Extension 3.0: Agriculture Education and Outreach in the Age of Connectivity

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Abstract

This paper develops the idea of "Extension 3.0" as an approach to agricultural education and outreach that capitalizes on the complex structure of local agricultural knowledge systems. Over the last century, agricultural knowledge systems have evolved to feature networks of actors with widely distributed and specialized expertise. Extension programs need to manage these systems in ways that maximize the synergy between experiential, technical, and social learning. Using empirical research from California farmers, we demonstrate the diversity of these networks within and across contexts, and the importance of boundary-spanning relationships. We provide some initial recommendations about actions needed to realize the goal of Extension 3.0 to deliver relevant agricultural knowledge to the right people, at the right time and place.

Extension 3.0: Agriculture Education and Outreach in the Age of Connectivity

Since the birth of the Land Grant system in the late 19th century, agricultural extension in the United States has relied on a top-down model of knowledge transfer from universities to farmers via Cooperative Extension specialists and county advisers. "For many years agricultural science assumed that research was done by scientists, repackaged by extension officers, and launched at farmers (Carr and Wilkinson 2005)." Twenty-first century agricultural knowledge systems have evolved to become more complex, dynamic, and networked, and the work of extension is no longer limited to universities. The proliferation of new communication technologies, specialization within agricultural industries, growing numbers of formally educated practitioners, and abundance of agricultural support organizations means that knowledge is distributed across a diverse array of interconnected actors. In this paper we argue that agricultural extension should adopt an approach that capitalizes on the network structure of contemporary agricultural knowledge systems. We call this approach Extension 3.0, to imply the idea of leapfrogging to a new model of extension that connects relevant knowledge to the right people, at the right time and place.

Extension 3.0 argues that agricultural knowledge systems are complex adaptive systems, which consist of interdependent and self-organizing components (Levin 1998; 2003). Within these systems, social networks connect a diverse set of actors including farmers, traditional extension professionals, consultants, non-profits, government agencies, and others. The networks include both face-to-face personal relationships and those mediated by communication technology. While many effective extension professionals have implicitly learned to leverage knowledge networks by building partnerships with others, this approach is rarely explicit in program planning or professional training.

Why the term Extension 3.0? To some extent the term is an accident of history, since the lead author coined it in 2010 in an informal memo within University of California Agricultural and Natural Resources (ANR), which is the primary coordinator of Cooperation Extension in California.   At the time, an official with ANR described the idea as "shaking up a can of soda in the hallway" (Lubell 2010); since then the term has become a regular part of ANR's internal dialogue. Of course, the term is also deeply rooted in a large existing literature on collaborative partnerships in agriculture (Warner 2007) and environment (Sabatier et al. 2005). This paper builds on these ideas by developing theoretical hypotheses, illustrating Extension 3.0 with empirical data, and advocating for strategic incorporation of these ideas into education and outreach programs. A better understanding of the structure and function of agricultural knowledge systems will advance agricultural extension in the United States and many other countries.

We want to be clear about what Extension 3.0 is not. Extension 3.0 is not a call to eliminate traditional extension professionals at either the university or county levels. Cooperative Extension specialists and farm advisers, as well as university researchers, continue to play important roles as relatively neutral knowledge-brokers. But Cooperative Extension needs to understand how their knowledge plugs into the wider system, and find ways to structure the knowledge networks in useful manners. In other words, outreach and education programs do not just broadcast knowledge but seek to actively manage knowledge networks.

Extension 3.0 is not a call to convert all outreach strategies into new communication technology such as social media or smart phone applications. Communication technology certainly does play an important role for reaching wide audiences in a relatively inexpensive manner, and it is useful for bringing diverse sources and large amounts of information to bear on real-time decisions. But while communication technology can provide opportunities for new forms of knowledge sharing, it will never completely replace the development of social networks through repeated face-to-face interaction—a strategy Cooperative Extension has a well-known reputation for achieving. Extension 3.0 seeks to understand how personal networks and communication technology can work together in a synergistic fashion.

Extension 3.0 is not claiming that social networks are somehow new to agriculture, or that others have not previously recognized their importance (Bandiera and Rasul 2006; Lubell and Fulton 2008; Röling and van de Fliert 1994; Rogers 2003; Warner 2007). Social networks have been crucial since the emergence of human society, and also for our primate relatives and ancestors. Farmers have always been influenced by social networks, as witnessed by the apocryphal "coffee shop" meetings in rural communities. Successful extensionists, especially Cooperative Extension county farm advisers, have found ways to integrate themselves into these social networks. But the last decade has seen a massive increase in the popular awareness of networks due to technology like social media and the Internet, as well the recent emergence of the field of "network science"(Lazer et al. 2009; Borner et al. 2007). We now have many different theories and methods that can help make networks an explicit component of the design and implementation of outreach and education programs.

We build our case for Extension 3.0 in stages. First, we describe how agricultural production and knowledge systems have evolved since the birth of Land Grant universities. Next, we outline the core components of agricultural knowledge systems, with a deeper focus on the structure and function of social networks. We then illustrate some of the ideas of agricultural knowledge systems with empirical data from farmers in California. Lastly, we provide a series of recommendations for actions that Land Grant universities could take to better capitalize on the nature of these processes.

Transforming Agriculture and the Role of Land Grant Universities: From Continuum to Network

Agriculture in the United States and many other developed countries has evolved into a specialized industry with knowledge widely distributed across different types of stakeholders. This transformation has been driven by three trends: increased concentration and specialization, increased education and expertise, and the expansion of communication technologies. Furthermore, individual agricultural operations are growing many different types of crops in varying agro-ecological contexts, making it important to adapt information to specific cases. At the same time, the decline in financial resources experienced by many extension programs constrains traditional outreach strategies. Communication technology and other "network-smart" strategies provide new opportunities for overcoming these barriers.

The Changing Face of Agricultural Knowledge Systems

Modern U.S. agriculture has fundamentally changed since the Land Grant and Cooperative Extension systems were ushered into being with the Morrill Acts of 1862/1890, the Hatch Act of 1887, and the Smith-Lever Act of 1914. From an economic activity that once included 30% of the workforce, agricultural production has become more concentrated and specialized and now includes only about 2% of the workforce (NIFA). In 1920, there were more than 6.4 million farms spread across 955 million acres of land (United States Census Bureau). By 2010 there were only 2.19 million farms, though still covering 922 million acres of land (National Agricultural Statistics Service). Between 1920 and 2010, the average farm size increased from 148 to 418 acres (United States Census Bureau 2012). More recently, agriculture has witnessed a "disappearing middle" (Buttel and La Ramee 1991)—from 1997 to 2007 the number of middle size farms (50-2000 acres) dropped by 10% while the number of large farms (over 2000 acres) increased by 8% and small farms (less than 50 acres) increased by 16%.

The change in farm structure has been accompanied by an increase in the knowledge levels of farmers and rural Americans. In 1940, only 7.6% of rural farm Americans had high school degrees and 1.8% had any college education.[1] By 2006, 81.8% of all non-metropolitan (though not necessarily farmers) individuals obtained a high school diploma and 16.1% had four or more years of college.[2] While differences in data collection make it difficult to provide precise quantitative comparisons over time, it is clear that the level of formal education available to rural areas of the United States has increased. Cooperative Extension's early mission was to provide education to the rural workforce, who were often excluded from university system of the early 20th century. The increase in education levels, along with the emergence of many specialized professions within agricultural industries, creates a system with a wealth of widely distributed knowledge.

Farmers have also become important participants in the information age. In 2011 62% of U.S. farms had internet access and 14% of farmers utilized the internet for the purchase of agricultural inputs. Sixty-five percent of farms had access to a computer and 37% used one for business. Farmers are using the internet for economic purposes--13% indicated that they obtained USDA reports and 35% conducted business over the internet (National Agricultural Statistics Service, 2011). Farmers have also joined the ranks of social media users, which unlocks a new source of social learning. In an Idaho study (Guenthner and Swan 2012), 97% of farmers were using text messaging, 93% were using email, 90% used YouTube and 70% were using Facebook.[3] Technology use was most common among younger farmers, which has also been corroborated by Seger (2011) who noted that 96% of "Generation Y" had joined a social networking site.

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[1] 1940 is the most recent year from the US Census Bureau containing educational attainment data

[2] 2006 is the most recent year the US Census Bureau has data comparing rural versus urban residential educational attainment data

[3] This is may be an overestimate of social media use among the broader population of farmers, because the survey sample was focused on farmers who participated in outreach meetings and organizations. An important empirical question is whether farmers who do not frequently participate are also less innovative in technology use.

These trends among young farmers- the future clientele of Cooperative Extension- cannot be overlooked as we consider Extension 3.0.

Constraints and Opportunities for Cooperative Extension

Cooperative Extension has faced considerable constraints in keeping up with these changes. Many states have experienced decreases in funding and extension positions, with many extension agents being asked to expand the geographic range of their territories and serve more clients with fewer resources. Part of the problem is declining political support for Cooperative Extension; there are fewer farmers, and many of them have enough of their own expertise to operate without help from Extension. Hence the political demand to elected officials for maintaining extension budgets has become less effective.

The historically top-down model of Extension has created inertia in the uptake of communication technology (Diem et al. 2009, Diem et al. 2011)—"to an organization that has maintained a traditional model of knowledge dissemination for the past 100 years, new technologies and the complexity of how social media influences our lives can seem incredibly intimidating[4]" (Seger 2011). Technology use among Cooperative Extension appears to be low (O'Neill et al. 2011), including Cooperative Extension's online portal for communities of practice called eXtension (Harder and Lindner 2008; Arnold et al. 2012). It may be that Cooperative Extension is unaware of the saturation of technologies by their clientele and may think they will be irrelevant (Alston et al. 2011; Diem et al. 2011).

Despite these challenges, there is a growing awareness of the potential benefits of communication technology and many individual examples of innovation. In a time when farmers are "tweeting from the tractor" (Seger 2011) and using mobile phone applications to make real-time decisions (Dvorak et al., 2012;Drill 2012), it is important to recognize the potential for these tools to build knowledge networks by reaching new and larger audiences in different ways at low cost (Hill 2013; Cornelisse et al., 2011). Extension professionals can use information technology to catalyze their existing networks (Bartholomay et al. 2011; Springer and de Steigner 2011). Extension professionals tend to agree that they should utilize technologies and internet-based applications more and that they can play a strong role in promoting new technologies (Alston et al. 2011; Elbert and Alston 2005; Rich et al. 2011). Uptake of these emerging communication tools should happen with clear goals and institutional changes (Leuci 2012) that avoid haphazard implementation without long-term impact or sustainability.

Keeping pace with the changing face of agricultural knowledge systems requires Cooperative Extension to replace the top-down "continuum" model with a more bottom-up, networked approach. Successful Cooperative Extension farm advisers are already relying on networks to deliver knowledge, but the principles of Extension 3.0 should be more explicitly recognized and become part of professional training. Cooperative Extension can add value by taking steps to manage the structure of the knowledge system, rather than being just a one actor that broadcasts information. Communication technology can be an important tool in this context, but is only

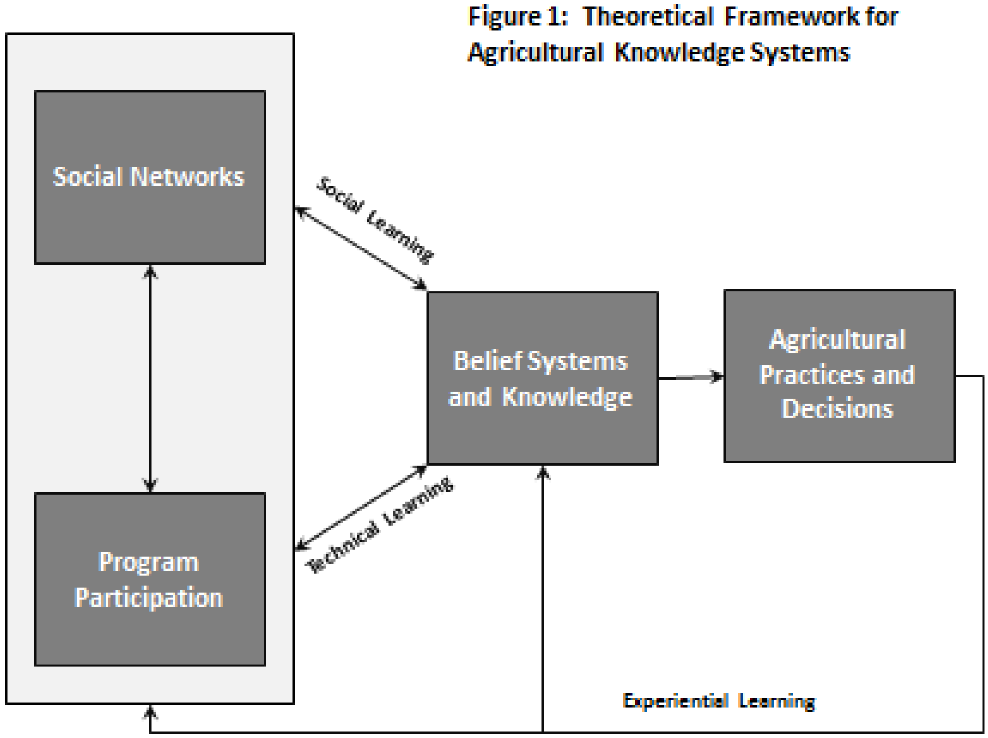
[4] Quote from George Siemen, Associate Director of Research and Development with the Learning Technologies Center at the University of Manitoba.

part of a broader milieu of strategies. Since traditional agricultural clientele has become much smaller, it is also important to build support among urban and environmental interests who are also stakeholders in broader food systems.

Agricultural Knowledge Systems and Social Networks

This section describes a theoretical framework of agricultural knowledge as complex adaptive systems defined by four core components pictured in Figure 1: program participation, social networks, belief-systems, and practice adoption. These core components are mutually interdependent and co-evolve over time in response to the parameters of the contexts in which agricultural systems are embedded (Lubell et al. 2011; Lubell et al. 2013). The knowledge system supports three learning pathways (Foster and Rosensweig 1995; Hoffman 2013): social learning, experiential learning, and technical learning. After describing the overall knowledge system, we hone in on the role of diversity and boundary spanning in social networks, which will be illustrated with empirical data from California farmers.

Figure 1: Theoretical Framework for Agricultural Knowledge Systems



The Core Components of Agricultural Knowledge Systems

At the center of knowledge systems are individual belief-systems and knowledge. Belief systems encode how people perceive the world, and are the proximate basis for decision-making. Belief systems are shaped by an individual's social values, management goals, and understanding of social, economic, political, and natural processes (Hurwitz and Peffley 1987; Stern et al. 1999). Belief systems represent "knowledge" when they reflect a broad social or scientific consensus and real-world experience. [5]

Learning produces changes in knowledge, and over time can lead to convergence in the belief systems of diverse sets of actors who often have different perceptions of causal processes in agricultural systems. For example, there remains debate about whether or not organic production methods produce higher valued and more environmentally friendly products. This debate has generated a large body of research, and the results of that research are one type of information transmitted in knowledge systems. Another example is the debate over the meaning of sustainability, where stakeholders have different perceptions about the central goals of sustainable agriculture and appropriate strategies for achieving them (Hansen 1996; Hoffman 2013). As the dialog over sustainable agriculture evolves in the context of participation in outreach programs and interaction in social networks, there can be some convergence in beliefs about sustainability.

The different components of the knowledge system support three mutually reinforcing learning pathways. First, Participation in outreach and education programs provides a *technical learning pathway*, which is the traditional means of knowledge transfer to farmers and other organizations involved in agriculture. These programs are a core strategy of Cooperative Extension, and are also offered by a wide variety of other stakeholders including producer associations, Resource Conservation Districts, non-governmental organizations, government agencies, and others. Most programs feature a combination of written or digital materials combined with classroom-style or field meetings. Many regions have witnessed the formation of collaborative partnerships to find synergies among the extension programs of different organizations (Shaw et al. 2011; Warner 2007).

Second, Social networks among farmers and other stakeholders represent a *social learning pathway*, where farmers learn from each other, and from other knowledgeable actors within the system. Program participation catalyzes the formation of social networks by providing opportunities for social interaction (Lubell and Fulton 2008; Hoffman 2013). Conversely, existing social networks influence participation by spreading awareness about programs and providing mechanisms for persuading others to attend meetings and access outreach materials.

Third, the *experiential learning pathway* is activated when individual farmers make decisions based on their belief systems, and then adjust their behavior over time in response to feedback. These decisions are "boundedly rational" (Gigerenzer and Selten 2002) in the sense of choosing behavior that people believe to be effective at achieving their management goals, subject to

[5] The distinction between beliefs and knowledge is the subject of centuries of philosophical debate in the field of epistemology. It is impossible to do justice to this area of inquiry in this paper; see Audi 2010 for a nice introduction.

limitations on information and cognitive constraints on information processing. Decision-makers often follow heuristics that balance decision accuracy with costs and complexity (Payne et al. 1988). Management decisions produce observable outcomes that serve as the basis for experiential learning over time.

Extension 3.0 seeks to manage the dynamic structure of knowledge systems to catalyze innovation and cooperation. The different components of the knowledge system are interdependent, with multiple feedback processes and mutually reinforcing learning pathways. No single actor controls the system, and different actors specialize in generating knowledge about different aspects of food systems. Outreach programs enhance adaptive capacity when they capitalize on the structure of knowledge systems in ways that help farmers react to the changes in economic, social, and environmental processes.

Diversity and Boundary Spanning in Knowledge Networks

Social networks that connect food system stakeholders are the component of the knowledge system that supports social learning. Social networks consist of "nodes"—farmers and other agri-food system stakeholders--connected by "links"—social relationships of different types through which information and other social processes flow (Wasserman and Faust 1994). Both theory and practical evidence demonstrate that social networks accelerate innovation and cooperation (Gerlak and Heikkila 2011; Ostrom 1990; Pahl-Wostl 2009). While social networks have always been important in agriculture, they have remained implicit and under-researched as a part of outreach and extension. Understanding social networks can help Cooperative Extension develop strategies for managing agricultural knowledge systems.

Extension 3.0 hypothesizes that knowledge is distributed across diverse types of actors in the social network. Unlike the assumption of the top-down model, university-based researchers and extension agents are not the sole source of knowledge. Experts and knowledge brokers—many with post-graduate education—can be found throughout knowledge networks. Sources include farmers, government agencies, consultants, producer groups, and others. While Cooperative Extension is still an important node in the network, it is not the only source of knowledge. Extension 3.0 argues that in addition to this traditional role, Cooperative Extension professionals should be competent at managing and assembling the networks.

A corollary hypothesis about how knowledge is distributed *within* contexts is that the structure of networks will be heterogeneous *across* contexts. For example, extension agents are not equally relied on in different counties or types of crops. When a long-time extension agent retires, a newly hired person will not automatically inherit the predecessors' reputation and trust among farmers and have the same contacts to farmers and stakeholders. Or as often occurs with recent budget cuts, the extension agent may not even be replaced, and other agents may be expected to pick up the responsibilities. In other cases, a particular organization like a Resource Conservation District, a producer group, or a local partnership might take on a leadership role in addressing some important agricultural issue. This is illustrated by the Irrigated Lands Regulatory Program in California, where different organizations took on the role of coordinating farmers in each region (Lubell and Fulton 2008). In all of these cases, there is heterogeneity across contexts in how knowledge is distributed among different actors and farmers learn to trust different organizations and people.

A second hypothesis is that boundary spanning relationships are crucial for tapping into diverse sources of knowledge and accelerating innovation and cooperation. At the individual level, people can span boundaries between different groups to broker knowledge across communities (Gould and Fernandez 1989). People whose social networks span "structural holes"—connecting to subsets of actors who themselves are less connected—can access non-redundant information and social resources (Burt 2009). In the case of conflict, network theory suggests the importance of building "bridging" social capital among members of different groups (Adler and Woon 2002). At the organizational level, agriculture has witnessed the emergence of "boundary organizations" (Guston 2001) like local partnerships or research programs, which seek to be accountable to multiple groups at once. Cooperative Extension is well situated as a boundary organization: Extension strategies that explicitly seek to increase boundary spanning, at both the individual and organizational levels, can accelerate information and potentially build cooperation among diverse groups.

Empirical Illustrations of Extension 3.0 in Social Networks

This section provides some empirical illustrations of Extension 3.0, with a specific focus on the diversity of social networks and the role of boundary spanning. The diversity of social networks is demonstrated with survey data from a wide range of agricultural communities in California, where all of the surveys asked questions regarding the information sources used by farmers. The boundary-spanning example comes from data on the social networks of winegrape growers in Napa County, Lodi, and the Central Coast of California.

Illustration: Information Sources Used by California Farmers

Over the last decade, our research group has worked on several different projects in California using surveys to analyze agricultural decision-making (Haden et al. 2012; Niles et al. 2013; Lubell and Fulton 2008; Lubell et al. 2013). Table 1 summarizes the type of farmer populations sampled, issue focus, year, response rates and total sample size for the surveys. Each project focused on different spatial and issue contexts, but environmental practices in agriculture provides a common theme. The studies also targeted relatively new issues that required farmers to learn and adapt to new policy, environmental, and economic circumstances.

Table 1: Summary of Agricultural Decision-Making Surveys				
Farmer Type	Issue Focus	Year	Sample Size	Response Rate
Sacramento Valley Farmers	Water Quality Regulation	2004	1,229	24%
Central Coast Farmers	Water Quality Regulation	2006	453	27%
Lodi Winegrape Growers	Sustainability Partnerships	2011	227	53%
Central Coast Winegrape Growers	Sustainability Partnerships	2012	358	32%
Napa County Winegrape Growers	Sustainability Partnerships	2012	237	42%
California Ranchers	Rangeland Ecosystem Services	2011	511	34%
Yolo County Farmers	Climate Change Mitigation and Adaptation	2011	162	33%
Note: All response rates calculated according American Association of Public Opinion guidelines including estimate of ineligible non-respondents. For Central Coast, the 27% response rate refers to 425 mail survey respondents only; remaining observations are for Spanish language respondents who received survey during workshops and had response rate of 11%.				

Each survey asked respondents to identify who they communicate with about agricultural issues, from among a common set of communication targets including Cooperative Extension. Table 2 shows the percentage of respondents who indicated any type of communication with the common set of actors.[6]

The communication patterns clearly demonstrate that Cooperative Extension remains an important actor in all of these systems, with levels of contact around 70% or higher except for the Central Valley water quality regulation. However, Cooperative Extension is far from the only source of information for farmers—almost all of the other types of organizations appear as an important source for at least one group of farmers. Even environmental organizations receive a reasonable amount of contact, although the values for winegrape growers are very high because the question refers to a local winegrape sustainability program rather than just environmental groups. There is also evidence of a substantial amount of farmer-farmer interaction, except in the Central Valley.[7]

At the same time, the relative ranking of these information sources varies across context. For instance, Resource Conservation Districts are a top source of information for Lodi winegrape growers but not as much for the other farmer populations. The State/Regional Water Quality Control Board (the main agency responsible for issuing water quality permits for agriculture)

[6] The form and frequency of communication was usually included in the surveys, but not in exactly the same format. For the purposes of this paper, we just considered any form or frequency of communication as a "1", and a zero if there was no communication at all.

[7] The low level of farmer-to-farmer communication in the Central Valley is probably some type of artifact of survey question wording, since we asked about "other farm operations in the Sacramento River watershed". Respondents may have interpreted this to be about more distant neighbors. The question was also framed in terms of water quality management, which may have narrowed the range of farmer-to-farmer communication. However, the Sacramento Valley farmers do appear less connected in a number of dimensions, so even a more accurate measure may have showed lower farmer-to-farmer communication than in other regions.

Table 2: Communication Patterns for Agricultural Outreach Organizations							
	Central Valley Farmers	Central Coast Farmers	Lodi Winegrape Growers	Central Coast Winegrape Growers	Napa County Winegrape Growers	California Ranchers	Yolo County Farmers
Producer Groups	31%	49%	80%	85%	87%	95%	57%
State or County Farm Bureau	47%	59%	62%	71%	85%	83%	79%
Environmental Groups	18%	48%	72%	60%	65%	25%	21%
Cooperative Extension	41%	69%	90%	96%	95%	74%	77%
Resource Conservation Districts	21%	28%	81%	50%	64%	38%	45%
County Agricultural Commissioner	53%	69%	55%	72%	89%	NA	92%
Water Quality Control Board	17%	63%	86%	63%	62%	NA	NA
Natural Resources Conservation Service	14%	28%	77%	50%	61%	57%	NA
Agricultural Consultant	NA	68%	64%	89%	90%	20%	NA
Other Farmers	31%	93%	63%	92%	93%	90%	NA

receives a very low contact level in the Central Valley, but quite high in the Central Coast for the exact same issue. At the time of the survey, the Central Coast Regional Board had a much better relationship with agriculture than the Central Valley Regional Board. California ranchers are less likely to use agricultural consultants than other types of farmers, perhaps because they are not as reliant on irrigated crops or pastures as other types of agricultural producers. Sacramento Valley farmers overall appear quite disconnected to the knowledge network, potentially reflecting the large spatial extent of the Valley and general distrust of government in the realm of water quality regulation.

Of course, there are a number of different potential explanations for the variance across regions. The nature of the sample was different for each study; for instance the rangeland study was based on the membership of the California Cattleman's Association so their contact with producer groups was especially high. The issue focus of the survey and question wording can also affect responses. For example, Central Valley farmers were upset about impending water quality regulations, and thus their expressed contact patterns were probably different than if the survey had been about marketing of agricultural products. The timing of the survey can also be important; climate change is among the newest problems being recognized by agriculture while water quality regulation has been happening for several years. However, the point here is not to explain a specific number, but rather to demonstrate that knowledge networks are diverse both within and across contexts.

Illustration: Boundary-Spanning in Viticulture Networks

The analysis above does not attempt to directly measure social networks using network analysis methods. In contrast, the sustainable viticulture project asked each respondent to nominate other growers and outreach professionals who they communicate with about viticulture management.[8] The respondent also indicated the type of job held by each outreach professional mentioned; a total of 12 different types of outreach professionals were mentioned: for-hire vineyard managers, Pest Control Advisors, viticulture consultants, vintners, vineyard sales representatives, University of California Cooperative Extension staff (farm advisers and specialists), winery representatives, labor contractors, research scientists, partnership staff, NRCS staff, and County Agricultural Commissioners. In addition, we asked each respondent if they also worked as an outreach professional, such as a Pest Control Advisor.

Based on this information, we constructed knowledge networks consisting of growers, outreach professionals, and some individuals who were both growers and provided outreach services of some type. The respondents who did both are “boundary spanning” between the advice and expertise of outreach professionals, and the experience of growers. Figure 2 shows an example network from Lodi. The visualization of the Napa and Central Coast networks exhibited similar patterns.

The centrality of a particular actor in the network is one important measure of influence and potential role in diffusing information. One intuitive measure is total degree centrality, which is the total number of ties associated with a given node (Wasserman and Faust 1994). [9] Table 3 reports the average centrality score for different categories of actors, and clearly demonstrates that boundary-spanning growers who also provide outreach services are the most central in the network across all three regions. Furthermore, growers are more central than people who are just outreach professionals, which reinforces the point about how learning is distributed throughout knowledge networks.

[8] In Lodi, the respondents were asked to nominate up to four other growers and four outreach professionals. In Napa/Central Coast, they were asked to nominate up to eight individuals in each category.

[9] We used total degree centrality because it is an intuitive measure and is much easier to interpret in real-world terms than others centrality measures. Total degree centrality does not capture the tiered nature of actual social networks as well as well as other centrality measures, such as eigenvector centrality. However, we found our measured of total degree centrality to be highly correlated (r=0.830, p=0.000) with eigenvector centrality, and is thus qualitatively similar.

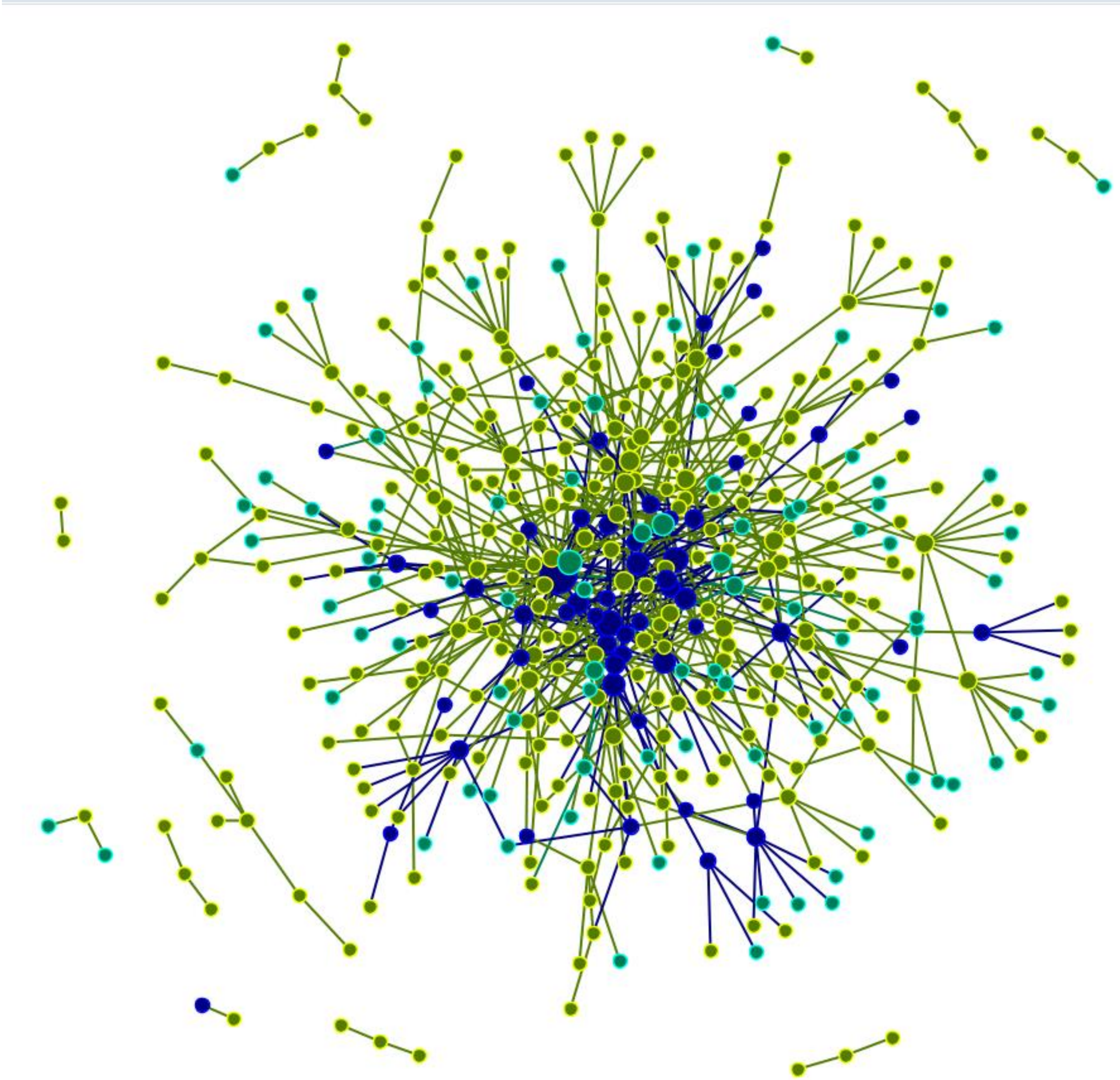


Figure 2: Lodi Winegrape Grower Knowledge Network. Nodes represent individuals and ties represent communication relationships. Nodes are color coded: yellow nodes represent individuals who are exclusively growers, aqua nodes individuals who are exclusively outreach professionals, and blue nodes individuals who are both growers and outreach professionals. Nodes are scaled by total degree centrality, with higher centrality represented by larger diameter nodes.

Table 3: Mean Centrality by Type of Actor			
	Central Coast	Lodi	Napa Valley
Both	5.512(4.9843)	6.491(6.334)	6.180 (5.226)
Grower Only	2.453(2.889)	2.753(3.526)	2.496(2.833)
Outreach Only	1.417(1.631)	2.137(2.819)	1.252 (.850)

To further understand the diverse and regionally-specific nature of knowledge networks, Table 4 reports the average centrality scores for the 12 specific types of outreach professionals. These numbers include actors who are "outreach only", as well as "both". Again, UC Cooperative Extension professionals are central nodes, but their importance varies widely across regions. Furthermore, other types of outreach professionals are central in the network in different regions. For example in Lodi, "partnership staff" from the sustainability program of the well-established Lodi Winegrape Commission are central in the network. It is also important to recognize the centrality of the various actors associated with the economic activities of winegrape and wine production, which has developed into an industry with many specialized roles. When seeking to establish a broad idea like "sustainable agriculture" through a region or industry, all of these nodes should eventually be reached.

Table 4: Mean Centrality of Different Types of Outreach Professionals, by Winegrape Region			
	Central Coast	Lodi	Napa Valley
UCCE Staff	4.00	21.50	4.80
Vineyard Management	5.24	5.25	5.50
Pest Control Advisor	2.70	3.82	4.47
Sales Representative	1.88	7.00	4.0
Viticulture Consultant	2.60	3.00	3.16
County Agricultural Commissioner	1.00	--	2.0
Partnership Staff	1.00	4.00	--
Winery Representative	2.00	1.80	1.50
Labor Contractor	1.43	1.00	2.00
Research Scientist	2.00	2.00	1.00
Vintner	1.25	1.00	1.59
NRCS	1.00	--	1.00

Towards Extension 3.0: Some Recommendations

Local knowledge systems have evolved over time in response to program participation and the dynamics of social networks. In some cases these systems may be created or strengthened by communication technology. These ideas should be strategically integrated into statewide planning in terms of what programs to fund, what types of positions to hire, what skill sets outreach professionals are expected to have, and other key decisions. The following recommendations will help achieve the goals of Extension 3.0 by more explicitly building on the principles of knowledge systems and networks:

- <u>Document the extent of ongoing Extension 3.0 activities</u>: We have only anecdotal knowledge of what types of outreach professionals are engaged in Extension 3.0

activities such as using communication technology and building boundary-spanning institutions. Strategic planning cannot occur without a more systematic understanding of the groundswell of current activity. To what extent are we already implementing Extension 3.0?

- Map existing knowledge networks: Mapping existing knowledge networks around sustainable agriculture will provide a better understanding of the structure and function of knowledge systems, including the diversity of network actors within and between contexts, and the most central and disconnected types of organizations. Understanding the structure of the current knowledge system is critical before we design new "network smart" extension strategies that leverage the existing networks to accelerate social learning.
- Provide professional incentives: Many of the outreach professionals currently experimenting with Extension 3.0 simply think it is a good idea, rather than reacting to professional incentives. Targeted grants and awards that recognize innovative outreach strategies will accelerate implementation. Personnel evaluations should recognize innovative outreach strategies like social media as legitimate activities to be considered with more traditional metrics like publications.
- Decision-support tools for real-time application: Decision-support tools that allow information to travel across social networks, or quickly integrate agro-ecological and spatial data, will enable access to knowledge at the right time and place. Such tools could include social media, virtual forums, and Smartphone applications. Also critical is farmer and outreach professional training on how to use such technologies.
- Hire Extension 3.0 outreach professionals: Hiring initiatives in Land Grant universities and other organizations should recruit outreach professionals who are trained in the theory and methods of social networks, complex systems, and community building. To meet their research expectations, these outreach professionals can also use agriculture as a study system to analyze basic and applied science questions about networks and complex systems.
- Build new boundary-spanning partnerships: Local, county, regional, and state boundary-spanning partnerships that include Cooperative Extension plus other key knowledge network actors should be supported to focus on important issues facing agricultural systems, such as climate change, sustainable agriculture, and others. Cooperative Extension should provide in-kind and funding support for these partnerships as a mechanism for assembling and managing knowledge networks. Existing organizations such as research stations can adopt new approaches that reflect boundary-spanning ideas.
- Stakeholder participatory research: Participatory research incorporates local stakeholders directly into the design and analysis of agro-ecological research. Participatory research not only increases the relevance of research projects and results, but reinforces the experiential, social, and technical learning pathways that support knowledge systems.

These recommendations are only a starting point; more details need to be fleshed out and other strategies will be articulated in response to dialog and experience with Extension 3.0. The basic goal of this paper is to start developing a theoretical framework to anchor the idea of Extension 3.0, and provide concrete empirical illustrations of the importance of knowledge networks. We hope to inspire further research and practical experiments with outreach and education strategies that are designed with these ideas in mind.

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