and long term research component with sufficient funding, incentivizing management practices, and providing technological and education information for farmers and ranchers will sustain agriculture in the future while reducing GHGs. Several recommendations on overcoming these hurdles are listed below, including policy and financial needs. Additionally, a list of activities provided by CDFA and agriculture has been provided below. Such activities must continue so that agriculture can maintain social and economic sustainability while working to reduce GHG emissions.

Recommendations
Increase communication, cooperation, and collaboration between agencies (e.g., CDFA, CalRecycle, CARB, CEC) to promote streamlined permitting and enhance GHG mitigation opportunities from agriculture.

Establish stable funding sources to provide short and long-term research and incentive opportunities to determine and fund the cost effective and environmentally beneficial practices that reduce GHG emissions for California farmers and ranchers.

Review existing spending authorities so that GHG mitigation measures can be effectively funded, incentivized and implemented on California working lands.

Develop a plan-of-action to identify, test, fast-track, and transfer new technologies that reduce GHG emission in the agricultural sector.

Promote new technologies, management practices, and infrastructure development that mitigate GHG reductions by providing financial and regulatory incentives.

Continue the clear and consistent process for offset protocol creation and implementation with consultation from stakeholders on the practical feasibility of each protocol.

Develop a comprehensive crop specific list or recipe of GHG management practices, using existing agronomic expertise in state agencies and research Universities for voluntary use in agriculture.

Design policies to ensure farmland protection in consideration of population and urban growth will ensure agricultural sustainability and limiting urban GHG emissions.

Provide regional scale implementation and incentives for GHG mitigation measures from agriculture.

Develop regional scale management practice applications that have multiple co-benefits including GHG mitigation and carbon sequestration.

Create financial incentives for upgrading irrigation pumps in order to reduce GHG emissions and improve air quality in the State's agricultural regions.

CDFA GHG Activities

The California Department of Food and Agriculture (CDFA) has been engaged in several activities aimed at addressing GHG emissions from agriculture. These activities involve both long and short term solutions and consider GHG emissions from both animal and crop production agriculture. The activities completed to-date by CDFA involve measures related to bringing awareness to GHG mitigation from agriculture, providing education on GHG from agriculture, and promoting action, through research activities, on understanding GHG from agriculture systems.

Nitrous Oxide Research

The CDFA Fertilizer Research and Education Program (FREP) provides technical education to "users of fertilizer materials in the development and implementation of nutrient management projects that result in more agronomically sound uses of fertilizer materials and minimize the environmental impacts of fertilizer use, including…greenhouse gases resulting from fertilizer use" and fund research that "to improve nutrient management practices resulting in more agronomically sound uses of fertilizer materials and to minimize the environmental impacts of fertilizer use, including…greenhouse gases resulting from fertilizer use" (Section 14611 [b] [1] and [2]). FREP continues to fund research to understand baseline nitrous oxide (N_2O) levels from synthetic nitrogen fertilizers added at different rates to specific crops in California. Nitrous oxide is one of six green house gases identified in the Kyoto Protocol. The crops being investigated under CDFA FREP funding are corn, cotton, and tomatoes. The collected data will establish a baseline N_2O emission concentration from synthetic nitrogen applied to agricultural soils. Initial study results indicate that N_2O emissions are lower than originally thought, highly episodic, complex given the microbial nitrification and denitrification biological cycles involved, and dependent on environmental factors such as water content and temperature. Field trials are being completed by scientists at California State University, Fresno, and the University of California, Davis. Research is expected to be completed in 2014.

CalRecycle is funding research to also understand N_2O emissions from compost production and use in agriculture working lands. The research project aims to clarify GHG emissions from compost production and from compost use, including compost impacts on N_2O emissions from agricultural lands. The research is being completed by scientists at the University of California, Davis. Research is expected to be completed in Spring, 2014.

CalRecycle has engaged in several other activities and projects including a report on compost best management practices and benefits for erosion control, program environmental impact report (EIR) for anaerobic digestion facilities, collaborating with the ARB on development of low carbon fuel standards pathway for biogas production from anaerobic digestion of food and green waste, collaborating with the Department of Water resources to model water efficient landscapes practices by using compost that consequently results in conservation measures and promotes soil health, and evaluating life-cycle methodologies to quantify the GHG reductions from compost use and management.

CDFA also provides funding for GHG research as part of a Specialty Crop Block Grant Program (SCBGP). The program is designed to enhance the competitiveness of specialty crops. Implementing research on climate change is one method of addressing future concern to remain in a competitive market. The research focus called for projects that address specialty crop agriculture's contribution to adaptation to and/or mitigation of climate change. The results of the funded research projects are expected to have a direct impact on the current understanding of GHG emissions from agriculture and potential offset strategies. For instance, a 2010 project was titled, "Field Testing a

Carbon Offset and GHG Emissions Model for California Winegrape Growers to Drive Climate Protection and Innovation," is expected to provide knowledge and tools to help California winegrape growers reduce GHG emissions and increase carbon sequestration. Titles of several other funded projects include:

- Carbon dynamics of orchard floor applied chipped almond prunings as influenced by irrigation methods, soil type, cover crop management and farm practices (2010);
- California Wine Climate Protection Initiative: Calculating Scope Three Greenhouse Gas Emissions to Mitigate Climate Change, Reduce Costs, and Address International Market Demand (2011); and
- Life Cycle Assessment of Air Emissions and Greenhouse Gas Offset Potentials in Perennial Fruit and Nut Crops (2012).

This research is critical in addressing knowledge gaps in GHG emissions for California specialty crops. More information on this and other funded projects can be found at http://www.cdfa.ca.gov/Specialty_Crop_Competitiveness_Grants/.

Dairy Digester Research

Methane (CH_4) is a powerful GHG and exerts about 25 times more warming impact than CO_2 per unit mass emitted over a hundred-year time period. In the near term, methane is even more potent, with more than 70 times the climate impact of CO_2 in a 20-year period. As the importance of making substantial near-term reductions to climate-forcing agents has emerged based on scientific findings over the past decade, the need for policies to reduce methane emissions has gained attention. Dairy and poultry farm operations generate significant amounts of methane from manure handling. Anaerobic digesters (or biodigesters) use manure to generate and capture methane gas, which is in turn used for energy production. This process results in reduced greenhouse gas emissions from dairy farm operations. The widespread adoption of these technologies in California has encountered numerous challenges. In 2011, CDFA, in partnership with the U.S. Environmental Protection Agency (U.S. EPA) and the U.S. Department of Agriculture (USDA) began a series of meetings to discuss the barriers to digester implementation and create an advancement strategy. CDFA, U.S. EPA, and USDA, among others, will work with other relevant state and local agencies, as well as industry stakeholders, to address the technical, regulatory and economic barriers for a robust dairy digester sector in California.

Biofuel Crop Research

Biofuels (fuels from plants) can release less GHG compared to fossil fuels on a full life-cycle basis. CDFA, in partnership with scientists at UC Davis, and with funding from the California Energy Commission Public Interest Energy Research Program, have undertaken research to evaluate the economic, beneficial environmental factors, and costs of biofuel feedstock crops. Crops under evaluation include oilseed crops camelina, canola and meadowfoam which can be formulated into biodiesel along with grasses sweet sorghum, energy cane and sugar cane which can be transformed into ethanol. Field trials are evaluating different crop varieties, fertilization, irrigation, and planting date trials. Outcomes will focus on cropping systems for California with best management practice recommendations, estimates of direct environmental costs such as water use, inputs levels and effects, and potential off-farm environmental consequences.

Workgroups and Panels

CDFA uses workgroups to discuss an issue with the objective of identifying practical solutions. CDFA has implemented several workgroups to address climate change mitigation and adaptation. The information is used to guide policy, address the issue directly, and identify gaps.

Climate Action Teams (CAT and AgCAT)

CDFA Secretary, Karen Ross, is a member of the Climate Action Team (CAT). CDFA staff is engaged in monthly meetings on coordinating statewide efforts to study, identify, and implement global warming emission reductions. CDFA also convenes the Agricultural Climate Action Team (AgCAT) workgroup on a need or issue basis. AgCAT is staffed by other state agency personnel working on climate change at the interface of agriculture. The initial review of this scoping document was reviewed using the inter-agency resources and feedback of AgCAT.

Fuel Quality and Standards

Transportation fuels have been identified as the largest contributor to greenhouse gas emissions making up approximately 40 percent of the total emissions. California has adopted the Low Carbon Fuel Standard (LCSF) to reduce the carbon intensity of fuels as well as the Zero Emission Vehicle (ZEV) implementation mandate to reduce dependence on petroleum-based fuels. The California Department of Food and Agriculture, Division of Measurement Standards (CDFA) is at the forefront with the California Air Resources Board (CARB) for both of these vital initiatives.

The LCFS is expected to reduce 15 million metric tons of carbon per year from California's fuels by 2020 and will ultimately lead to the development of non-petroleum fuels. By 2050, the majority of the fuels is expected to be produced from non-petroleum renewable sources. CDFA is working with innovative fuel producers to develop the fuel quality standards needed to bring these new alternative low carbon fuel technologies to market and expand the use of biodiesel, biomass-based diesel and alternatives to gasoline. CDFA's Developmental Engine Fuel Variance Program affords an opportunity for the use of these fuels while collecting data needed to develop a consensus fuel standard. CDFA is an active member of the ASTM and SAE national work groups developing fuel quality standards and laboratory analytical test methods for new fuels such as dimethyl ether and CNG. CDFA is working with CARB to develop regulatory pathways to expand use of alternative diesel fuels. CDFA is part of the State's LCFS Advisory Panel and Cal EPA's Fuel Guidance document working group.

The success of the Governor's Executive Order for ZEV implementation will depend on wide spread deployment of hydrogen fuel cell and battery electric vehicles. CDFA's development of fueling dispenser standards and method of sale requirements will give consumers an accurate and uniform purchasing experience and facilitate acceptance of ZEV vehicles. The fuel quality standards for hydrogen originally developed by CDFA have been adopted through the consensus process and published by SAE. CDFA is leading the development of quality testing procedures, that when adopted by ASTM, will become the standard nationwide. Similarly, CDFA's hydrogen fuel dispenser and public electric charging station type evaluation and testing procedures will likely become the models that the National Conference on Weights and Measures approves for use in all states.

Agricultural Offsets
CDFA and CARB, in collaboration, have initiated and organized several stakeholder meetings with the agricultural community, in addition to regular public workshops and meetings, to discuss issues related to agricultural offsets, including quantification, monitoring, and verification. These meetings are important as an interface for CARB to update agricultural stakeholders on agricultural protocol development, discuss issues related to identifying greenhouse gas reduction measures from agriculture, strategize on best practices that can mitigate greenhouse gases from agriculture, and identify incentives for practices that support climate change policy.

Energy Commission activities include:

- In partnership with federal and State agencies, the Energy Commission has played a leading role in developing anaerobic digester systems. Specifically, the Energy Commission has funded a number of projects to develop and demonstrate advanced anaerobic digestion and power generation technologies in a variety of configurations, to explore the economics of these systems, and to measure system performance. These projects will help address the importance of reducing California's methane emissions and the possibility of doing so in a manner that is economically and environmentally attractive to California's agricultural sector. Furthermore, these projects will help reduce the air quality impacts of biogas produced from anaerobic digester systems, an important consideration in most of California's agricultural areas which are non-attainment for ozone.

- The Energy Commission is in the process of analyzing the opportunities and challenges for biogas and biomethane development in California. The Energy Commission will provide an update of the industry and recommend additional policy recommendations to the legislature and the Governor's office in the 2013 Integrated Energy Policy Report.

- The Energy Commission has proposed providing a minimum of $27 million in funding through the Electric Program Investment Charge Program (EPIC) for bioenergy technologies and deployment strategies. To meet the guidelines of the program as set forth by the CPUC, EPIC can fund research and development of pre-commercial technologies that improve the environmental performance of existing biomass/biogas technologies and commercialize technologies that show promise for meeting current environmental quality standards.

- The Energy Commission's Alternative Renewable Fuel and Vehicle Technology Program (ARFVTP) has sustainability incentives imbedded in its project evaluation criteria, which promote and incent sustainability throughout the life cycle of biofuel production.

- Market-based incentives - ARFVTP is coordinating with CARB to support the development of sustainability incentives that would increase the value of LCFS credits for biofuels production

- Coordination and technical support – ARFVTP is collaborating with CalRecycle to inform mutual policy development and to encourage CalRecyle technical support for the implementation of ARFVTP projects that are producing biogas,

- Monitoring and reporting - The Energy Commission's ARFVTP requires grant recipients to monitor and report on production activities during their project and for 6 months following the term of the agreement. If agricultural feedstocks are used in the biofuel production process, this monitoring function includes sustainability practices employed by the project's feedstock suppliers.

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