Agriculture, Resources, and the Environment

Ia. Energy and Climate Footprinting of Food Production and Supply Chains

Summary

This initiative quantifies energy use and greenhouse gas (GHG) emissions, focusing on the entirety of the food production and supply chain to identify energy and emissions "hotspots", evaluate the impacts of new practices and technologies, and assess trade-offs between interventions at different stages of the supply chain for selected categories of foods. The research uses a life cycle assessment approach, a methodology well-suited for examining environmental impacts emanating from across an entire supply chain, from production to processing, distribution, retailing, preparation, and waste management. This initiative also includes basic field research to measure greenhouse gas emissions and the carbon sequestration potential in cropping systems. Finally, an additional goal is to offer training and outreach for farmers, UC Extension, and related professionals on strategies for reducing energy use and emissions in farming operations.

Problem statement/ Baseline

The food system, including production, processing, distribution, retailing, preparation, and waste handling, looms large as a major user of fossil fuels and producer of greenhouse gases (GHG). Estimates indicate that it accounts for up to 30 percent of the total anthropogenic GHG emissions generated by the consumer economy in industrialized nations.[i] Livestock alone account for a large portion of all human-induced GHG emissions, with estimates varying from 3 percent in the US[ii] to 18 and as high as 50 percent on a global scale.[iii,iv] A stream of new policies are aimed at reducing greenhouse gases, including AB32 in California, which requires a 20% reduction in greenhouse gas emissions across all economic sectors in the state by 2020 and 80% by 2050. To date, however, the main emphasis in implementing this legislation is to regulate emissions from individual sectors. This approach does not account for significant upstream and downstream impacts that occur when changes are made at a single stage in the life cycle of consumer products such as food.

Structural issues/ Broad drivers shaping change

- Global markets, relatively low fuel prices, and new developments in containerized shipping have made exotic, perishable foods shipped long distances as well as highly processed foods easily accessible to most people in industrialized economies like the US.
- Changing American lifestyles and the preponderance of households with both spouses employed has increased the popularity of eating pre-packaged, pre-cooked foods and eating outside of the home.
- Increasing affluence worldwide, especially in emerging economies like China and India, is driving increasing demand for livestock products, which are known to be energy and GHG-intensive.

Strategic opportunity

Individual foods vary tremendously in their energy and climate footprints due to differences in production methods and input intensity, processing technologies, transportation modes, and preparation and waste handling options. Moreover, changes made in one stage of the supply chain often affect energy use and emissions in downstream stages. Research that analyzes these impacts and identifies the key sources of variation for individual foods can help decision makers at all stages of the supply chain to understand opportunities for greater efficiency and potential impacts of energy price increases and possible new climate-related regulations. In addition, interest in "carbon footprinting" and "food miles" is increasing rapidly among the consumer public, the food industry, and policy makers.

Desired outcomes

- Producers, processors, retailers, and food service companies understand the energy and GHG implications of a variety of technical options for their operations. As a result, they make informed management choices that lower the energy and climate impacts of their operations, improve their resource-use efficiency, and prepare their operations for climate-related regulation.
- Consumers understand the differences between key food choices and know which parameters are most important to consider in making environmentally sound choices.
- Policy makers have a more complete understanding of where to target policies for maximum GHG reductions, and how policies to reduce emissions in specific sectors will potentially affect emissions from other sectors.

Key Potential Partners

- Producers (farmers, ranchers, dairies)
- Food processors (California League of Food Processors, Morningstar)
- Food distributors, retailers and institutional food service providers
- UCCE
- CA Air Resources Board and Dept of Food and Agriculture

Potential Activities

- Life cycle assessments. Collaborate with food industry companies to conduct applied research on strategically selected food products, accounting for key production and processing methods, and distribution and consumption choices that are most significant in energy and GHG savings (or hotspots). Examine trade-offs in impacts from new technologies or methods in different stages of the food production and supply chain.
- Field research on emissions in cropping systems. Conduct field-level research to quantify nitrous oxide and methane emissions as well as carbon dioxide emissions and sequestration in different crop and livestock systems under different management regimes.
- Training in climate science and emissions reductions methods for producers. Train UCCE farm advisors, crop advisors, and producers in methods to assess opportunities for lower field emissions and increased carbon sequestration. Additional training may include issues of "carbon footprinting", food labeling, and carbon credit schemes for growers.

- Website development. Create a one-stop shop for UCCE, farmers, and ranchers seeking to increase energy efficiency and reduce GHG emissions.

Agriculture, Resources, and the Environment

Ib. Responding to Climate Change

Summary
This initiative focuses on identifying adaptations and mitigations needed in agriculture to respond to climate change. Over a longer time frame, adaptation to higher temperatures, intermittent drought, and climate variation will be necessary, and these adaptations will be facilitated by programs that consider individual farms within a larger landscape (e.g., greater diversity at the landscape level may serve as a source of resilience). This initiative will complement other ASI initiatives that measure greenhouse gas emissions in the food system, test the efficacy of different technologies to reduce emissions on the farm scale, and investigate how landscape-scale nutrient cycles affect greenhouse gas emissions. Methods adopted in agriculture to mitigate climate change are likely to directly complement methods needed for adaptation (e.g. conservation tillage methods might facilitate more carbon sequestration, thus reducing emissions, while also conserving soil moisture in a drier climate). This initiative will utilize results from the other initiatives and will take a larger level, landscape-scale approach to understanding cross-scale relationships and formulating strategies for integration of mitigation and adaptation.

Problem statement/ Baseline
How climate change will impact specific regions is still widely debated by scientists. In California, some scientists predict that changes in temperature regimes will likely affect important crop-specific variables like chilling hours and evapotranspiration rates, requiring geographic shifts northward in Central Valley cropping systems.[i] In addition, water availability throughout the West is predicted to decline due to decreases in the mountain snowpack and earlier spring runoff, with important implications for irrigation capacity.

Structural issues/ Broad drivers shaping change
- Historical neglect of climate change issues by the federal government has hindered progress in the climate change science and has slowed the development of policies needed to make societal-scale adaptations.
- Specialization in commodity production increases the difficulty for growers to shift to new crops.

Strategic opportunity
- California's 'Global Warming Solutions Act' (AB32) is creating new opportunities to sequester carbon on farms, and, at the same time, is requiring new technologies to reduce greenhouse gas emissions.
- Recent changes in the federal government are focusing more political attention on climate change and its impacts on the national economy and opening up new funding sources to examine these issues.
- Agriculture is already subject to environmental regulations regarding water use and air pollution, some of which may offer synergies with future climate change regulations.

Desired outcomes

- A list of agronomically and economically feasible practices that can be implemented to reduce greenhouse gas emissions in agriculture.
- Policy makers increase their understanding of regional and landscape-scale changes needed for agriculture to remain sustainable under changing climate regimes.
- Producers, processors, and other elements of the food industry can anticipate changes needed in their operations in order to facilitate the continued viability of their businesses in a world of greater climate uncertainty.

Key Potential Partners

- Farmers
- Regional and state level planning agencies
- UCCE

Potential Activities

- Multidisciplinary research on the landscape-scale biophysical effects of changing climate regimes and the economic and social impacts of these changes in agriculture.

- Modeling a variety of adaptation scenarios to test their economic, social, and agronomic feasibility

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[i] Jackson, L.E., F. Santos-Martin, A.D. Hollander, W.R. Horwath, R.E. Howitt, J.B. Kramer, A.T. O'Geen, B.S. Orlove, J.W. Six, S.K. Sokolow, D.A. Sumner, T.P. Tomich, and S.M. Wheeler. Potential for adaptation to climate change in an agricultural landscape in the Central Valley of California. Report from the California Climate Change Center. CEC-500-2008-xxx. 170 pp. In press.

Agriculture, Resources, and the Environment

II. Sustainable Management of Nutrients and Water in Agricultural Landscapes

Summary

This initiative involves close engagement with farmer groups and other key agricultural stakeholders to address critical issues of nutrient flows and water use in California agriculture. The primary aims are to identify and quantify the key biogeochemical cycles that drive the flow of agriculturally applied nutrients through the agroecosystem and beyond, quantify the environmental impacts of those flows, identify the socioeconomic and agronomic factors that shape the use of agricultural inputs, and identify and communicate best management practices for improving on-farm efficiency and minimizing off-farm impacts. Several of the projects in this initiative are likely to follow an ecosystem assessment framework, modeled after the Millenium Ecosystem Assessment and other global efforts. Using such a framework involves compiling and synthesizing existing scientific knowledge on a topic and maintaining close engagement with stakeholders in order to ensure that products resulting from the assessment can achieve maximal decision making and policy impact.

Problem statement/ Baseline

Many of the most pressing environmental and economic sustainability challenges faced by California agriculture in the 21st century stem directly from the dynamics of nutrient flows and water use on our farms. In the case of nitrogen, a highly mobile nutrient, large amounts "leak" from the system and cause eutrophication and anaerobic dead zones in rivers, pollution of estuaries and coastal areas, nitrate contamination of groundwater, and high fluxes of nitrous oxide, a potent greenhouse gas. However, the exact location, extent, and severity of these environmental impacts and how they are related to one another and to on-farm nitrogen use are only partially documented, and the feasibility of ameliorating them is poorly understood. Similar concerns apply to phosphorus, which additionally is facing the potential for production to decline and/or become significantly more expensive in coming decades.[i] In the case of water, a series of drought years has heightened already existing political tensions between agricultural, environmental, and urban water users for an increasingly scarce resource, and some farmers are fallowing their fields for lack of irrigation water. Concurrently, some areas of the San Joaquin Valley are becoming unfit for crop production due to excess salinity, a problem closely tied to irrigation and nutrient applications.

Structural issues/ Broad drivers shaping change

- The general public as well as farmers and ranchers have little awareness of the landscape-scale problems associated with fluxes of nitrogen and other agricultural nutrients.
- Until recently, farmers have had few incentives to increase nutrient use efficiency because of low costs of energy, inorganic nitrogen fertilizer, and irrigation water.

Strategic opportunity

- Recent spikes in fuel prices and fertilizer costs have heightened farmers' interest in increasing their nutrient use efficiency for economic reasons.
- Recent changes in methods of regulating water quality of agricultural runoff have also heightened farmers' interests in nutrient use efficiency, for regulatory reasons.
- Drought coupled with new environmental water flow regulations for the Bay Delta region are increasing concerns among farmers, the general public, and policymakers about water use issues in agriculture.

Desired outcomes

- The capacity of UC researchers and UCCE staff to conduct multidisciplinary research and large-scale ecosystem assessments is increased.
- Key research and information gaps will be identified and will provide the basis for a research and communication plan on nutrient flows.
- A broad array of stakeholders, ranging from farmers and ranchers to fertilizer manufacturers and policy makers, will better understand nutrient flow dynamics, how they affect other natural resources, and best management practices for improving on-farm efficiency and minimizing negative off-farm impacts. Adding salinity
- Agricultural water users will have better information resources for choosing from an array of best management practices for water use efficiency.

Key Potential Partners

- Producers (farmers, ranchers, dairies) as represented by approximately 30 commodity groups
- Input suppliers: fertilizer industry groups
- Irrigation districts
- UCCE
- Certified crop advisors
- Policy makers and regulators: and CA Dept of Food and Agriculture and Fertilizer Research and Education Program
- Environmental and agricultural NGOs

Potential Activities

- California Nitrogen Assessment. Conduct pilot statewide assessment of nitrogen fluxes, based on internationally accepted ecosystem assessment methodology, foster interdisciplinary research teams with junior faculty, build and implement a strategic communications plan to engage with the farming community, extensionists, policy makers, and the general public.
- Longterm Research on Agricultural Systems (LTRAS). Entering 17th year of research at the Russell Ranch facility on long term agricultural plots to understand relationships between sustainability and external inputs (N, P, water, energy) by assessing trends in

yield, profitability, efficiency in use of limited resources, and environmental impacts, such as N losses.

- Ecosystem Assessment of Greenhouse Gas Emissions in CA Agriculture. Conduct research and outreach on GHG emissions from agriculture and food industries in CA, using a large-scale ecosystem assessment framework and building on work already completed on N_2O in the nitrogen assessment and other work in the Climate Footprinting Initiative. Preliminary work on carbon being done in California Agroecosystem Planning Project.
- Life Cycle Assessment of Water Use in Agriculture. Build on life cycle assessment capacity developed by ASI in the Climate Footprinting Initiative to address water use and soil salinity issues.
- Build farmer networks and communities of practice to communicate, plan, and experiment with new nutrient management strategies

[i] Cordell, D., Drangert, J.O., and White, S. 2009. The story of phosphorus: global food security and food for thought. *Global Environmental Change* doi:10.1016/j.gloenvcha.2008.10.009.

Agriculture, Resources, and the Environment

III. Harnessing Ecosystem Services to Increase Agricultural Sustainability

Summary
This initiative assesses the ecological, agronomic, and economic viability of methods to conserve and increase on-farm biodiversity and accompanying ecosystem services. By analyzing landscape-wide characteristics that affect ecological functioning on farms, research under this initiative will help farmers, ranchers, and government agencies such as NRCS to better understand how to ensure the continued provision of services essential to agriculture, such as crop pollination, water filtration, pollutant degradation, pathogen elimination, pest control, and nutrient cycling. It will also clarify the role that agricultural landscapes play in providing ecosystem services needed by sectors outside of agriculture, for example, wildlife habitat and groundwater storage. Finally, this initiative offers the potential for applied research and engagement with stakeholders to identify the social and economic drivers responsible for increasing the value assigned to non-marketed ecosystem services by the agricultural community as well as the general public.

Problem statement/ Baseline
While ecosystem services are becoming more widely recognized as essential to agriculture and to other natural and human systems, scientific understanding of the complex and often interrelated landscape-scale factors that affect these services is still weak. Meanwhile, examples of failures of ecosystem services continue to appear, such as recent food safety problems, soil salinization, and colony collapse disorder in honeybees.

Structural issues/ Broad drivers shaping change

- Economic value is traditionally assigned to cropland based on the value of its harvested products, and not based on the value of other, non-marketed services provided to the farm as well as to the larger surrounding community. As a result, farmers and ranchers have little financial incentive to protect or enhance ecosystem services from their land.
- The current regulatory environment is so complex that it inhibits landowners from pursuing activities such as hedgerow planting and stream bank restoration.
- In some commodities such as dairy, declining profit margins and low crop prices motivate farm managers to maximize productivity from "fence row to fence row", leaving little room for biodiversity on field margins.
- Numerous products are on the market that purportedly promote biodiversity but lack the scientific foundation to support their claims, and they are being sold to a public with minimal exposure to basic concepts of biodiversity.

Strategic opportunity
The widespread incidence and media coverage of colony collapse disorder in honeybees has signaled the need for more attention on the non-marketed ecological services required by and

also provided by healthy agroecosystems. Climate change legislation is also providing impetus for farm and ranch managers to consider methods for increased carbon sequestration on their land, methods which often correspond with increased biodiversity.

Desired outcomes

- Increased scientific understanding about how to manage agricultural landscapes for specific ecosystem services, such as pollination and efficient nutrient cycling.
- Policy makers, NGO's, and farm service agencies such as NRCS, have information about priority socioeconomic factors that influence producer and public interest in enhancing ecosystem services.
- Government agencies understand what types of streamlining efforts are needed to make biodiversity-enhancing practices on private lands easier to implement.

Key Potential Partners

- Producers (farmers, ranchers, dairies) - special emphasis on organic producers who are pioneering biodiversity-related management practices
- Beekeepers
- Agricultural and environmental NGOs, such as Sustainable Conservation, Audubon, CAFF, Wild Farm Alliance, etc.
- County and regional planning agencies; irrigation districts
- CA Dept of Fish and Game
- UCCE
- Horticulture industry that provides planting materials for ecosystem restoration (such as Hedgerow Farms)
- Industries promoting microbial inoculants and other products promoting microbial activity

Potential Activities

- Research projects on crop pollination services:
  - Effect of farm management on the stability/ reliability of crop pollination by wild and managed bees.
  - Modeling how landscape composition and configuration impacts pollinator diversity and the delivery of pollination crops.
  - Identification of native plants to enhance pollinator diversity and honeybee health within intensive agricultural landscapes.
- Research projects on soil biodiversity:
  - Metagenomic analysis of plots at Russell Ranch
  - Functional genes microarray analysis of microbial diversity in soils
  - Investigations of below-ground insect biodiversity at agricultural-wildland interfaces
- Research projects on policy and institutional needs for increasing adoption of practices that enhance ecosystems services

- Field days to provide producers and researchers with focused opportunities to share information and insights
- Hiring of a Program Representative to work as "Biodiversity Ombudsman" with UCCE to assess needs in local areas and to help producers connect with regulatory agencies, plant retailers, and science-based information resources
- Communications and outreach via website and information pamphlets geared toward producers and extension staff

Agriculture, Resources, and the Environment

IV. 'Closing the Loop': Integrating Sustainable Waste Management in Agriculture

Summary

This initiative focuses on developing and assessing the feasibility and sustainability of new methods for redirecting urban, rural, and industrial waste flows into agricultural systems. The emphasis is on recycling used (or "grey") water in agriculture and preventing leakage of important crop nutrients from the larger food system after they leave agricultural fields in the form of harvested products. Accordingly projects will focus on environmental impacts of municipal wastes used in agriculture and sustainable methods for directing food wastes back into farming. Research will also examine the feasibility of re-using irrigation water for multiple purposes in the landscape and explore more sustainable ways to handle and re-direct dairy waste.

Problem statement/ Baseline

Across the country, large accumulations of animal waste at dairies and other concentrated animal feeding operations (CAFOs) have aroused concerns about negative environmental and health impacts and have instigated local community backlash against these operations. At the same time, nutrients contained in pre- and post-consumer food waste are lost to the agroecosystem when they are landfilled or disposed of by other means. Replacing nutrients lost via harvested crops is a major driver for application of synthetic fertilizer on crop fields. Water issues are also coming to head in California, with several years of drought heightening concerns for farmers as well as urban water users, while water of potable quality continues to be used for non-potable needs, such as crop irrigation.

Structural issues/ Broad drivers shaping change

- Separation of urban and rural populations as well as institutionalized, large-scale waste management schemes are all factors that foster a lack of awareness about the generation and ultimate fate of municipal waste and its potential value for agricultural uses.
- Current regulations governing land application of dairy wastes as well as food safety regulations constrain dairy managers and farmers from making more widespread and sustainable use of these resources.

Strategic opportunity

Several years of drought in California have heightened concerns about water availability for agriculture and have pitted rural, urban, and industrial users against each other. Improving our understanding of appropriate and sustainable use of grey water systems may not only increase water available to agriculture, but can also create opportunities to bring opposing sides together to work more collaboratively on a common issue. Furthermore, another ASI initiative is examining the environmental impacts of synthetic nitrogen use in agriculture. The work described here on recycling food and other municipal waste back into agriculture will contribute to the identification of best management practices for nitrogen use in that initiative.

Desired outcomes

- Policy makers and staff at environmental and health regulatory agencies understand the potential benefits and risks of redirecting municipal wastes into agriculture and have options for managing risks.
- Farmers and ranchers are eager to start using municipal waste and grey water and understand appropriate ways for doing so.
- Irrigation district managers and private industry become interested in collaborating on projects for new uses of used irrigation water.

Key Potential Partners

- Producers (farmers, ranchers, dairies)
- State environmental health and safety regulators
- Municipal waste management operations
- UCCE

Potential Activities

- Research on environmental impacts of municipal wastes (biosolids) on soil communities and processes.
- Research on use of used irrigation water for raising algae/brine shrimp for multiple functions (feed, biofuel, selenium removal)
- Research and demonstration projects on sustainable management of dairy waste.
- Training workshops on opportunities and risk management in agricultural uses of municipal wastes and grey water, targeted to government agencies, UCCE, waste management workers