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Field edge plantings for pesticide reduction and enhanced biodiversity on farmlands

Pest Management Alliance Grant, 2016

This Final Report summarizes our 2013-2016 project on enhancing field edge biodiversity on farms, that was funded by the Pest Management Alliance Grant program from the California Department of Pesticide Regulation.

This Project Report was prepared by Project Managers: Rachael Long[1], Dr. Kelly Garbach[2], Laurel Sellers[1], and Mary Fahey[1]

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Overview of the Project

Maintaining clean farm edges results in excessive herbicide use, water quality impairment, and a loss of biodiversity, including wildlife as well as beneficial insects (natural enemies and pollinators) that help with pest control and pollination services in adjacent crops. This project focused on education and outreach to growers and landowners to provide information on the value of bio-diverse field edge management practices to minimize herbicide use, increase beneficial insect activity, reduce insecticide use, and enhance biodiversity. We planted nine demonstration hedgerows with native California shrubs in the Sacramento Valley, helping to diversify field edges, suppress weeds, and increase beneficial insect activity. A survey was conducted with growers and landowners to determine how they manage field edges and where they get information to help with outreach programs for enhancing habitat on farm field edges. This project had three specific objectives as outlined below.

Objective 1

We developed and conducted a landholder survey to identify how field edges are currently managed in the Sacramento Valley. We also included questions on the benefits and concerns of hedgerow plantings on farms. In addition, we looked at the communication channels of landholders for sharing information on field edge management practices, including hedgerow plantings. That is, we evaluated "who-speaks-with-whom" and which individuals and organizations function as information hubs, helping to distribute information to landholders, to address opportunities and constraints for adopting field edge plantings. We identified grower and landowner participants in the Sacramento Valley, sent out about 3,000 surveys via email as well as hardcopies, and followed up with phone interviews and farm visits. The '2013 Hedgerow Survey', on "Field Edge Management Practices on Farms," can be found online at at our UC Cooperative Extension (UCCE) website at: http://ceyolo.ucanr.edu/Custom_Program/Hedgerows/.

Data from 109 participants in the Field Edge Practices survey were evaluated, analyzed, and interpreted. Our working manuscript titled, "Determinants of field edge habitat restoration on farms in California's Sacramento Valley," by Dr. K. Garbach and R. Long, is at the end of this document as well as online at the UCCE Hedgerow website listed above. In our survey, we found that financial and technical support as well as grower perceptions of potential benefits of field edge plantings were key factors in their use on farms. Top benefits included attracting bees, supporting natural enemies of crop pests, improving farm aesthetics, and providing wildlife habitat.

In addition to the field edge survey, we conducted follow up post surveys at our workshops. These twelve workshops focused on disseminating field-based information on the benefits of hedgerows and how to establish them. We had a response rate of 50% (154 returned surveys out of a total of 309 participants at our workshops). In the post-workshop survey, 53% of the respondents self-identified as a grower and/or a landowner. We found that 97% of participants stated that the information useful; 51% said that they would change their field edge management practices with 85% considering planting a hedgerow or other habitat feature on their farm. In total, 90% of respondents said they would recommend hedgerow plantings to others. When asked if drought would keep them from installing a hedgerow, 50% replied that it would not and 37% noted only temporarily.

Objective 2

We planted nine demonstration hedgerows of native California perennial shrubs, forbs, and grasses on farms and ranches in the northern Sacramento Valley (Table 1). The total feet planted in this project was 18,565 feet or 3.52 miles. Based on Natural Resources Conservation Service (NRCS) statistics for California, this represents 23% of the total hedgerow feet planted in California during this grant period. This is a significant contribution to establishing field edge plantings on farms for enhanced ecosystem services in adjacent crops as well as for wildlife habitat. Photos of these sites can be found on our UCCE hedgerow website listed above.

All hedgerow farm and ranch sites were analyzed, measured, and designed with the landowner's goals in mind. Some people did not want native grasses (concerns of rattlesnake habitat); others did not want elderberry due to the protected elderberry longhorned beetle. Some growers were fine with elderberries with minimal concerns of endangered species regulation. One grower tried managing the native grass stand organically and even planted the grass seed using GPS technology with the thought that he would cultivate the weeds. But, the weeds still took over the stand and he had to disc it up. The planting of the hedgerows included setting out the drip irrigation as well as putting tubex tubes around the plants for weed and rodent control.

Our focus was on establishing hedgerows in intensively farmed areas where they do not usually occur and we met this goal. This was important to help outreach information on the benefits of hedgerow plantings because we know from our field edge survey that growers learn through the experience of other landowners in their community. That is, if growers see a hedgerow and become

familiar with their benefits, they are more likely to plant one on their farm.

Table 1. Demonstration hedgerows planted in the Sacramento Valley including year planted, location, and length of planting in feet.

Year	**County**	**Length (ft)**
2014	Colusa	1,400
2014	Colusa	900 (upland)
2014	Colusa	500 (rice field)
2015	Colusa	1,200
2015	Colusa	400
2015	Yolo	530
2015	Yolo	760
2015	Colusa	985
2016	Solano	10,030
2016	Colusa	660
2016	Sutter	1,200

Objective 3

Our project focused on implementing integrated pest management outreach on bio-diverse field edges through workshops, printed materials, and web-based information. This included producing six infographics on hedgerows, two informational handouts on plant selection for the Sacramento Valley, and resources for hedgerow plantings. These are listed in Table 2 below and available at our new website, Hedgerow Hub, www.hedgerowhub.org as well as on my UCCE website, http://ceyolo.ucanr.edu/Custom_Program/Hedgerows/.

Table 2. Publications produced through our project on hedgerows available online at www.hedgerowhub.org and http://ceyolo.ucanr.edu/Custom_Program/Hedgerows/.

Hedgerows, Recommended plants for hedgerows in the Sacramento Valley
Hedgerows: Best locations on farms
Hedgerows: Benefits on farms
Hedgerows: The dynamics of a hedgerow planting
Native bee nesting habits[1]
Native bee nest locations[1]
Hedgerow plant selection for the Sacramento Valley
Hedgerows: Incentives to connect our landscape[2]

[1]These infographics were made by former UC Berkeley Graduate Student Intern Dr. Hillary Sardinas, a summer intern working on hedgerows with R. Long in 2014 from UC Berkeley. [2]This brochure was produced by L. Sellers when she was a MSc. graduate student at UC Davis.

Dr. Kelly Garbach developed the new hedgerow Hub website for enhanced outreach, www.hedgerowhub.org. Our project was regularly updated with news about the project on this site as well as through my UCCE Yolo County Hedgerow page. In addition, Dr. Gornish, UCCE Restoration Ecologist at UC Davis received funding through UC ANR in 2016 to develop an online Restoration Ecology Research and Information Center. She will add a link on her site to our Hedgerow Hub website, bringing good visibility to this site.

We also successfully facilitated 12 hedgerow workshops with about 400 attendees, listed in

Table 3 below. Participants primarily included landowners, growers, and government agencies (UCCE, NRCS, RCD). Each program included a discussion on the benefits of hedgerows (including natural enemies and pollinators), concerns (such as rodents and bird pests), as well as management practices to establish them, including plant selection. More information on these workshops can be found on our UCCE homepage hedgerow website.

Handouts, brochures, and other informational materials were disseminated at each workshop. Items included the handouts listed above, as well as UC ANR publication 8390, "Establishing Hedgerows on Farms in California," and NRCS-EQIP cost share programs. Hedgerow information was sent out in 12 UCCE Pest Control Notes Newsletters, which reaches 350 people during each mailing. Announcements for the workshops were also posted in the Colusa, Solano, and Yolo County Resource Conservation District (RCD) newsletters as well as the Xerces Society, reaching 1000's of members. An article written by a workshop attendee was featured in Solano RCD's newsletter. K. Keatley Garvey, renowned insect blogger at UC Davis, posted her experience of attending one of our workshops, reaching over 400 subscribers. An article was published in Ag Alert, December 2014 titled, 'Hedgerows can offer multiple benefits to growers'. R. Long also published a blog titled, 'Hedgerows next to crops can enhance pest control,' that included information about our CA DPR Pest Management Alliance Grant grant at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=18708.

Table 3. Hedgerow workshops, location, and number of participants from 2013-15.

	Date	**Location**	**Attendees**
1	2/5/14	Colusa Farm Show, Colusa, Colusa Co.	45
2	4/30/14	Center Land Based Learning, Winters, Solano Co.	30
3	6/19/14	Davis Ranch, Colusa, Colusa County	41
4	8/27/14	Hedgerow Farms, Winters, Yolo Co.	32
5	10/8/14	Ramos Ranch, Arbuckle, Colusa Co.	16
6	2/3/15	Colusa Farm Show, Colusa, Colusa Co.	35
7	4/11/15	Barrios/Long Ranch, Zamora, Yolo Co.	30
8	5/21/15	Gill Farms, Dixon, Solano Co.	25
9	6/2/14	Morning Star Ranch, Williams, Colusa Co.	35
10	6/11/15	UC Oakville Station, Oakville, Napa Co.	50
11	6/17/15	White Oak Ranch, Esparto, Yolo Co.	20
12	10/3/15	Hoes Down Festival, Guinda, Yolo Co.	20

Milestones Achieved

In addition to workshops, R. Long gave 12 talks on hedgerows to various agricultural related groups from Five Points, CA to Yreka, CA reaching an additional 681 people during this grant period. She also presented the results of our Field Edge Survey at the National Entomological Society of America meeting, an Ag Biodiversity workshop in Portland, OR, and at the Small Farms Conference in Sacramento. Our survey information is also being used by researchers to help obtain grant funding for additional work on field border plantings (gives justification for projects based on landowner/grower needs).

Our manuscript, "Pest control and pollination cost benefit analysis of hedgerow restoration in a simplified agricultural landscape," by Morandin LA, RF Long, and C Kremen, has been accepted to the Journal of Economic Entomology and should be published soon. This should help alleviate the financial concerns of hedgerow investments (as identified in our Field Edge Survey)

and enhance grower adoption of field edge plantings on farms.

As an offshoot of this project, R. Long mentored 5 UC Davis graduate students, 1 UCD undergraduate student, and one intern, all of whom worked on hedgerow projects during this review. One worked on native bees, another on rodents, one on weeds, one on groundwater and nitrates with vegetated drainage ditches, one on birds, and one on bats. The students were instrumental in participating in our hedgerow workshops and gave outstanding talks on their research. They are now in the process of publishing their results, documenting the multiple benefits of hedgerows for pollinators, water quality protection, and habitat for migratory birds and bats. At the same time, we are documenting minimal weed and rodent concerns with hedgerows, helping to alleviate grower concerns of pests in hedgerows (as found in our Field Edge Survey). These students are now moving into careers in agriculture (Xerces Society, NRCS, and CDFA), supporting our next generation of professionals working in agriculture. The timing of this grant was perfect to coincide with these students' research projects. Their combined input to our workshops was invaluable in terms of providing interesting, relevant information to our participants.

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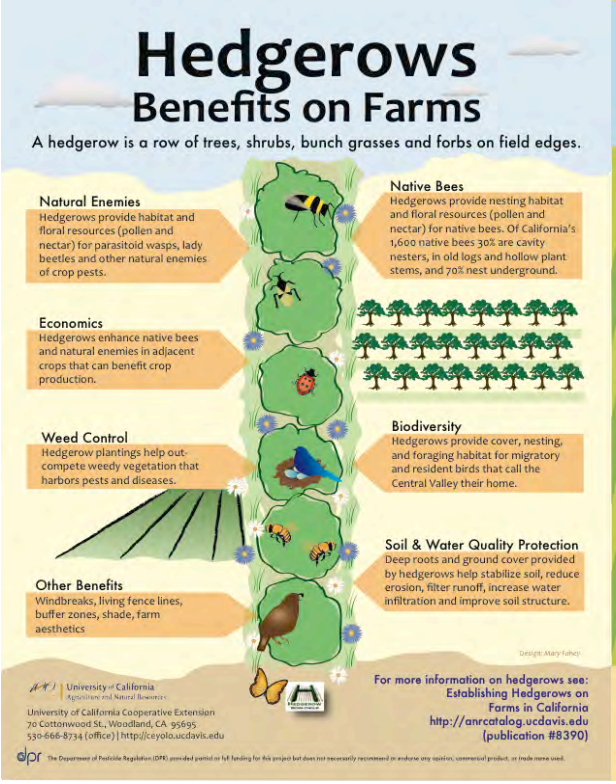
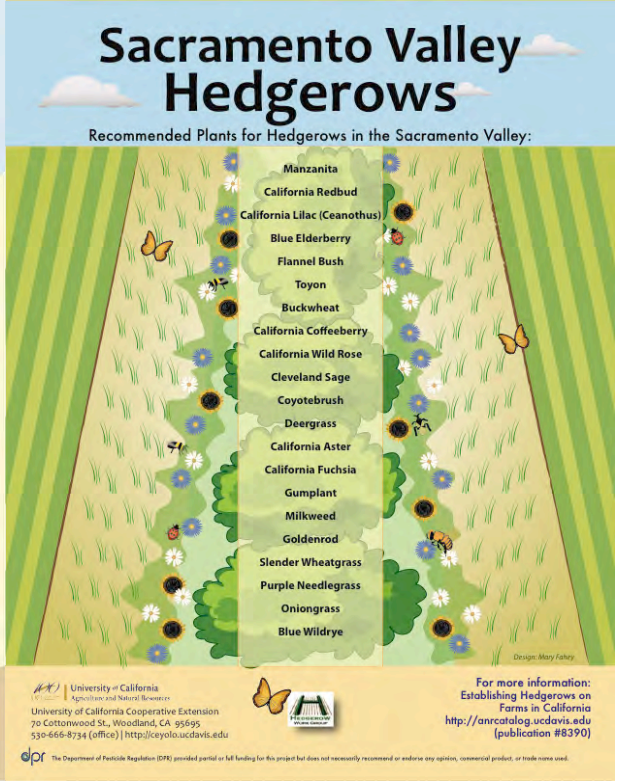
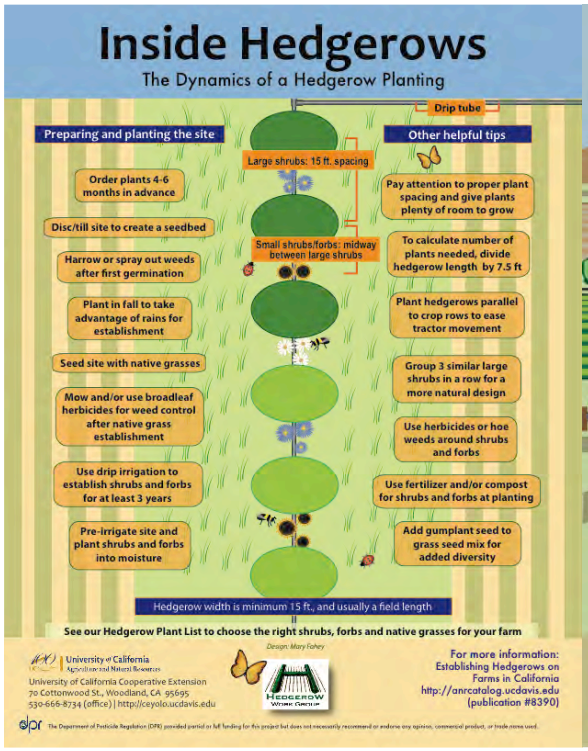
Hedgerow Handouts, also available at: http://ceyolo.ucanr.edu/Custom_Program/Hedgerows/







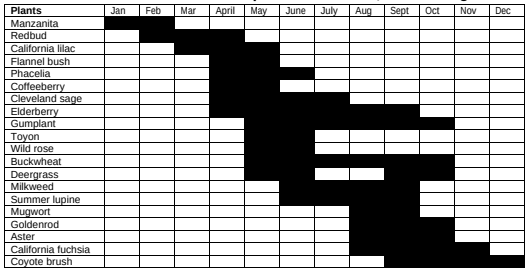
HEDGEROW PLANT SELECTION FOR THE SACRAMENTO VALLEY

All plants listed are California native perennials

SHRUBS (size: small = 3-5' tall, large >10' tall and/or wide; use 1 gallon container stock)	
Manzanita *Arctostaphylos spp.*, var. Howard McMinn – small; var. Louis Edmonds – large	
Western redbud *Cercis occidentalis* – large	
California lilac *Ceanothus spp.* – large; Nitrogen fixing plants; var. Yankee Point and Ray Hartman	
Flannel bush *Fremontodendron californicum* – large; Minimize summer watering	
California coffeeberry *Rhamnus californica* – large	
Blue elderberry *Sambucus nigra* – large; host to valley elderberry longhorn beetle, a protected species	
Cleveland sage *Salvia clevelandii* – small	
Toyon, Christmas berry *Heteromeles arbutifolia* – large	
California wild rose *Rosa californica* – small	
California buckwheat *Eriogonum fasciculatum* – small	
Coyote brush *Baccharis pilularis* - Plant males only to prevent spreading – large	
FORBS & GRASSES (Plug planted)	FORBS[1] & GRASSES[2] (Seeded)
California phacelia *P. californica*	Purple needlegrass *Stipa pulchra*, 35%
Summer lupine *Lupinus formosus*	Slender wheatgrass *Elymus trachycaulus*, 25%
Mugwort *Artemisia douglasiana*	California onion grass *Melica californica*, 15%
Goldenrod *Euthamia occidentalis*	Blue wildrye *Elymus glaucus*, 25%
Narrow leaf milkweed *Asclepias* fascicularis, Monarchs	Creeping wildrye *Elymus triticoides*, add where good soil moisture
Pacific aster *Symphyotrichum chilense*	[1]Gumplant *Grindelia camporum*, 0.8 lb/ac add to grass seed mix
California fuschia *Epilobium canum*, var. Catalina	[2]Drill grass seed at 20-25 lbs/ac; broadcast at 30-35 lbs/ac, using percent of seed in mix (bulk lbs/ac) as listed above.
Deergrass *Muhlenbergia rigens*	

Trees: Valley oak *Quercus lobata*, Blue oak *Q. douglasii*, Grey pine *Pinus sabiniana*, California buckeye *Aesculus californica*

Bloom times for California native perennial shrubs, forbs and grasses



Sacramento Valley Native Plant Nurseries:
Cornflower Farms, Elk Grove, www.cornflowerfarms.com
Floral Native Nursery, Chico, www.floralnativenursery.com
Hedgerow Farms Inc., Winters, www.hedgerowfarms.com

For more information on plants visit *Calflora:* www.calflora.org

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Hedgerow Work Group

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WORKING DRAFT, 3/31/16

Garbach and Long: Determinants of field edge habitat restoration on farms

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Determinants of field edge habitat restoration on farms in California's Sacramento Valley

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Abstract

Field edge habitat restoration in simplified agricultural landscapes increases biodiversity and ecosystem services on farms. This includes habitat for beneficial insects, such as bees and natural enemies, that provide pest control and pollination services in adjacent crops and enhanced water quality protection. Despite these potential benefits, implementation of field edge plantings, such as hedgerows, on farms is minimal. We surveyed 109 individual landholders (farmers and landowners) in California's Sacramento Valley to better understand the social determinants of small-scale habitat restoration on farm field edges. Our data show that the predictors for hedgerow adoption by farmers primarily include: 1) the perception of their benefits, 2) increased agency collaboration, and 3) financial assistance. Overcoming barriers to the adoption of field edge habitat plantings on farms should be addressed by outreach programs that focus on a combination of social networks as well as experiential and technical learning to share the value of ecosystem service benefits of small-scale restoration on farms.

Keywords: Agroecosystems, field edge restoration, ecosystem services, diffusion of innovations, social-ecological systems

Simplified agricultural landscapes are highly productive, but these large-scale mono-culture cropping systems lead to a loss in habitat, biodiversity, and associated ecosystem services. As a result, there is wide-spread concern that our farming systems cannot sustain food production or critical regulating services (Tilman 1999, MEA 2005, Hobbs 2007, Foley et al. 2011, Rusch et al. 2016). Best management practices (BMPs) designed to voluntarily restore or conserve habitat on farms are emerging as a strategy to enhance farm sustainability, with significant policy support (e.g., Farm Bill 2014). The goal of these programs is to engage private landowners in a conservation program that bridges the private interests of landholders and the public benefits of conservation (USDA 2014).

Field edge habitat plantings, in particular, have received a great deal of attention as a way to bring biodiversity back to farmlands. This includes hedgerows of shrubs, wildflowers, and native perennial grass plantings along the narrow, mostly linear strips that define field boundaries (Williams et al. 2015, Long and Anderson 2010). Benefits of field edge habitat includes water quality protection, enhanced biodiversity, and habitat for native bees and natural enemies that enhance pollination and pest control in adjacent crops without taking land out of production (Zhang et al. 2010, Fahrig et al. 2011, Kremen and Miles 2012, Morandin et al. in press). Despite these benefits, there has been poor adoption of agri-environment and biodiversity enhancement incentives by landholders, comprising landowners and farmers (Burton et al. 2008, Griffiths et al. 2008, Carvalheiro et al. 2011, Mckenzie et al. 2013).

There is considerable debate about the factors that facilitate (or hinder) landholders' adoption and use of BMPs (Prokopy et al. 2008) and factors that affect a farmer's decision making process to establish habitat on farms (Brodt et al. 2009, Farmer et al. 2011). Recent syntheses emphasize the importance of farmers' environmental knowledge, attitudes, and behavior (Camboni and Napier 1995) together with farm characteristics and capacity (Prokopy et al. 2008) as potential influences on practice adoption. While these characteristics are hypothesized to have a positive

relationship with adoption, a recent review found mixed signals for each category (Prokopy et al. 2008).

One explanation for this variation is tied to inherent differences in the information sharing (Lubell & Fulton 2008) and learning pathways (Lubell et al. 2014) that can support adoption of new practices as well as the context of these farming systems. Our knowledge system supports three learning pathways including social, experiential, and technical learning (Lubell et al. 2014). Social learning refers to the social networks whereby farmers learn from each other as well as knowledgeable people in their community. Technical learning refers to obtaining information through traditional extension programs and support resources, such as websites, books, and social media. Experiential learning is the process of learning through "hands-on" experience and trial and error. Each of these pathways can inform management decision-making (Lubell et al. 2014), by providing information on the benefits and concerns associated with innovative practices, ultimately shaping patterns of adoption (Rogers 2003). A core challenge is understanding how learning pathways, and tools such as financial assistance provided by conservation policy, articulate with barriers to and drivers of adoption of on-farm conservation practices.

This study investigates drivers of adoption of field edge plantings in California's Sacramento Valley region, which ranks as the worlds' top leading producers of almonds, walnuts, and tomatoes (NASS data[1]). The region exemplifies primary challenges of conserving ecosystem services in working farmlands: the opportunity costs of encroaching on cultivated areas in high-value, large-acreage specialty, crops may affect field edge management decisions, regardless of farm demographics. To understand patterns of adoption of field edge habitat plantings, we conducted a survey of landholders in California's Sacramento Valley in 2013. Our interest was to determine the influence of landholder preferences, information networks, and use of policy support (e.g., financial, technical assistance) on adoption of field edge plantings, including information

sharing through technical learning (e.g., extension and outreach agencies), experiential learning (trial and error), and social learning (e.g., farmer-to-farmer) channels, and demographic variables. We also looked at the role of farmers' experience with potential benefits and concerns associated with field edge plantings, and their perceptions of benefits in terms of enhanced ecosystem services. Our ultimate aim is to use information on the learning pathways to develop a better understanding of how to direct outreach programs to target areas that are likely to have the highest impact on increasing field edge habitat plantings for enhanced sustainability on farms.

Materials and Methods

To explore the determinants field edge plantings as a best management practice on farms, we surveyed landholders, comprising both growers and landowners, in the Sacramento Valley in 2013. Our specific target area was Yolo, Solano, Sacramento, Colusa, Sutter, Yuba, and Glenn Counties. This area was chosen to cover the diversity of farming practices and crop types including field, row, and orchard crops, organic and conventional production, and large and small scale cropping systems. We also selected multiple counties to ensure that we included a range of farmer demographics in our survey, such as education level, income, and gender diversity that occur in this area (Table 1).

Our survey questionnaire investigated the following thematic areas: field edge management practices; information sources used by landholders on field edge management; perceived benefits and concerns of field edge plantings; agencies and partner organizations with which landholders work; and demographic data (e.g., crops grown, acreage, income). We focused on landholders to ensure we reached those who make farm decisions on practices such field edge management. Prior to distributing the survey, we tested the survey with a small group of growers to help assure relevance and clarity of survey questions. Questions included a mix of multiple-choice and free-response options. Landholders reported their current field edge management practices, including

those used currently, in the past, and never. Ratings of information sources, benefits, and concerns were rated on a 5-point Likert-scale (e.g., rating information sources 0=never used, 4= very useful; benefits/concerns, 0=none, 4=highest). We investigated learning pathways by evaluating sources where landholders get information for managing field edges, including a list of agencies and types of personal contacts with whom they exchange information. We also gathered data on farm demographics such as size, income, and landholder education level. The survey can be found online at: http://ceyolo.ucanr.edu/Custom_Program/Hedgerows/.

To reach the agricultural community, we used mailing lists provided by local county RCD's, UCCE, and Audubon California. We used a modification of Dillman's tailored design method (2000), following the introduction letter and initial mailing with two follow-up reminders. Our survey questionnaire was mailed to 300 farms via hard copies with self- addressed stamped return envelopes. We also distributed the same survey electronically to 2,840 landholders by emailing them an electronic link to the survey hosted on the website listed above. In addition, we asked landholders to take our survey at two hedgerow workshops we held on farms in Colusa and Yolo Counties in 2014.

Returned surveys were coded into an electronic database and quantitative data were analyzed using R. We first evaluated descriptive statistics for respondents as a whole, and then summarized the field edge management practices currently used, used in the past, and never used. We then split respondents into two groups, those who currently used field edge plantings (including hedgerows of native shrubs and forbs and plantings dominated by trees, flowers, and grasses) and those who did not. After exploring demographics, we investigated differences in preferences for information sources, and perceptions of potential benefits and concerns between adopters and non-adopters of field edge plantings and used logistic regression models, selected to included relevant variables, minimize multiple collinearity, minimize Akaike Information Criteria (AIC) score, to evaluate factors that are significantly associated with adoption. This allowed us to better explore

how local knowledge and context affect the decision-making processes in establishing field edge habitat on farms. We modeled adoption of all field edge plantings together, including hedgerows, trees, and strips dominated by flowers and grasses. We included county as a random effect in the model to control for potential differences, and evaluated the effects of farm size, experience with benefits, experience with concerns, the number of agency partners, and whether the farmers had financial assistance. Results are summarized by arithmetic means ± standard error (se), unless otherwise noted.

Results

Demographics

A total of 167 respondents filled out and returned the survey, a 14% response rate to the paper survey and 4% response to the online survey. Of these, 109 were from landholders (farmers and landowners) within the Sacramento Valley, identified by the zip code of the land they manage; our analyses focused on these data. Respondents were 85% male, 11% female, 4% undisclosed; the average age was 56-65, with the category <35-years the smallest age demographic (n=4 respondents, 3.5% of total), which is representative of the farmer age demographics of the study area. The mean farm size of respondents was 986 acres (median 500 acres), which is larger than average farm size in the study area. However, the mean gross income was $100,000-499,999 in our survey and encompassed the county average for market value of products sold (Table 1).

In our survey, 58% of respondents owned their land, 36% both owned and rented ground, and 7% rented ground. Crops primarily grown were walnuts, almonds, tomatoes, sunflowers, wheat, and alfalfa, all typical for the Sacramento Valley area (NASS 2016). Of the respondents that identified a production style, 72% identified as conventional, 10% certified organic, and 16% both. The response represented approximately 1.5% of the farming operations in the study area, which is similar to previous coverage at a single county scale (Brodt et al. 2009); the sample is sufficient in

both size and variation of practices to pursue the study goals of investigating the determinants of field edge management practices by landholders, and evaluate differences in perceptions and information sources between adopters of field edge plantings and non-adopters.

Field Edge Management

Landholders reported using a range of management practices on field edges (Fig. 1). The three most current commonly used were mowing (74%), herbicides (70%), and disking (55%), practiced on one or more field edges. Taken together, combinations of these current dominant practices were used by most landholders on one or more field edges. Twenty-six percent of landholders currently manage one or more field edges through burning, which is notably lower than the past; 23% of landholders currently do not use any management on their field edges. Current use of field edge plantings by landholders was modest relative to the conventional practices. In total, 38% of landholders surveyed currently used some type of field edge planting. In general, these plantings comprised less than 5% of external property edges (estimated from farm size), ranging in length from 40-ft to 5,280-ft in length. Hedgerows of mixed native plants and shrubs were used more frequently (27% of respondents) than plantings primarily comprised of remnant trees, perennial grasses or flowers (respectively, 6%, 4% and 1%). Most of the floral and grass plantings and 53% of hedgerows were in Yolo County. For other field edge plantings, 3% were in Solano, 17% in Colusa, 5% in Sutter, and 3% in Glenn Counties.

Information Sources

Landholders that adopted field edge plantings accessed information from more sources (7.08 ± 0.21) compared with those who did not (4.49 ± 0.37) out of a list of nine possible ($p < 0.01$). On the whole, landholders rated personal observation and personal communication with other landholders as the most useful source of information on managing field edges, reflecting the importance of

experiential and social learning, respectively. The set of sources that received the next highest ratings were information from agencies, print resources, meetings (e.g. workshops), and online, reflecting the technical learning pathway; the lowest ratings were for commercial suppliers, membership organizations, and commodity boards. The greatest difference in usefulness ratings between landholders that had adopted field edge plantings and non-adopters was for communication with agencies, respectively (3.4 ± 0.23) and (2.6 ± 0.16, $p < 0.01$ Fig. 2). Overall, landholders that had adopted field edge plantings reported average usefulness ratings that were higher than non-adopters for all sources except for commercial suppliers and commodity boards.

Potential Benefits and Concerns

Among landholders that currently use field edge plantings, there was a suite of benefits that were rated significantly higher than non-adopters (Figure 3a). The top-rated benefits directly support on-farm productivity, including increasing the presence of native bees and honey bees, and attracting natural enemies of crop pests. The perceived benefits of aesthetics were roughly double for adopters (2.5 ± 0.13) and (1.7 ± 0.20), respectively, ($p < 0.01$). Although not a top-rated benefit, weed control was also perceived as significantly higher by adopters versus non-adopters. The suite of potential benefits that received similar ratings across adopters and non-adopters included erosion control, soil quality, and water quality.

Growers that currently use field edge plantings answered additional questions about on-farm benefits. Two thirds of growers that currently use field edge plantings reported that they expected on-farm benefits from the plantings. However, of these growers, only 25% assigned a monetary value to the plantings' benefits; the remaining majority emphasized the difficulty of estimating a dollar value for field edge restoration. In terms of off-farm benefits, 70% of landholders with field edge plantings reported that the plantings have broader societal benefits, comprising recreational and cultural benefits, such as hunting areas for game birds. Aesthetics and enhanced public

perception of their farm also emerged as top considerations. Adopters also listed hedgerows as being important for windbreaks.

The top concerns related to field edge habitat for non-adopters were associated with weeds, rodents, and limiting equipment (Figure 3b). Weeds were also a top concern for landholders with field edge plantings, as were lack of time and monetary costs. In general, concerns about crop pests (rodents, insects, birds) and diseases were perceived as higher concerns for non-adopters. The suite of concerns that received similar ratings from adopters and non-adopters included those related to costs, lack of time, lack of space, and food safety. Food safety was a lower concern, likely due to the fact that most of the crops grown in the Sacramento Valley (and reported in the survey) are processed. Floral resource competition for bees was the lowest concern in our survey for both adopters and non-adopters.

Predictors of adoption

A subset of 48 respondents listed the network of contacts with whom they shared information about field edge management. This included the contacts' roles in terms of the type of position they held. Our data showed that landholders networked most frequently with contacts in agencies that provide technical and financial support (28%), including the NRCS, RCDs, Agricultural Commissioner and other agencies; other landholders (27%); extension and research (16%); commercial suppliers (12%); Non-government organizations, NGOs (9%); Pest Control Advisors (PCAs), (3%); commodity groups (1%) and other roles (5%), such as Farm Bureau and commodity boards (Figure 4). Both agencies and landholders were reflected nearly equally in landholder communication networks, with many landholders accessing multiple types of contacts and creating an opportunity for complementary or mutually reinforcing learning pathways.

Next we developed a model with factors that helped predict characteristics of landholders that are likely to adopt field edge plantings, versus non-adopters. This information is critical to

understand how to target outreach and extension efforts where they are most needed. We found two factors to have a significant positive association with adoption of field edge plantings: financial assistance and communication with agencies (Table 2). These model estimates represent the log odds; exponentiating the coefficients allows us to interpret them as odds-ratios; the odds of using a field edge planting increased by 11.98 when financial assistance was received. For each additional agency contact (range 0-4, including UC Cooperative Extension, NRCS, RCDs, and other agencies) the odds of using field edge plantings increased by 2.11. There was a detectable, positive trend toward adopting field edge plantings as the perceived benefits increased at the 90% confidence level ($p = 0.07$); we note that the 95% confidence intervals around the perceived benefits estimate are always positive (lower = 0.157, upper = 9.110), which suggests a detectable, positive effect.

For those who had hedgerows, only two of these factors were significantly related to the plantings use. The odds of using hedgerow plantings increased by 16.54 when financial assistance was received ($p = 0.047$). In addition, as farm size increased the probability of using field edge plantings decreased ($p = 0.048$) (data not shown).

Discussion

In large-scale mono-cropping systems, field crop edges are generally used for field access, water conveyance, storage areas for crops and equipment, and firebreaks. As a result, they are usually kept free of vegetation to adhere to these primary needs. Herbicides and discing were the main methods of weed control on field edges in our survey. Among landholders who listed these practices as the best way to manage field edges, economics was the driving factor. Burning was also listed, though this practice is notably lower than the past, possibly due to increased air quality restrictions (R.F. Long, personal observation).

Despite this overall need for keeping field edges clean, a modest number of landholders in our study chose to plant hedgerows of shrubs, wildflowers, and native grasses on their field edges.

Though this was on small amounts of land, comprising only about 5% of their field edges, these landholders are at the forefront of a relatively new innovation to bring biodiversity and much-needed ecosystem services back to our simplified agricultural landscapes. Comparing the decision making process for adopters and non-adopters of field edge plantings in this study, allowed us to understand the relative contributions of social, experiential, and technical learning in the knowledge-gain process (Lubell et al. 2014).

Landholders' perceptions of benefits of field edge plantings was a significant factor in patterns of adoption. The potential benefits that landholders ranked reflected considerations of economic interest (Costanzo et al. 1986) and personal orientation toward stewardship (Stonehouse 1996), which have been shown to influence adoption of conservation practices. Both were reflected in the top ranked benefits by landholders that adopted field edge plantings. For example, attracting bees and natural enemies can enhance yield and pest control in adjacent crops (Morandin et al. in press), leading to economic gains. Other top-rated benefits were cultural services, enhancing farm aesthetics, and attracting wildlife, which reflect stewardship more than immediate financial gain. Adopters' responses highlighted near-term of ease of use and future considerations, including anticipated changes in policy. One grower summarized, "While disking is fast and the cleanest [for] weed control, hedgerows [and] filter strips may be best (especially the downslope side), due to pending agricultural irrigation waiver regulation changes." Responses from other growers qualified that the benefits of field edge plantings would need to be documented and have reasonable assurance of meeting water quality standards.

Non-adopters reflected similar patterns of perceptions of benefits including those beyond potential financial gain. Top rankings for non-adopters included enhanced erosion control, attracting wildlife, bees, and enhanced water quality, benefits that accrue to off-site users (Garbach et al. in press). Their emergence as top-ranked benefits among non-adopters suggest that in addition to technical information that emphasizes clear economic benefits, benefits that accrue at broader

scales, and cultural services should also be included in outreach and extension materials that aim to increase adoption of on-farm conservation practices.

The negative perceptions of biodiversity-enhancing field edge management practices were much stronger for non-adopters than for adopters. In general, the high concerns about crop pests (rodents, insects, birds) and diseases, especially for non-adopters, suggest that this is an area in which field data have not been as well developed or widely circulated to the agricultural community. This observation is consistent with Stonehouse's (1996) assertion that technical and performance information about practices is inadequate. New data showcasing the benefits of hedgerows for pollination and pest control services (Morandin et al., in press) clearly need to be extended to the agricultural community to help overcome this constraint. At the same time, research in other areas, such as bird pests, rodents, and weeds is critically needed to overcome barriers for the adoption of field edge plantings on farms.

For information sources on field edge management practices, both adopters and non-adopters rated the usefulness of different resources fairly similarly. Overall both groups listed personal observation, personal communication, and agency collaboration, as most important. This documents the universal power of social, experiential, and technical learning in the transfer of information and adoption of new innovations, as had been found in many other studies (Lubell and Fulton 2008, Lubell 2014, Hoffman 2013). Landholders are learning from others, especially other farmers. For example, in our survey, Hedgerow Farms, Yolo County, CA, a promoter of habitat restoration on farms that hosts tours and workshops, was named by more than half of the field edge planting adopters as a source of information. Promoting field edge plantings through experience or 'hands-on' activities is likely why 53% of the total field edge plantings in our survey were in Yolo county. Collaboration with other agencies, such as RCD's and UCCE, was likewise important with agency interactions being a significant predictor for adopting field edge plantings. Agencies provide technical information, on-farm demonstrations, plant lists, sources of plant materials, establishment

strategies, and research-based data on ecosystem service benefits of field edge plantings, critical for technical learning about field edge management practices. Strong agency presence may be why 28% (18 miles) of the total hedgerow plantings in California since 2010 are in Yolo County (NRCS 2016).

Print information (e.g., newsletters, books, magazines) was slightly more useful than on-line materials (e.g., websites, e-newsletters, blogs). This may reflect the older demographics of our survey population and lower internet use compared with younger generations (Coleman and McCombs 2007). Meetings were also an important source of information, further documenting that technical resources play an important role in the transfer of information. The low usefulness of membership organizations, commercial groups, and commodity boards shows the need to share benefits of hedgerows with these groups to help with outreach. In particular, the Almond Board of California, with their commitment and need to protecting bees for crop pollination is an important outreach potential (http://www.almonds.com/growers) .

Overall, landholders that had adopted and currently use field edge plantings accessed approximately three more information sources, on average, then non-adopters. This is substantial, as additional information sources may help to supply technical information, or provide complementary details (e.g., filling in the gaps between one source and another), as growers triangulate among different sources to inform decision-making (Lubell 2014). Technical information in particular is needed about most conservation practices, and in order for the information to be effective in supporting their use, it needs to be matched to individual landholders' levels of management skill, economic circumstances, and access to capital (Stonehouse 1996). Landholders accessing more information sources may effectively be increasing the possibilities of amalgamating evidence and tailoring it to their personal skills and circumstances.

Cost share funding and technical advice is available through the U. S. Department of Agriculture, Natural Resource Conservation Service (USDA-NRCS). EQIP, the Environmental

Quality Incentives program provides funding for field border practices with 50-75% cost share for qualifying growers and landowners. Given that financial support was also a significant motivator for field edge plantings, continued funding for bio-diverse field edges is critical. Areas that work well for field edge plantings in the Sacramento Valley include terraces left over from land leveling, old fence lines, under some power lines, and along waterways (canals, streams, and ditches). These areas generally cannot be farmed, so land would not be taken out of production. If managed properly with native plants, field edges can be turned into biologically productive sites to provide ecosystem service benefits in our agricultural landscapes without taking cropland out of production.

The results of our study document that a combination of social, experiential, and technical learning play an important role in the decision-making process for adopting field edge plantings on farms in the Sacramento Valley. In particular, networking was a strong predictor in adopting conservation practices on farms, with well-connected growers more likely to adopt field edge plantings. Documenting the benefits of bio-diverse field edge plantings and financial support were also important in the decision-making process. These data have universal application for educators and policy makers in other regions to identify network-smart-extension strategies that help target programs that will encourage more bio-diverse farming in our landscapes.

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http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/California/st06_2_031_031.pdf

Field Seeds, Hay & Forage:

http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/California/st06_2_026_026.pdf

Field Crops:

http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/California/st06_2_025_025.pdf

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Table 1. Farm characteristics and demographics of the Sacramento Valley and field edge survey respondents, NASS 2016). Our survey respondents were representative of the study area for age, gross income and gender, but farm size was more than double the average for the study area.

	Colusa	**Glenn**	**Sacramento**	**Solano**	**Sutter**	**Yolo**	**Yuba**	**Total**
Study Area by County								
Number of farms	782	1311	1352	860	1358	1011	795	7469
Farm size *M* acres	579	510	183	473	275	456	236	404
Market value, *M*	$738,251	$486,165	$241,559	$357,463	$374,209	$555,134	$243,332	$428,016
Age, *M* years	57	58	58	61	58	58	59	58
% Male	91	87	78	76	84	81	87	82%
Survey Response								
Number of farms	15	7	14	16	6	51	0	109
Farm size *M* acres, range	924 2- 5322	918 40 -2500	1199 10-7500	1494 2.5-10,000	510 30-1500	841 1-10,000	NA	986 2-10,000
Income, gross *M*	$100,000-499,999	$100,000-499,999	$100,000-499,999	$100,000-499,999	$100,000-499,999	$100,000-499,999	NA	$100,000-499,999
Age, *M* years	56-65	56-65	56-65	56-65	56-65	56-65	NA	56-65
% Male	71	100	100	88	100	88	NA	85

Table 2. Farm characteristics, benefits, and concerns related to adoption of field edge plantings

Variable	Description	Estimate	Std. Error	2.5% CI	97.5% CI	z-value	p-value	
Intercept	Non-adopters	1.667	1.466	-0.714	6.701	1.137	0.256	
Farm size	log acres	-0.416	0.210	-1.156	-0.066	-1.984	0.047	*
Benefits	% benefits highly rated	3.886	2.175	0.157	9.111	1.787	0.074	.
Concerns	% concerns highly rated	-0.064	1.432	-3.161	2.775	-0.045	0.964	
Agencies	count 0-4	0.750	0.380	0.094	1.660	1.974	0.048	*
Financial assistance	yes/no	2.484	1.249	0.445	5.641	1.989	0.047	*

Figure 1. Field edge management practices currently used by growers and landowners.

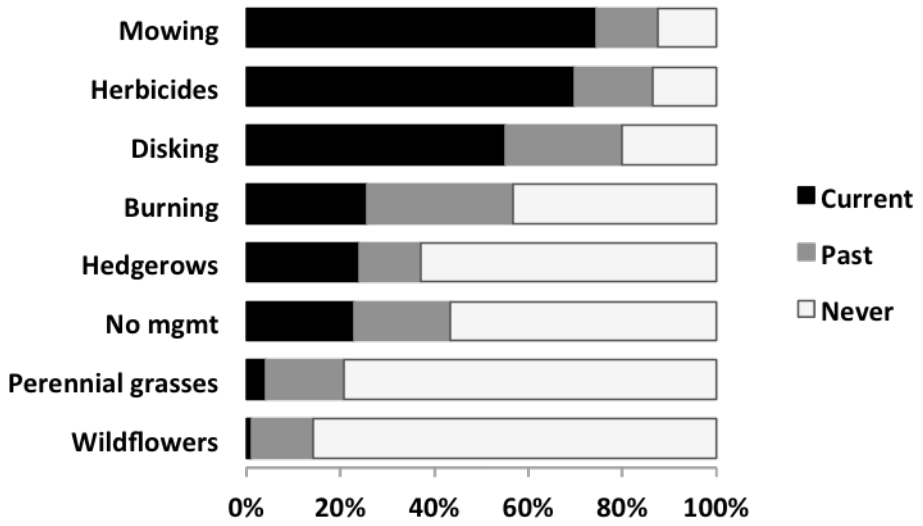

Figure 2. Landholder ratings of information sources on field edge management (0 = never used, 4 = most useful). *Adopters* reflects ratings for growers that currently use field edge plantings; *Non* reflects ratings for growers that do not use field edge plantings.

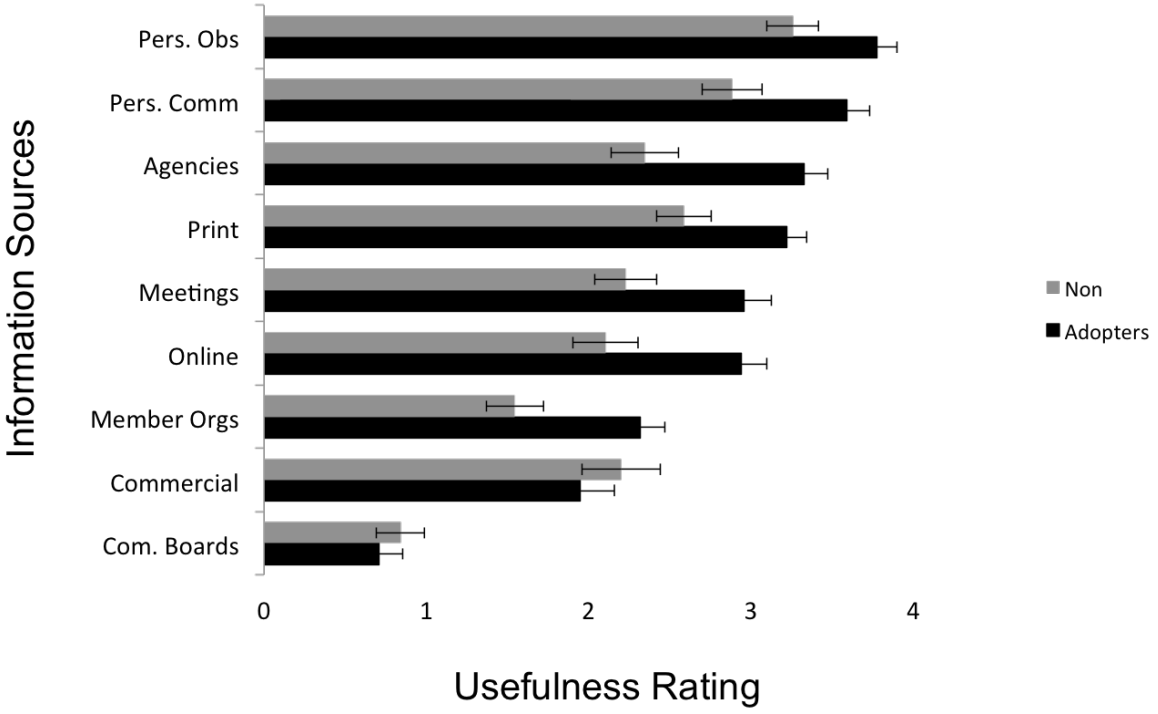

Figure 3a. Landholder ratings of potential benefits of field edge management (0 = never used, 4 = most useful). *Adopters* reflects ratings for growers that currently use field edge plantings; *Non* reflects ratings for growers that do not use field edge plantings.

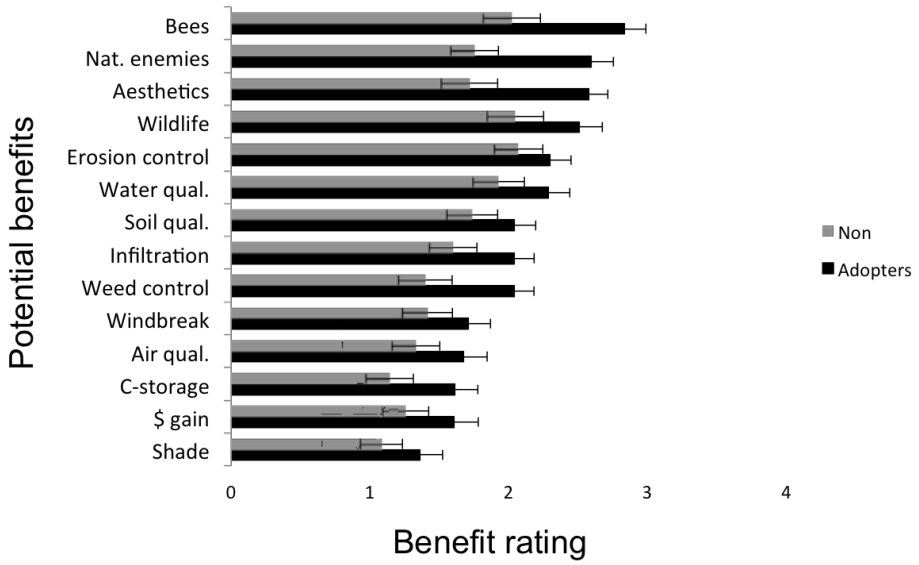

Figure 3b. Landholder ratings of potential concerns of field edge management (0 = never used, 4 = most useful). *Adopters* reflects ratings for growers that currently use field edge plantings; *Non* reflects ratings for growers that do not use field edge plantings.

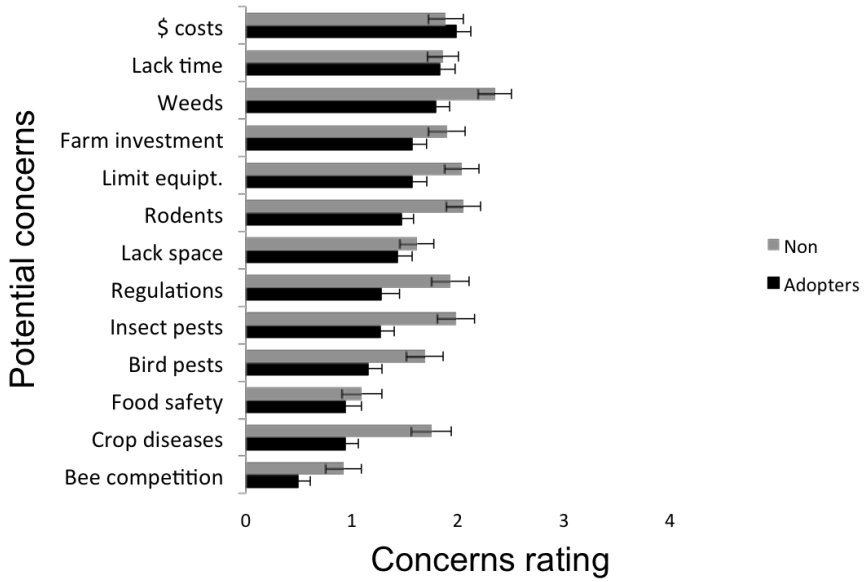
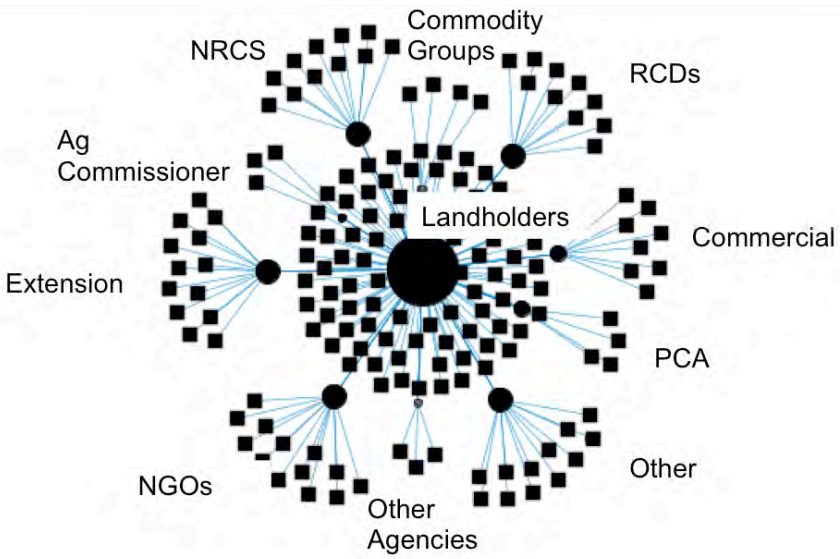
Figure 4. Components of the grower knowledge network. Landholders networked most frequently with contacts in agencies that provide technical and financial support (28%), including the NRCS, RCDs, Agricultural Commissioner and other agencies; other landholders (27%); extension (16%); commercial suppliers (12%); Non-government organizations, NGOs (9%); Pest Control Advisors (PCAs), (3%); commodity groups (1%) and other roles (5%) (network data, n = 48 respondents).