Project Narrative

Mapping Sustainable Agriculture Knowledge Networks in California

***Goals and objectives*:** The overarching goal of this proposal is to understand the structure and dynamics of sustainable agriculture knowledge networks in California. Agricultural knowledge systems have transformed as agricultural production has scaled-up and become more concentrated, specialized, and knowledge-intensive. Sophisticated local networks have evolved to link growers to a diverse range of stakeholders and knowledge brokers throughout food systems. The emergence of communication technology such as social media and smart phones has enabled new network connections and real-time social learning. While some outreach professionals have developed programs to capitalize on these trends, there is not a set of guiding principles, organizational structures, or training. California has an opportunity to be an international leader in developing outreach programs that catalyze knowledge networks. The project focuses on five main tasks:

- Map sustainable agriculture knowledge networks in California: A web-based snowball survey will be delivered to a seed population of ANR employees and other sustainable agriculture knowledge brokers in every California county. The survey will ask them to identify the other key stakeholders in their network, who will then also receive the survey. Social network analysis will be applied to the resulting relational data.
- Inventory the uses of social technologies among knowledge network members: The survey will ask each respondent to identify any social media platforms or smart-phone applications they use for accessing and sharing agricultural information. This will help develop a broader understanding of how communication technologies are linked to networks.
- Analyze the dynamics of communication technology using "big data" methods: The inventory of communication technology can be analyzed to understand the dynamics of online communication. For example, "big data" methods use Twitter #hashtags to see who tweets and re-tweets various types of messages, allowing the uncovering of online communities-of-practice.
- Measure stakeholder belief-systems about sustainable agriculture: Belief systems about sustainable agriculture can be elicited with cognitive networks in which nodes represent goals and strategies and links measure a participant's degree of belief in the causal relationships among the nodes. We will measure the belief systems of central stakeholders in the knowledge network and the implications of those belief systems on the likely diffusion of information.
- Develop a knowledge networks and social media short-course: The results of the study will be used to develop a short-course that will train outreach professionals in social network theory and analysis, and principles of social media outreach. Such training will be useful statewide for providing a more principled basis for effective program development, and catalyzing effective knowledge networks.

While the idea of knowledge networks can usefully be applied to any type of agricultural issue (e.g., disease and pest management), sustainable agriculture is an excellent starting point because it integrates social, economic, and environmental issues, and complements the broader concept of food systems. Sustainable agriculture is a high priority throughout the world, including programs within ANR and at individual UC campuses. Sustainable agriculture embraces the ideas of knowledge networks (Lubell et al. 2011), boundary spanning (Guston 2001), communities of practice (Wenger 2002), cooperation (Ostrom 1990), innovation (Rogers 2003), and communication technology—themes that will be central to our project.

The term "Extension 3.0" encompasses many of the ideas addressed in this proposal. The core goal of Extension 3.0 is to capitalize on the structure and dynamics of local knowledge systems (Bartholomay et al. 2011; Cash et al. 2003) to deliver relevant information to the right stakeholders at the right time and place. This project supports the idea of Extension 3.0 with evidence-based research into how ideas about sustainable agriculture are transmitted through networks, along with specific training on how to incorporate network principals and social media into education and outreach programs. The scientific results and training generated from this project can thus help improve the effectiveness of local knowledge networks in California, with lessons applicable to agricultural systems across the globe.

***Relation to previous work*:** Social networks and social learning are crucial resources for integrating new concepts like sustainable agriculture into beliefs and practice Lubell and Fulton 2008; Warner 2007). At any given time, individual farmers have beliefs about the costs and benefits of implementing different agricultural practices. They learn about agricultural practices from a combination of individual learning through experience, and social learning via knowledge networks (Foster and Rosenzweig 1995). Knowledge networks are thus a key to the diffusion of innovation, as well as problems like water quality, which require cooperation from multiple individuals (Lubell et. al. 2011)

One of the assumptions of this proposal is that 21st Century agricultural knowledge networks are substantially different than ones that existed in the early 19th century when Cooperative Extension was first developed. As agricultural systems in the US and other Western developed countries have evolved, agriculture has become more concentrated and specialized with many types of differentiated professions. Many more types of governmental and non-governmental stakeholders have become involved. The overall level of expertise and education has increased, and many farmers and stakeholders now have advanced degrees. Agricultural expertise is no longer a monopoly of Cooperative Extension, but rather is distributed throughout the knowledge networks. Understanding how these knowledge networks are structured provides a basis for strategic planning.

Communication technology is a part of this transformation, although far from the only important aspect. The number of farmers connected to the internet and using computers for agricultural decision-making continues to increase (NASS 2011). Farmers are using smart-phone applications and other technology to make real-time decisions in the field, where the decision-support tools aggregate a wide variety of scientific and other types of data (Guenther and Swan 2012). Farmers and outreach professionals are increasingly using communication technology to efficiently disseminate information to new audiences (Arnold et al. 2012). However, most of this work is being done without any systematic application or strategic use of principles of social networks or human decision-making. The people working on these issues are doing it via trial-and-error learning. While some of this is successful, this proposal can provide a better knowledge base to support the groundswell of activity.

Engagement in social networks leads to changes in stakeholder belief-systems. For example, as dialog about sustainable agriculture occurs within a network, stakeholder beliefs begin to reflect a consensus on the definition of sustainability and strategies for achieving it. Stakeholder belief systems can be represented as semantic networks, or cognitive maps, which are elicited from interviews, testimonies, written opinions, or objective factual accounts. Semantic networks summarize peoples' beliefs about cause and effect relationships pertaining to a particular subject, including the complexity of internal representation and the importance of different concepts to different people. In a semantic network the nodes represent real or abstract objects or concepts and the edges represent the direction and strength of causality connecting the entities. The resulting networks can be summarized statistically using the same types of graph-theory metrics (e.g. centrality, in/outdegree, edge density) as social networks.

The proposal builds on PI Lubell's previous work on the role of social networks in agricultural decision-making, including farmer participation in local water quality management including the Agricultural Waivers in California (Lubell and Fulton 2008), sustainable viticulture (Lubell et al. 2011), rangeland management, climate change adaptation, and wood canker disease management. These projects have all successfully implemented large-scale surveys of farmers and outreach professionals. The previous surveys provide a lot of questions that can be translated into the current proposal. Lubell's work typically uses a combination of traditional quantitative methods along with social network analysis.

Co-PI McRoberts leads the Quantitative Biology and Epidemiology (QBE) lab in the Plant Pathology Department at UC Davis. He works at the intersection of plant pathology, agro-ecology, and social science. He has applied semantic networks to a range of topics including; public attitudes and policy alternatives about adoption of GM crops and GM foods in the EU, farmers' attitudes to environmental stewardship incentives (Ortolani et al., 2010), derivation of agent types from farmer questionnaire data for use in agent-based models of policy responses, the politics of trans-boundary river management (Kafetzis et al., 2010), the dynamics of adoptability of technological innovations in agriculture (McRoberts & Franke, 2008), and the role of GM insects to manage citrus green diseases in the United States.

The collaborators is a statewide team of outreach professionals in ANR and industry who are leaders applying network thinking and communication technology to sustainable agriculture in California. Some are working in the field directly the county level or within a particular agricultural industry, while others are working at the system level of ANR. They work in both direct outreach to farmers, and more broadly on marketing and communication. Many of them are heavily involved in boundary organizations, like the UC Davis Agricultural Sustainability Institute and the Kearney Agricultural Research and Extension Center, which seek to connect practitioners and scientists. Their combined experience will be crucial for advising on the design and implementation of the survey, providing examples for short course, and coordinating delivery of the short course.

Design and methods: We will discuss the specific details of design and methods for each of the key components of the project. We note in parentheses that key personnel that will provide leadership for each research component. While this research does involve human subjects, human subject protocols have been approved for many similar projects in the past and recent changes to IRB procedures have been exempting these types of surveys from detailed review.

Map sustainable agriculture knowledge networks in California (Lubell, Post-Doctoral Researcher, ANR collaborators)**.** A web-based snowball survey will be delivered to a seed population of ANR employees and other knowledge brokers in every California county (Bartholomay et al. 2011). The sample population will be developed by identifying all Cooperative Extension employees in each county, as well as key contacts in other organizations involved with sustainable agriculture (e.g; Resource Conservation Districts, producer groups). Potential organizations and programs will be identified through a Google search using a combination of geographic and substantive search terms such as “sustainable agriculture Yolo county”. Other search terms may also be used. The webpages of organizations will provide contact information for individual professionals involved with sustainable agriculture, as well as additional partner organizations

The resulting “seed” population will be targeted for the first wave of the survey. Each survey respondent will be asked identify other key stakeholders in their networks who they are partnering with on sustainable agriculture. These may include growers and many other types of organizations. At least one layer of this “snowball” set of contacts will also receive the survey. All survey respondents will be asked a filter to question that asks them to identify which sustainable agriculture concepts they work on. If they do not work on any of these concepts, they will exit the survey. The filter question narrows the survey sample to people involved in some aspect of sustainable agriculture, rather than agriculture in general.

The survey will ask questions related to attitudes about sustainable agriculture, participation in activities, linkages to knowledge networks, and use of social media and information technology. The questions will be modified from Lubell’s survey on sustainable viticulture (http://environmentalpolicy.ucdavis.edu/project/sustainable-viticulture-practice-adoption-and-social-networks), which is the most closely related project. Respondents will be asked to evaluate how effectively the agricultural system in their region achieves the economic, environmental, and social goals of sustainable agriculture. They respondents will also answer an open-ended question asking them to write-in their definition of sustainable agriculture, which can be one input into the semantic network mapping described later.

Activities will include participating in local partnerships and outreach programs related to sustainable agriculture. Based on input from collaborators, we will develop a list of “strategies” (Hansen 1996) related to sustainable agriculture. For example, we might ask whether or not the respondent supports (on a scale of do not support, somewhat support, fully support) the use of “integrated pest management”, “conservation tillage”, “use of native pollinators”, “sustainability certification” or other broad approaches considered to contribute to sustainability goals. This is an alternative to the tactic used on grower surveys that ask about specific practices. Asking about broad strategies is necessary because not all respondents will be growers, and they will be working with many different types of crops. The list of strategies will be developed in consultation with the full team of ANR collaborators.

Networks are measured with a "name generator" (Henry et al. 2012) network question that asks growers to identify up to 8 other individuals and organizations they work with on sustainable agriculture issues. The respondent will be asked to identify the organization the person works for, and the type of stakeholder (farmer, consultant, producer group, etc). At the end of the survey, the respondent will be asked to provide contact information for each individual. The organizational names will then become the "nodes" in the knowledge network, and identified communication relationships are the "links" in the network. The resulting relational data can be analyzed using social network analysis, to determine the overall structure of the network as well as the location of individual nodes within it. Our analysis will be able to test hypotheses about how networks across counties, what types of individual actors are connected, and the existence of subgroups within California.

Figure 1 (below) illustrates the approach with social network data from Lodi, California. The links indicate two individuals who communicate about viticulture management. The nodes are individual people, who are classified either as growers, outreach professionals or both. For example, some individuals are growers but also contract out as Pest Control Advisors or viticulturalists. One hypothesis from this network is that individuals who are both growers and outreach professionals are more central in the network, because they play a boundary spanning role between the grower community and outreach professionals. A measure of network centrality confirms this hypothesis; boundary-spanning actors who are both growers and provide professional outreach services have the highest centrality scores in all three regions of California in which data was collected (Table 1).

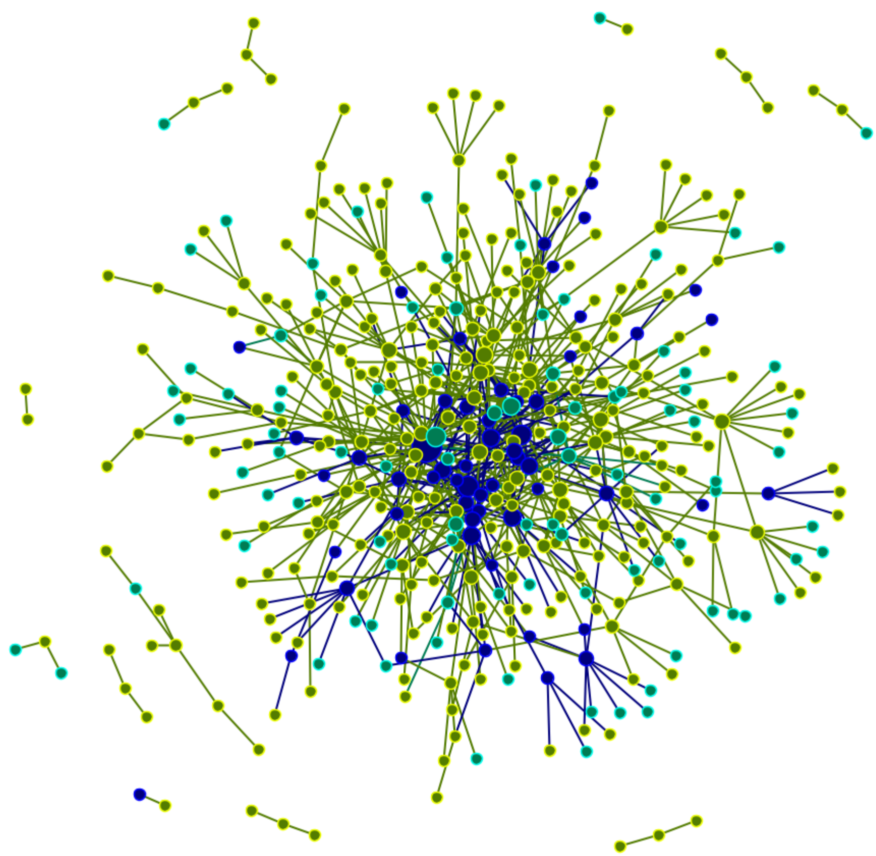
Table 1: Centrality Scores by Type of Actor

	Mean centrality (*se*)			
	California	Central Coast	Lodi	Napa Valley
Both	5.512 (5.350)	5.302 (4.943)	6.491 (6.334)	6.180 (5.226)
Grower	2.519 (3.107)	2.453 (2.899)	2.753 (3.526)	2.496 (2.833)
Outreach	1.511 (1.789)	1.417 (1.631)	2.137 (2.819)	1.252 (0.850)

To achieve an adequate response rate, the team of collaborators will promote the survey via their various contact lists. ANR will send out a message system-wide, asking all employees to complete the survey if they receive it. The sustainable viticulture study was successful at generating enough response, with response rates ranging from 32% to 53%. The survey will be programmed in LimeSurvey, an open-source web-based survey software that is capable of customized programing in JavaScript. Limesurvey allows individual tracking of survey responses and reminder follow-ups to non-respondents. The overall process of survey delivery will follow the total design method of Dillman (2000) .

<u>Inventory the uses of communication technologies among knowledge network members(Lubell, Post-doctoral researcher, collaborators).</u> The survey will ask each respondent to identify any social media platforms or web applications they use for accessing and sharing agricultural information. Targeted social media platforms include Facebook, Twitter, LinkedIn, and others identified by the respondents. We will also ask

Figure 1: Knowledge Networks for Sustainable Viticulture in Lodi, California. Yellow nodes represent individuals who are exclusively growers, aqua nodes individuals who are exclusively outreach professionals, and dark blue nodes individuals who are both growers and outreach professionals. Nodes are scaled by total degree centrality, with higher centrality represented by larger diameter nodes.



about any webpages or blogs they use to deliver outreach information. For purely descriptive purposes, this will provide an overall measure of the most popular communication technologies. Furthermore, this will provide ANR with a searchable database that can be used more systematically than the fragmentary anecdotal information we currently have. The data can also be used to analyze what characteristics of individuals predict the use of communication technology, and whether or not the people who use communication technology are better connected within knowledge networks.

<u>Analyze the dynamics of social media communication using "big data" methods (Lubell, Post-doctoral researcher)</u>: A more sophisticated approach to analyzing the social media information collected from the survey is to use "big data" methods to understand the communication dynamics of on-line communities (Butts and Cross 2009; Ediger et al. 2010; Gonzalez-Bailon et al. 2013). For example, Twitter users can be identified by their handles (or user names) and relevant content can be classified using #hashtags, which are the labels that users apply to their messages to identify with certain communities or

information domains. Links between users can be reconstructed via “re-tweets” (i.e. the broadcasting of messages previously sent by other users), “mentions” (i.e. direct appellations to other users), or the underlying structure of “followers” (which creates the channels for a potential flow of information via mentions or re-tweets). Facebook “friends” can also be considered links in a social network, as well as links between different blogs.

Much of this data is available using “big data” techniques, such as blogosphere aggregators (http://spinn3r.com/; http://www.weblogs.com/api.html;) and “application programmer interfaces” (APIs). These data sources allow tracking of communication over time, which is a big advantage over survey-based data collection that usually is limited to one or two time periods. By seeding a big data collection process with specific social media and blog sites discovered by the survey, we can track the dynamics of web-based communication regarding sustainable agriculture.

Data extracted from social media sources can also be analyzed with network science methods (Wasserman and Faust 1994; Newman 2010), along with content analysis of text (Grimmer and Stewart 2013). We will be able to identify central Internet resources that receive or broadcast the most information about sustainable agriculture. Community detection algorithms (Newman 2012) can identify different subgroups within the social media network, which can translated into communities of practice. The dynamic aspects of online communication can be used to track the emergence of key issues as central discussion topics and potentially can be used as early warning systems for emerging conflicts and problems. Thus the “big data” networks have a number of potentially practical applications, as well as providing a study system for basic research into the dynamics, structure, and function of knowledge networks.

Measure stakeholder belief-systems about sustainable agriculture (McRoberts, Graduate Student): Belief systems about sustainable agriculture can be elicited with cognitive networks in which nodes represent goals and strategies and links measure a participant's degree of belief in the causal relationships among the nodes. The method uses a graphical approach in which stakeholder focus groups will draw their own semantic networks in a process facilitated by a member of the project team. On separate sheets of paper, participants will be asked to make four lists. List 1 will contain things which help to promote the existence/success of sustainable agriculture. List 2 will contain things which inhibit the existence/success of sustainable agriculture. List 3 will contain things which are caused/enhanced by sustainable agriculture. Finally list 4 will contain things which are inhibited by sustainable agriculture. Using a variety of questions, participants quantify the strength and direction (positive/negative) of connections among list items. The resulting data is a square matrix that can be analyzed with a variety of network and graphical methods to identify structural characteristics.

A set of counties will be selected to provide a range of climates, resource availabilities, agricultural activities and levels of involvement by UCCE in sustainable agriculture development. The selected counties will also allow the project to build on existing relationships between the project team and agricultural commodity groups. A preliminary list of counties is San Diego, Ventura, Monterey/San Benito, Tulare/Fresno, Napa/Sonoma, and Shasta/Lassen. Results from the survey will be used to further refine this list.

We expect to the semantic networks to be related to the broader knowledge system in which the stakeholders are embedded. The content and complexity of stakeholders' semantic networks will differ among stakeholder populations in different counties according to the nature and intensity of issues facing them. The degree of consensus among individuals' semantic networks will be higher in locations with a longer history of interest in sustainability, and where knowledge networks are more densely connected as measured by the survey.

Develop a knowledge networks and social media short-course (Entire team): The results of the study will be used to develop a short-course that will train outreach professionals in social network theory and analysis, and principles of outreach with communication technology. Such training will be useful statewide for providing a more principled basis for effective program development. Short courses have been effectively delivered for a number of other issues, including water quality management (http://ucanr.edu/sites/farmwaterquality/The_Farm_Water_Quality_Planning_short_course942/) and rangeland management (Larson et al. 2005). This short course represents a synergy between Extension 3.0 ideas and more traditional outreach tools.

Although the final content of the short course will change based on the results of the study, at this stage the course is expected to have the following components:

1. Information about how agricultural knowledge systems have transformed over the last century.
2. Definition of sustainable agriculture from literature and according to stakeholder belief systems.
3. Theories about the role of social networks, including social capital, diffusion of innovation, communities of practice, and local self-governance.
4. Basic approaches collecting social network data
5. Basic approaches to visualizing and analyzing social network data
6. Illustrations of knowledge network analysis from sustainable viticulture, sustainable agriculture blogsphere, and current study.
7. Examples of successful use of social media from the field (e.g. Almond Doctor, Grape Tweets)
8. Principles of how to structure effective social media
9. Recommendations about steps need in overall Cooperative Extension system to capitalize on knowledge networks

All project personnel will be involved in the development of the short-course and trained in the delivery. It will be available as a completely on-line course similar to a MOOC (massive open online course), for example the MOOC on climate change developed at UC Davis (http://www.climatechangecourse.org/). It will also be delivered via in-person seminars.

Project leadership and capacity: The project will be led by PI Lubell, who has extensive experience in survey research, network analysis, and agricultural decision-making. Lubell will hire and supervise the "big data" post-doctoral scholar, who will be responsible for collecting and analyzing the social media and blogosphere data from the web. Lubell will also supervise the programmer who works for the Center for Environmental Policy and Behavior. The programmer will assist with specialized programming of the online survey, support the post-doc in "scraping" the social media communication data from the Internet, and implementing the online materials for the short-course.

PI Neil McRoberts will supervise a graduate student to collect the data needed for estimation of semantic networks. We will interview ANR collaborators and stakeholders to gather the information on extension efforts on sustainable agriculture in the six pilot regions listed above. PI McRoberts and the student will design the statistical re-sampling routines for the hypothesis testing using the R statistical programming language.

ANR and industry collaborators at the county and statewide level will review all research and outreach products, providing suggestions on survey design and content of the short course. They will help advertise and promote the survey in order to increase response rate. They will also provide specific content for the short course, and help coordinate local delivery of the short course to key knowledge network stakeholders. The ANR collaborators will be added as co-authors for any relevant publications for which they provide a substantive contribution. Given the novel an innovative aspects of this project, the extent of collaborative relationships with ANR experts will continue to evolve with ongoing dialogue. The letters of support provide additional details about how individual outreach professionals envision connecting their programs with this project.

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