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Extension 3.0: Managing Agricultural Knowledge Systems in the Network Age

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Abstract: This paper develops the idea of "Extension 3.0" as an approach to agricultural extension that capitalizes on the network structure of local agricultural knowledge systems. Over the last century, agricultural knowledge systems have evolved into networks of widely distributed actors with a diversity of specializations and expertise. Agricultural extension programs need to manage these networks in ways that maximize the synergy between experiential, technical, and social learning. Using empirical research from California farmers, we highlight the structure 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, which is to deliver relevant agricultural knowledge to the right people, at the right time and place.

Keywords: agricultural extension, agricultural sustainability, Agriculture and the Environment, farmer cooperatives and supply chains, human behavior in the environment, social networks, survey methods,

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Introduction

Since the birth of the Land Grant system in the late 19^{th} century, agricultural extension in the United States has primarily 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 witnessed the proliferation of new information and communication technologies (ICTs), specialization within agricultural industries, higher levels of education among farmers, and the creation of extension organizations beyond universities (Warner 2007). Current agricultural knowledge systems feature a diverse network of actors (Bartholomay et al. 2011) and multiple learning pathways including experiential learning from practice, technical learning from outreach materials, and social learning from other people (Hoffman et al. 2014; Lubell et al. 2011).

The core argument of this paper is that agricultural extension should be modified to capitalize on the networked structure of knowledge systems. The term Extension 3.0 connotes a new approach to agricultural extension that seeks to strategically manage knowledge systems to synergistically integrate social, technical, and experiential learning pathways (Leuci 2012). Extension 3.0 highlights the importance of networks of actors who cooperatively work together to deliver relevant knowledge to the right people at the right time and place. Linking such knowledge to action—especially at the level of farm management decisions and practices—may enhance the sustainability and resilience of agro-ecological systems (Cash et al. 2003; Van Kerkhoff and Lebel 2006).

Achieving these goals requires changing the institutional structure of agricultural extension systems, training extension professionals in the principles of Extension 3.0, and updating on-the-ground outreach and education programs. Since the term was first coined by the lead author (Lubell 2010) in an internal memo, Extension 3.0 has become a regular part of the dialogue within University of California Agriculture and Natural Resources, the unit that manages Cooperative Extension in California.

We want to be clear about what Extension 3.0 is not. Extension 3.0 is not a call to eliminate traditional extension professionals, who continue to play important roles as relatively neutral developers, reviewers, translators, and distributors of scientific and other types of agro-ecological knowledge. However, Cooperative Extension is embedded in the larger knowledge system and there is a need to develop extension programs that seek to actively manage knowledge networks to augment traditional extension strategies.

Extension 3.0 is not a call to convert all outreach strategies into ICTs such as social media, webinars, or smart phone applications. ICTs can potentially reach wide audiences in a relatively inexpensive manner (Drill 2012; Dvorak et al. 2012; Harder and Lindner 2008; Kennedy and Wellman 2007; Wellman 2001), and bring a wide array of useful information to bear on real-time farm management decisions. While ICTs do provide new platforms for knowledge sharing, they will never completely replace social networks based on repeated face-to-face interaction—

the merits of which have been demonstrated by the successes of Cooperative Extension. Rather, Extension 3.0 seeks to understand how personal networks and ICTs can work together in a complementary 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; Springer and de Steigner 2011; Warner 2007). Social networks have been crucial since the emergence of human society and—as evidenced by the apocryphal "coffee shop" meetings in rural communities—social networks have always been an important influence on farmer decision-making. But "network science" (Lazer et al. 2009; Borner et al. 2007) now provides many different theories and methods that can help make networks an explicit component of the design and implementation of agricultural extension.

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 the structure of knowledge networks with a meta-analysis of empirical data from several studies of California farmers. Based on the analysis of the network and structural aspects of knowledge systems, we develop a series of recommendations that advance the idea of Extension 3.0 through institutional changes at the extension system level, as well as on-the-ground outreach programs.

Before continuing, it is important to define some terms that are used in different ways throughout the literature on agricultural systems. Here, "agricultural knowledge systems" refers to the overall set of actors, organizations, institutions and relationships involved with producing and distributing knowledge about agro-ecological systems. "Agricultural extension" is the general activity of producing and distributing relevant agro-ecological knowledge. "Cooperative Extension" refers to the formal organizational structures associated with Land Grant universities; the key personnel in Cooperative Extension are university researchers, on-campus extension specialists, and county-level Extension Agents. "Extension professionals" include Cooperative Extension employees, but also professionals in other organizations who design and deliver "extension programs" consisting of specific educational and outreach materials and activities.

The Changing Face of Agricultural Knowledge Systems: From Continuum to Network

Modern U.S. agriculture has substantially changed since the Land Grant and Cooperative Extension systems were built by 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 2011). Between 1920 and 2010, the number of farms decreased from 6.4 million to 2.19 million, the average farm size went from 148 to 418 acres, and the total amount of land in farming shrunk from 955 million to 922 million acres (US Census Bureau 1920, 2012, USDA 2007). 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 large farms (over 2000 acres) increased by 8% and small farms (less than 50 acres) increased by 16%.

At the same time, the knowledge levels of farmers and rural Americans have increased. 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. Cooperative Extension's early mission was to provide education to rural populations, who were often excluded from the university system of the early 20th century. The increase in education levels, along with the emergence of many specialized professions within agricultural industries such as crop consultants and Pest Control Advisors, creates a system with widely distributed knowledge.

Farmers are also increasingly using ICTs. 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 also increasingly using the internet--13% indicated they obtained USDA reports and 35% conducted business over the internet (USDA, 2011). Farmers have also joined the ranks of social media users, which unlocks a new source of social learning (Guenthner and Swan 2012; Seger 2011).

These changes in knowledge systems have decreased the relevance of the traditional top-down continuum model of agricultural extension. Modern knowledge systems feature a diverse network of experts that includes universities and Cooperative Extension, but also many other types of actors who distribute information through multiple pathways including traditional outreach programs and new tools like ICTs. Extension 3.0 seeks to understand the structure and function of these knowledge systems, and manage them in such a way to maximize their value for linking knowledge to action in agricultural decision-making. This goal is especially important given the resource and budget constraints facing many Land Grant Universities in the United States.

Agricultural Knowledge Systems and Social Networks

Agricultural knowledge systems are defined by four core concepts (Figure 1): program participation, social networks, belief-systems, and practice adoption (Lubell et al. 2013; Lubell et al. 2011). The knowledge system supports three learning pathways (Foster and Rosensweig 1995; Hoffman 2013): social learning, experiential learning, and technical learning. This section briefly summarizes the conceptual model, and then provides more details about the role of social networks.

[Figure 1 about here: Conceptual Model of an Agricultural Knowledge System]

A Conceptual Model of Agricultural Knowledge Systems

At the center of knowledge systems are individual belief-systems and knowledge. Belief systems encode people's knowledge and perceptions of 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). 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.

The different components of the knowledge system support three mutually reinforcing learning pathways. First, extension program participation provides a *technical learning pathway,* which is the traditional means of knowledge transfer to farmers and other organizations involved in agriculture, including scientific studies. 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.

Second, social networks among farmers and other stakeholders represent a *social learning pathway*, where farmers learn from each other, and from other 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 spread awareness about programs and provide mechanisms for persuading others to participate.

Third, the *experiential learning pathway* is activated when individual farmers and other actors adjust their behavior over time in response to observable outcomes of management practices. Farmers constantly engage in experiential learning when they adopt a new management practice. Experiential learning happens at the individual level, but the knowledge gained from such trialand-error decisions can be transmitted through networks, further tested by researchers and other extension professionals, and integrated into technical materials.

Extension 3.0 seeks to maximize the synergies among these different components of the knowledge systems, which are complex adaptive systems consisting of diverse, interdependent, and self-organizing components (Levin 1998; 2003). No single actor controls the system, and different actors specialize in generating knowledge about different aspects of agro-ecological systems. Agricultural extension enhances adaptive capacity when it manages knowledge systems in ways that help farmers react to changes in economic, social, and environmental processes. For example, one winegrape grower involved in our research commented that social networks are activated by "climate surprises" like a particularly wet or dry year. In these cases, growers use their networks to help decide when and how to apply various crop management actions and methods. In complex and changing agro-ecological systems, such knowledge resources are crucial resources for enhancing resilience.

Diversity and Boundary Spanning in Knowledge Networks

Social learning depends on the degree to which actors are connected to others in the knowledge system (Bandura 1977). Social networks consist of "nodes" (farmers and others types of actors) that are connected by "links"—social relationships of different types through which information and other social processes flow (Borgatti and Halgin 2011; Wasserman and Faust 1994). Both theory and empirical evidence suggest that social networks accelerate innovation and cooperation (Gerlak and Heikkila 2011; Lubell and Fulton 2008; Lubell et al. 2013; 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 agricultural extension. A better understanding of the structure and function of knowledge networks provides a basis for changing how agricultural extension is implemented.

Extension 3.0 first argues that knowledge is produced and distributed by a network of diverse types of actors. While Cooperative Extension remains an important node in the network, it is not the only source of knowledge. The broader network includes farmers, government agencies, non-governmental organizations, consultants, producer groups, and others. Many of these experts have a high degree of education and technical knowledge; in other cases the expertise is derived from place-based experiential learning, sometimes over multiple generations.

A second argument is that the structure of networks will be heterogeneous *across* contexts. For example, county farm advisors are not equally relied on in different counties or varieties of crops. 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, such as climate change adaptation or water quality. Depending on the context, there is heterogeneity in how knowledge is distributed among different actors, and who is trusted to deliver that knowledge.

A third argument is that boundary spanning relationships are crucial for tapping into diverse sources of knowledge. 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 Kwon 2002) in order to facilitate better understanding of diverse viewpoints and empathy (Singer et al. 2006).

At the institutional level, agriculture and many other policy areas have witnessed the emergence of local partnerships and research organizations that serve as “boundary organizations”, where participants from multiple groups (e.g. scientists, farmers, non-profit organizations, private sector) work together to co-produce knowledge (Guston 2001). For example, the Lodi Winegrape Commission’s Sustainable Viticulture program provides knowledge and incentives that accelerate the adoption of sustainable agricultural practices (Shaw et al. 2011; Warner 2007). For sustainability and other agricultural issues, such boundary-spanning organizations help build social networks that connect actors with different types of experiential and technical knowledge. Extension strategies that explicitly encourage boundary spanning, at both the individual and institutional levels, can accelerate knowledge exchange.

Empirical Illustrations of Agricultural Social Networks

This section provides some empirical illustrations of the diversity of agricultural 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; Lubell and Fulton 2008; Lubell et al. 2013; Niles 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 about here: Overview of agricultural research projects]

Each survey asked respondents to identify who they communicate with about agricultural issues from among a common set of organizations and actors including Cooperative Extension. Table 2 reports the percentage of respondents who indicated any type of communication with the set of actors that were targeted in multiple surveys.[2]

[Table 2 about here: Communication Patterns]

The communication patterns demonstrate that Cooperative Extension remains an important actor in all of these systems, with levels of contact 65% or higher except for 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. Environmental organizations receive a reasonable amount of contact as well, although the values for winegrape growers are very high because the question refers to local winegrape sustainability programs associated with producer groups rather than just environmental groups.

The relative ranking of these information sources varies across region and issue context; the differences across samples are all statistically significant. For instance, Resource Conservation Districts and agricultural consultants are relied on more heavily by winegrape growers than more general farm populations. Central Valley and Central Coast farmers have lower levels of contact because the survey focused narrowly on the controversial issue of agricultural water quality regulations. However, there are regional differences on the water quality issues—Central Coast farmers report more contact with the Regional Water Quality Control Board (the agency in charge of agricultural water quality regulations). During that time when new water quality policies were being developed in both regions, there was a higher level of collaboration between agricultural interests and the Regional Board in the Central Coast than in the Central Valley.

Of course regional variance could also be affected by other factors. The nature of the sample was different for each study; for instance, the rangeland study was based on the membership in the California Cattleman's Association so their contact with producer groups was especially high. 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, despite these differences, our data demonstrates the diversity of knowledge networks across contexts.

Illustration: Boundary-Spanning in Viticulture Networks

To examine boundary-spanning, this section examines social network data that explicitly measures communication relationships between individuals. The viticulture surveys (see Table 1) asked each respondent to nominate other growers and extension professionals who they communicate with about viticulture management, and indicate the type of job held by each extension professional mentioned.[3] Respondents mentioned twelve different types of extension professionals: 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 extension professional, such as a Pest Control Advisor.

[Figure 2 about here: Network Diagram for Lodi knowledge network}

Based on this information, we constructed knowledge networks consisting of growers, extension professionals, and some individuals who were both growers and provided extension services of some type. The respondents who did both are “boundary spanning” between the advice and technical expertise of extensional professionals, and the experiential knowledge 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 associated with social influence and potential for diffusing information (Freeman 1979). One intuitive measure is total degree centrality, which is the sum of the total number of ties associated with a given node (Wasserman and Faust 1994). Table 3 reports the average degree centrality score for different categories of actors, and demonstrates that boundary-spanning growers who also provide extension services are the most central in the network across all three regions. This suggests that individuals who can span the perspective of both growers and outreach professionals have an advantage in diffusing knowledge through the network. Furthermore, growers are more central than people who are just extension professionals, which reinforces the point about how learning is distributed throughout knowledge networks.

[Table 3 about here: Average Centrality for different types of actors]

To further understand the regionally-specific nature of knowledge networks, Table 4 reports the average centrality scores for the 12 specific types of extension professionals. These numbers include actors who are “extension only” as well as “both”. Again, UC Cooperative Extension professionals are central nodes, but their position in the network varies across regions; the Cooperative Extension agent in Lodi appears to be a particularly effective knowledge source. The centrality of other types of extension professionals also varies across regions. For example in Lodi, “partnership staff” from the sustainability program of the Lodi Winegrape Commission is more central than a similar program in the Central Coast. 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 about here: Average Centrality for different types outreach professionals]

Towards Extension 3.0: Some Recommendations

The goal of Extension 3.0 is to incorporate the structure and function of agricultural knowledge systems and networks into the implementation of agricultural extension. Here we have highlighted how knowledge is distributed across a wide range of actors connected by social networks with heterogeneous social structures across geography and issues. Individuals and organizations that span different types of boundaries play key roles in diffusing knowledge within these networks. Building on these ideas, Table 5 lists some initial recommendations for moving towards the goals of Extension 3.0. These recommendations reflect Borgatti and Cross's (2003) four guiding principles for enhancing network-based learning: 1) actors must be aware of what knowledge is held by others; 2) actors must value the knowledge held by others; 3) actors must be able to access others' knowledge and; 4) the cost of knowledge access must be low.

The recommendations are relevant at two levels of action: the institutional context of agricultural extension, and the design of on-the-ground extension programs (Table 5 subheadings). The institutional context refers to the resources, knowledge and incentives that shape the decisions of extension professionals. For example, extension professionals are more likely to incorporate

Extension 3.0 ideas into their professional activities if they are trained in network ideas and receive professional recognition for using them. Achieving these changes is challenging in Land Grant universities with institutional structures that adhere to the traditional top-down model (Seger 2011).

Extension program design refers to the specific tools and outreach programs used by extension professionals to deliver information and promote learning among food system actors like farmers and consumers. For example, many extension professionals are experimenting with social media and other ICTs to spread information in new ways (Arnold et al. 2012; Cornelisse et al. 2007; Diem et al. 2011; O'Neill et al. 2011; Rich et al. 2011), or participating in the activities of boundary-spanning partnerships. While the boundaries between these levels of action are fuzzy, it is important to emphasize that Extension 3.0 is not just about the content of extension programs, but also about reshaping the overall institutional context and knowledge system in which extension professionals work.

Boundary-spanning plays a key role at both levels. Boundary-spanning partnerships at the institutional level provide opportunities for different types of actors to learn from each other. Examples include the previously mentioned Lodi Sustainable Viticulture Program, or programs sponsored by Land Grant universities such as the UC Davis Agricultural Sustainability Institute (http://asi.ucdavis.edu/front-page). Established organizations such as Research and Extension Centers (http://ucanr.edu/sites/rec/) can also adopt some of these ideas. Extension professionals can participate in partnerships, but they can also design extension programs to connect to central and boundary-spanning individuals within networks.

While space limitations prevent a detailed description of these recommendations, it is important to emphasize they are only a starting point. The exact strategies to achieve the goals of Extension 3.0 will different across contexts (Hoffman et al. 2014) and there is much to be learned from the many ongoing activities. Extension systems and professionals must be experimental, adaptive, and creative with program design and implementation. The goal of this paper is to provide a theoretical basis for ideas of Extension 3.0 and empirical illustrations of the importance of knowledge networks. We hope to inspire further research, institutional interest, and practical experiments with extension strategies that are designed with these ideas in mind.

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

[2] 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.

[3] 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.