APRIL–JUNE 2015 • VOLUME 69 NUMBER 2

California Agriculture

Water:
New approaches to aquifer recharge

Barbara Allen-Diaz retrospective:
UC ANR leader retires

University of California | Peer-reviewed Research and News in Agricultural, Natural and Human Resources

About *California Agriculture*

University *of* California
Agriculture and Natural Resources

California Agriculture is a quarterly, peer-reviewed journal reporting research and reviews, published by the University of California Agriculture and Natural Resources (ANR). The first issue appeared in 1946, making *California Agriculture* one of the oldest, continuously published, land-grant university research journals in the country. There are about 11,000 print subscribers.

Mission and audience. *California Agriculture* publishes refereed original research in a form accessible to a well-educated audience. In the last readership survey, 33% worked in agriculture, 31% were university faculty or research scientists, and 19% worked in government agencies or were elected office holders.

Electronic version of record. In July 2011, the electronic journal became the version of record; it includes printed and electronic-only articles. When citing or indexing articles, use the electronic publication date.

Indexing. The journal is indexed by AGRICOLA, Current Contents (Thomson ISI's Agriculture, Biology and Environmental Sciences and the SCIE databases), Commonwealth Agricultural Bureau (CAB), EBSCO (Academic Search Complete), Gale (Academic OneFile), Proquest and others, including open-access databases. It has high visibility on Google and Google Scholar searches. All peer-reviewed articles are posted to the ANR and California Digital Library eScholarship repositories.

Authors and reviewers. Authors are primarily but not exclusively from ANR; in 2010 and 2011, 23% were based at other UC campuses, or other universities and research institutions. In 2010 and 2011, 33% and 40% (respectively) of reviewers came from universities, research institutions or agencies outside ANR.

Rejection rate. The rejection rate has averaged 34% in the last 3 years. In addition, associate editors and staff may send back manuscripts for revision prior to peer review.

Peer-review policies. All manuscripts submitted for publication in *California Agriculture* undergo double-blind, anonymous peer review. Each submission is forwarded to the appropriate associate editor for evaluation, who then nominates three qualified reviewers. If the first two reviews are affirmative, the article is accepted. If one is negative, the manuscript is sent to the third reviewer. The associate editor makes the final decision, in consultation with the managing and executive editors.

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California Agriculture

Peer-reviewed research and news published by
University of California Agriculture and Natural Resources

VOLUME 69, NUMBER 2

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California Agriculture (ISSN 0008-0845, print, linking; ISSN 2160-8091, online) is published quarterly and mailed at periodicals postage paid at Richmond, CA, and additional mailing offices. Postmaster: Send change of address "Form 3579" to *California Agriculture* at the address above.

APRIL–JUNE 2015 • VOLUME 69, NUMBER 2

COVER: A field of tomatoes is irrigated with groundwater at the Russell Ranch Sustainable Agriculture Facility near UC Davis. California's prolonged drought is driving major increases in groundwater extraction in the state's agriculture regions. UC researchers are investigating new ways to recharge aquifers (page 75). *Photo by Will Suckow*.

Water: New approaches to aquifer recharge

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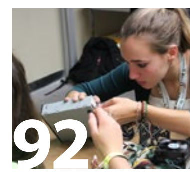
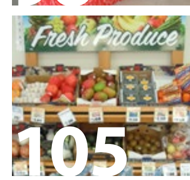
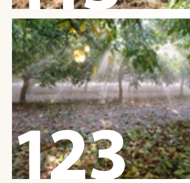




E-edition research articles

These articles can be found in full on the *California Agriculture* website; for a summary and link, see pages 110–111.



Corrections

On page 139 of the October-December 2014 issue, the timeline on glassy-winged sharpshooter (GWSS) management states that the first area-wide management program for GWSS began in Kern County in 2001. According to information from the California Department of Food and Agriculture Pierce's Disease / GWSS Board, another area-wide program was initiated earlier, in Temecula Valley (Riverside County) in 1999.

On pages 54 and 55 of the January-March 2015 issue, three photo captions contained incorrect information. The correct captions are as follows: page 54, Eroding channel within the meadow; page 55 (top), Eroded stream channel; page 55 (bottom), Riparian area with lodgepole pine.

Will Suckow

Sustaining the promise of the land-grant university system

One of the greatest inventions in the history of the United States, up there with the electric light bulb or the airplane or vaccines, was the the land-grant university system.

In 1862, visionary leaders, despite the upheaval of the Civil War, saw that education, and specifically higher education, needed to be open and accessible to all people in every state.

Barbara Allen Diaz

Vice President, Director of the Agricultural Experiment Station, Director of Cooperative Extension

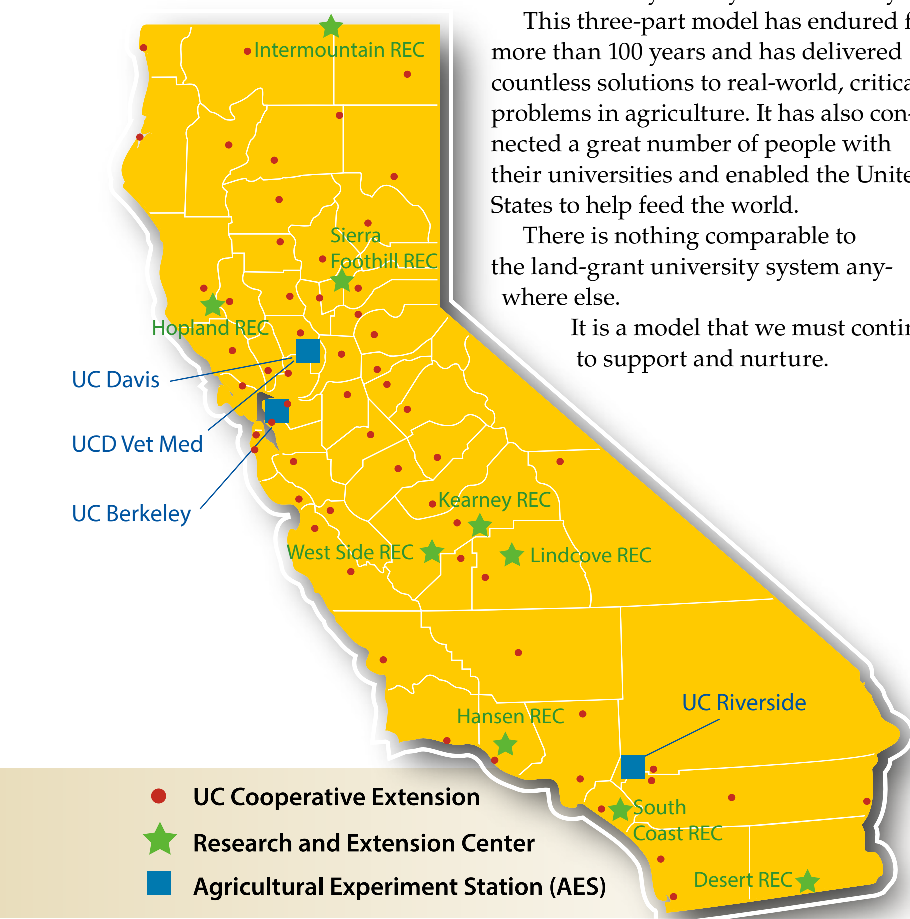
Congress went further a few years later, creating Agricultural Experiment Stations (AES) located on land-grant university campuses specifically to conduct pioneering, solution-oriented research in agriculture to ensure that the reunited and growing nation would have a plentiful, nutritious and safe food supply.

The third critical piece of the land-grant system — the Agricultural Extension Service (now Cooperative Extension) — was created with the passage of the Smith-Lever Act in 1914. This act linked the land-grant university faculty with Cooperative Extension faculty located in every county in the country.

This three-part model has endured for more than 100 years and has delivered countless solutions to real-world, critical problems in agriculture. It has also connected a great number of people with their universities and enabled the United States to help feed the world.

There is nothing comparable to the land-grant university system anywhere else.

It is a model that we must continue to support and nurture.



In California, the University of California is the land-grant university. The UC system includes 10 campuses from Davis to San Diego. The Agricultural Experiment Station includes programs on UC ANR's Research and Extension Centers and three campuses — UC Berkeley, UC Davis and UC Riverside — and includes faculty in the UC Berkeley College of Natural Resources; the School of Veterinary Medicine and the College of Agricultural and Environmental Sciences at UC Davis; and the UC Riverside College of Natural and Agricultural Sciences. UC ANR Cooperative Extension (UCCE) includes researchers, educators and other staff and is located in every county in California and at nine Research and Extension Centers and four campuses (UC Berkeley, UC Davis, UC Riverside and UC Merced). Together, these three complementary parts provide Californians with world-renowned research paired with local application of research and education programs, which test and deliver solutions to problems affecting communities and individual Californians throughout the state.

In California, the institution that ties together the three-part model — UC's land-grant mission, the AES and UCCE — is UC Agriculture and Natural Resources (UC ANR). It is a UC-wide organization with a specific mission to develop, coordinate and report on research and extension programs related to agricultural, natural and human resources. UC ANR provides programming based on research that helps ensure a safe, nutritious and secure food supply, healthy environments and thriving youth. The UC ANR Vice President — the position I have held since 2011 — is designated as the Director of AES and Director of UCCE on behalf of the UC system. UC ANR's system-wide mandate — with responsibilities spanning multiple program areas and the ability to engage partners on UC and California State University campuses, in public agencies and in the private sector — drives the division's activities and ensures that UC's agricultural and natural resources programs do not become overly focused on one campus or one geographic area.

UC ANR has four major sources of revenue: state revenue allocated to UC; federal revenue based on various federal AES and CE-related acts; indirect cost recovery from contracts and grants and patent revenue generated by UCCE academics; and endowments and gifts. In addition, counties provide considerable in-kind support to county-based UCCE offices, and clientele such as grower associations provide substantial program support to individual UCCE researchers. UC campuses have similar revenue sources but also have tuition revenue, which supports an increasing fraction of their budgets.

One of my top priorities as UC ANR Vice President has been to develop a stable funding model for UC ANR. We have made several gains. The UC ANR direct reporting line to the UC President has been restored, raising the division's profile within the UC system. We have hired 90 new UCCE academics and 45 more positions have been approved for recruitment; we are taking important steps to rebuild UCCE's capacity with a strategic focus on programs with strong demand and clear application to local needs. We have secured external salary support for six new UCCE advisor and specialist positions and also raised money for two endowed UCCE chairs, the first endowed chairs within UC ANR.

I believe that the UC ANR of the future will thrive. Cooperative Extension programs — which engage local communities and find solutions to local problems, often with worldwide applications — are more important than ever. As the world grows to 9 billion people, society's capacity to produce and distribute safe, nutritious and affordable food continues to depend on an understanding of multiple, interdependent factors. Soil is the foundation. Discovering and developing plant varieties resistant to drought, pests and diseases is critical. Research is ongoing to develop plant varieties that are nutritious, productive, salt tolerant and adaptable to climate change. Animal protein will continue to be grown from fiber produced on rangelands and finished with plant products to meet consumer demands for flavor, cost and sustainability. Developing and testing new plant varieties, integrated pest management techniques, plant and animal cultural practices, models for youth development, postharvest practices, irrigation and water conservation options and so much more is what great land-grant universities do.

The importance of feeding people, and of helping people to feed themselves, is currently well understood within UC. University of California President Janet Napolitano has launched the UC-wide Global Food Initiative (GFI), engaging faculty, centers, institutes, UCCE and the national laboratories. Individual campuses have created centers and institutes, like the World Food Center at UC Davis and the Berkeley Food Institute at UC Berkeley. UC ANR is an active partner, and many of the division's ongoing efforts help to further the goals of the GFI: strategically locating CE advisors and specialists throughout the state where the need for expertise is greatest; and investing in AES campus partnerships to foster collaborations and coordination toward finding solutions to real-world problems, with science as the foundation for informed farm, community and policy decisions.

Developing and testing new plant varieties, integrated pest management techniques, plant and animal cultural practices, models for youth development, postharvest practices, irrigation and water conservation options and so much more is what great land-grant universities do.

Healthy environments, healthy food systems, healthy communities and healthy people in body and mind have been the goal since the founding of the three-part land-grant university system — the University, the AES and Cooperative Extension. A century of experience has proven the model's value, and it will remain relevant, providing affordable, accessible higher education for all; a focus on broad agricultural science to meet the needs of a growing nation and the growing world; and a mechanism by which our universities remain engaged with their most important constituents: the public. CA

Michael Yang, UCCE small farms and specialty crops Hmong agricultural assistant in Fresno County, checks a Hmong grower's Thai hot chili and luffa plantings, which must be covered in tunnels or hot caps.

Elena Zhukova

UC ANR Cooperative Extension grows citizen scientists

Last year, as part of the May 8 centennial of the founding of the Cooperative Extension Service in the United States, UC ANR Cooperative Extension (UCCE) invited Californians to take a walk or visit a park or garden and be citizen scientists. The goals were to crowd-source information on pollinators, water use, and food production and consumption and to give participants a shared experience of observing and reporting on the world around them.

Each UCCE county office held centennial events. The Humboldt and Santa Cruz county offices provided public farm tours; in Del Norte County, UCCE staff visited school classrooms; in Fresno, Monterey and San Diego counties, staff hosted the public at their offices; Ventura County invited the public to a UC research and extension center; and other counties participated in community events, such as the one held at the California Academy of Sciences in San Francisco.

UCCE advisor Igor Lacan shows kids how to identify the insect species in their stream samples.

Both the date and the design of the project were significant. One hundred years earlier, on May 8, 1914, President Woodrow Wilson signed the Smith-Lever Act, creating the United States Agricultural Extension Service — which became, in California, UCCE. Since then, the federal-state-county partnership that UCCE represents has consistently promoted citizen science and service by enabling communities to pose research questions about agricultural, natural and human resources and to work in partnership with university researchers to find answers.

Last year's May 8 activities were also intended to connect modern-day Californians with a tradition of citizen science in the United States that began well before the Smith-Lever Act became law. For most of our nation's history, access to higher education was a privilege reserved mostly for the wealthy. But a lack of formal educational opportunities didn't rule out the possibility of scientific observation and experimentation in agriculture and other areas. American farmers were active citizen scientists, observing, experimenting and sharing information with other farmers in agricultural societies and at agricultural fairs and expositions. By the end of the 19th century, more than 3,000 agricultural publications had appeared in the United States and Canada. This culture of land-based learning and inquiry helped to foster a trajectory of federal legislation — beginning with the Morrill Land Grant Act signed into law by Abraham Lincoln in 1862 — that affirmed the importance of science-based inquiry and the vital contributions of government-funded scientific research to the public good.

Gathering data on May 8, 2015

Participants were invited to respond to one, two or all three surveys:

- How are you conserving water in your home, garden, yard or farm?
- Where is food grown in your community, and how do you get most of your food?
- How many pollinators can you count in 3 minutes?

Participants submitted their responses with a computer or smartphone. Responses were automatically tagged with location data, which enabled UCCE to map the location where each response was submitted and categorize it as urban or rural, based on the geographic classifications used by the U.S. Census Bureau. Between 62% and 69% of the responses were submitted from urban areas, depending on the survey. Every county in the state was represented among the respondents.

Water conservation

UCCE received responses to this question from more than 8,300 people. The large majority of respondents from rural and urban areas reported adopting basic water conservation practices, such as taking shorter showers (73% rural, 75% urban) and reducing landscaping water (71% rural, 79% urban). A smaller proportion reported more aggressive measures to reduce water use, such as undertaking some form of gray water reuse (22% rural, 15% urban) and capturing and reusing rainwater runoff (15% rural, 11% urban). Of the respondents who reported running a farm, roughly half said they were using drip irrigation.

California is in the midst of a long drought, and messages about water conservation appear to be reaching the public. UCCE is uniquely poised to help farmers, urban and rural residents and agencies work through the conservation challenges that this historic drought demands (see ciwr.ucanr.edu/).

Food

Just under 10,000 people submitted responses for this survey.

Interestingly, responses to the question, “Where do you get most of your food?” were closely aligned across rural and urban respondents: 86% of rural respondents versus 85% of urban respondents answered “from a grocery store,” 38% rural versus 38% urban said “from a farmers market,” 11% rural versus 10% urban said from a community supported agriculture (CSA) farm, and 37% rural versus 38% urban said “from a garden or farmer directly” (percentages total more than 100 because respondents were allowed to choose more than one food source).

As participants reported food-production sites, information was posted to a map on the UC ANR website.

Another series of questions asked respondents to use an online map to identify the location of a garden or farm and provide some information about it (see photo). Of the food-production locations submitted from rural locations, 40% were home gardens, 18% were community or school gardens and 42% were farms. Of the food-production sites submitted from urban areas, 57% were home gardens, 31% were school or community gardens and 11% were farms.

Pollinators

UCCE received responses to this survey from more than 10,600 people. Respondents showed great interest in counting bees, birds, bats and flies, which help distribute pollen that is essential to the production of many of the foods we eat. Public interest in pollinators has surged since the emergence of honeybee colony collapse disorder in 2007.

On May 8, 2014, kids and adults counted and recorded 17,861 bees, 7,582 flies, 7,548 birds, 2,518 butterflies, 2,345 beetles, 1,459 wasps, 1,021 moths and 173 bats. Urban and rural respondents submitted similar counts. There were differences between age groups: 18- to 29-year-olds saw the most bees, at 14 per respondent (an individual or a group of individuals), whereas 30- to 59-year-olds saw the most birds, at 4 or 5 per respondent. The ability to record and recognize pollinators increased with age: Children under 13 years old saw 11.5 pollinators per respondent on average, but older respondents saw more than 20 pollinators on average.

The interest demonstrated in this survey suggests the potential for broad public support of public policies to help pollinators. In May, the White House introduced the National Strategy to Promote the Health of Honey Bees and Other Pollinators, which links the health of pollinators with national security. It lays out a number of strategies to improve habitat and calls for additional public investment in research.


Kathy Keatley Garvey

Conclusion

When Cooperative Extension was created in 1914, the nation was at the beginning of a rural-urban population shift. Cooperative Extension primarily served rural residents to help improve on-farm productivity, to enhance home life through teaching best practices in home management and economics (including activities such as food preservation and poultry keeping), and to provide youth development programs in these areas.

While many of these themes persist, Cooperative Extension has evolved to reflect present-day sensibilities and needs. Cooperative Extension still partners with farmers to improve on-farm productivity, though it now also serves the increasing number of farmers and gardeners in cities and suburbs. Cooperative Extension continues to support small animal husbandry, but a growing number of clientele are based in urban areas. UCCE’s Master Food Preserver food program is having difficulty meeting the surging demand for courses in urban areas, where residents — many of them generations removed from the farm — are seeking to acquire skills to improve their ability to be good stewards of the abundant food California produces. UCCE helps to bridge urban and rural communities by working with growers to enhance local food systems that emphasize creative distribution and marketing models. And many of the talented, inspired young people who are joining UCCE today are women, as are the farmers they serve — another change from 100 years ago.

The enthusiastic response to the May 8, 2014 activities speaks to the potential for citizen science to be a vehicle for education and to deepen Californians’ engagement with the scientific process and with public institutions like UCCE that advance science for the benefit of all. CA

—Rose Hayden-Smith, Yana Valachovic and Brendan Twieg

Barbara Allen-Diaz: A career applying research to solve California's problems

After more than 4 years as the leader of UC Agriculture and Natural Resources, Barbara Allen-Diaz is retiring June 30. Ann Senuta, UC ANR Director of Publishing, provides this retrospective on her career.

Even while she works intensely to tie up her last projects at UC, Barbara Allen-Diaz's career is unspooling behind her in accolades and memories. She retires this month as UC ANR vice president, director of the UC Agricultural Experiment Station, director of UC ANR Cooperative Extension and Russell Rustici Chair in Rangeland Management at UC Berkeley. More broadly, she retires from a 37-year career of improving range science and the environment, mentoring future scientists and shaping a unique component of the UC system.

Allen-Diaz grew up in the Pacific Northwest, encouraged by her parents to love the outdoors and know the importance of education. They were practical people — she was accepted to Stanford University, Smith College and the University of Washington, but only the last offered a scholarship, so that is where she went.

Her introduction to UC came at age 20, when she transferred to UC Berkeley, where her new husband had been accepted to graduate school. "It was not a great decision," she says, because she had only two quarters left to graduate from UW; her double major of biology and human evolution was reduced at UC Berkeley to one — physical anthropology — and she lost her UW scholarship.

Berkeley was expensive, even then, and a culture shock. Frugal times and the breakup of her marriage led Allen-Diaz to reckon with another challenge, her career. "What I was looking for — it was the 1970s — was *to help save the world*. To help save the world, whatever that meant, as an applied ecologist," she says.

An opportunity arrived via Harold Heady, the associate dean of student affairs at UC Berkeley's College of Natural Resources, who told Allen-Diaz to think about range management. Overnight she considered it, seeing the subject as offering a better understanding of how ecosystems function to enable ecologically sustainable production of goods and services off the land. "The next day, Harold handed me a paper and said to enroll in these classes, and I was in grad school," Allen-Diaz recalls. "He did not say, 'Go away and take the GREs.' He believed in me and took a risk on me."

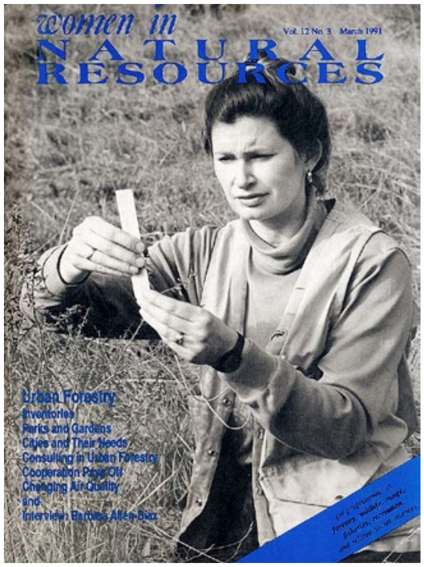
Allen-Diaz has replicated this support to graduate students throughout her career. "Too many times as professors we don't take a risk on students. But since someone did it for me, I think it is really

Allen-Diaz and Gidget explored Sierra Nevada conifer forests and oak woodlands for her research.

Elena Zhukova

important. And I have had some of the most incredible graduate students that you can imagine."

Allen-Diaz was invited to work with new UC Berkeley researcher James Bartolome, now a Professor of Environmental Science, Policy and Management, as his first graduate student at UC's Blodgett Forest Research Station in El Dorado County. The forest there, a study site for timber management, could not be sprayed aerially with herbicide after a 1977 ruling. Allen-Diaz and Bartolome looked at the feasibility of livestock grazing as an alternative way to reduce unwanted vegetation. They found that cattle would eat the vegetation, including deer brush, which is a palatable, nutritious species that when left to grow reduces forest space and shades young trees.



Allen-Diaz appeared on the cover of *Women in Natural Resources* in 1991.

"We did a lot of research about what species the cows were actually eating, the nutritional value of those species, and what was happening with the meadows," she recalls. Instead of finding overgrazed meadows, they discovered the potential of integrating cattle into a land management regime. Overgrazing could be avoided, they found, "as long as you thought about where you are logging, where you are reforesting, and how livestock are going to be used to help manage tree plantations," Allen-Diaz says. The work led to their first paper together, "Grazing Mixed Conifer Forests," published in *California Agriculture* in 1978.

Allen-Diaz earned a master's degree in range management that year and a doctorate in wildland resource science in 1980. She hoped to continue her research career as a university faculty member. But after a fruitless academic job search, she instead took a position with the U.S. Forest Service, launching an ecology research program out of the agency's Pacific Southwest Region office in San Francisco. There, Allen-Diaz says, she developed skills that would later serve her well as a university administrator, including "understanding people" and learning how to be effective within a large bureaucracy. The Forest Service also gave her the opportunity to continue her research, working in mountain meadows and oak woodlands, often with her horse, Gidget.

One day in the offices of the Cleveland National Forest in San Diego, Allen-Diaz met her current husband David Diaz, then a Forest Service botanist. They married in 1986, and that same year, Allen-Diaz returned to Berkeley as an assistant professor in the College of Natural Resources, the first woman in the country hired to a tenure-track position in range science.

Two key findings of Allen-Diaz's research were that cattle are not the primary source of excess nitrates in Sierra Nevada spring ecosystems or the main cause of declines in toad populations in the Sierra Nevada, as was widely thought at the time. These findings were important to ranchers, and Allen-Diaz became adept at giving talks at field days and interacting with ranchers at UC ANR Research and Extension Centers (RECs). Lake County rancher Russell Rustici, who later became a major benefactor to UC's range science programs, was often in the audience at her early field talks at the Sierra Foothill and Hopland RECs. Rustici developed a passion for range science and later told Allen-Diaz that her talks inspired him to will much of his estate to the university. In 2005, UC Berkeley named Allen-Diaz the first Russell Rustici Chair in Rangeland Management.

As she rose in the university, Allen-Diaz continued to be a leader in applied research on the management of rangelands and forests. This often meant stepping into controversy. She points to one example in particular, when she and several UC colleagues were asked to review, in just 5 weeks, the science in the Sierra Nevada Ecosystem Project study, a mammoth, multi-agency document intended to guide management decisions on public lands throughout the range.

Rudy Gonzales, UC ANR KARE

Barbara Allen-Diaz with fellow UC ANR senior administrators and Research and Extension Center directors at Kearney Agricultural Center's recent 50-year anniversary celebration.

Allen-Diaz and her team were broadly critical of the study. "In tracing statements back to their original source, we found a tendency to extend research results far beyond their original findings," reads their assessment. One example that Allen-Diaz is fond of citing: A key piece of evidence used to support the conclusion that grazing hurts amphibians was a 1958 laboratory study of salamanders, which found that, when deprived of water and exposed to light, the amphibians died fairly quickly. Over time, says Allen-Diaz, that study "got translated on up the chain into 'livestock are the primary cause of the decline in salamanders in the Sierra Nevada.'"

She cites her "two-sided personality" — researcher and administrator — for driving her to pursue new leadership challenges. She was appointed associate vice president of the UC ANR REC system in 2007 and associate vice president for UC ANR programs and strategic initiatives in 2009. Two years later, she became vice president of UC ANR, where she has worked to reposition the division as a proactive, high-achieving research and educational arm of UC, and to expand the division's footprint to better serve California's communities and sustain its ecosystems.

Author of more than 170 peer-reviewed papers, Allen-Diaz still values the journal in which she got her start. "*California Agriculture* is an incredible peer-reviewed journal for applied research and communicating why people should care about the research," she says. Applied research that solves problems is the strength of UC ANR and a value Allen-Diaz has championed as its vice president: "It is so important in our fields of agriculture, natural resources, nutrition and youth development. I say to people, this is why they should support their universities."

After retirement she will be taking this idea further in a book she plans to write about higher education. But first she and David will build a writing room on their property in central Oregon, clearing some new ground for Allen-Diaz to continue her lifelong love of learning and the land. CA

Allen-Diaz introduced her daughter Tianna to the mountains at a young age.

Allen-Diaz's Career Highlights

UC ANR Leadership

- Vice President of UC Agriculture and Natural Resources (ANR), Director of the Agricultural Experiment Station and Director of Cooperative Extension in California (2011–2015)
- UC ANR Associate Vice President for Programs and Strategic Initiatives (2009)
- UC ANR Associate Vice President of the Research and Extension Center system (2007)
- Purchased the UC ANR building in east Davis and consolidated more than 145 staff from six buildings in and around the UC Davis campus into one building
- Hired 90 new Cooperative Extension academics to begin rebuilding the UCCE footprint across the state
- Restored UC ANR's direct reporting line to the UC President
- Established two UC ANR institutes, the California Institute for Water Resources and the Nutrition Policy Institute
- Located two UCCE specialists on the UC Merced campus
- Raised external commodity salary support for six UCCE advisor and specialist positions
- Raised money for two endowed Cooperative Extension Chairs for UC ANR

UC Berkeley Faculty Member

- UC Berkeley faculty member since 1986; retiring as Russell Rustici Chair in Rangeland Management, Department of Environmental Science, Policy and Management
- Associate Dean, Executive Associate Dean and Acting Dean, College of Natural Resources, UC Berkeley (2000–2005)
- Division Head, Ecosystem Sciences, UC Berkeley (1994–1996)
- Chair, Department of Environmental Science, Policy and Management, UC Berkeley (1996)
- Society for Range Management Frederick G. Renner Award for lifetime achievement (first female SRM member to receive the award in the society's 68-year history), 2015
- Society for Range Management Outstanding Achievement Award (2001)
- Society for Range Management California Chapter, Range Manager of the Year (2002)
- Shared in the Nobel Peace Prize awarded to the Intergovernmental Panel on Climate Change (2007)
- Author of more than 170 peer-reviewed articles

Elēna Zhukova

Research Article

Soil suitability index identifies potential areas for groundwater banking on agricultural lands

by Toby A. O'Geen, Matthew Saal, Helen Dahlke, David Doll, Rachel Elkins, Allan Fulton, Graham Fogg, Thomas Harter, Jan W. Hopmans, Chuck Ingels, Franz Niederholzer, Samuel Sandoval Solis, Paul Verdegaal *and* Mike Walkinshaw

Groundwater pumping chronically exceeds natural recharge in many agricultural regions in California. A common method of recharging groundwater — when surface water is available — is to deliberately flood an open area, allowing water to percolate into an aquifer. However, open land suitable for this type of recharge is scarce. Flooding agricultural land during fallow or dormant periods has the potential to increase groundwater recharge substantially, but this approach has not been well studied. Using data on soils, topography and crop type, we developed a spatially explicit index of the suitability for groundwater recharge of land in all agricultural regions in California. We identified 3.6 million acres of agricultural land statewide as having Excellent or Good potential for groundwater recharge. The index provides preliminary guidance about the locations where groundwater recharge on agricultural land is likely to be feasible. A variety of institutional, infrastructure and other issues must also be addressed before this practice can be implemented widely.

California is experiencing its third major drought since the 1970s, and projections suggest that such episodes will become longer and more frequent in the second half of the 21st century (Barnett et al. 2008; Cayan et al. 2010). Droughts place more demand on groundwater resources to buffer surface water shortfalls. Ordinarily, about 30% of the water applied to crops in California (roughly 34 million acre-feet per year) is supplied by groundwater sources, but in times of drought the proportion can increase to as much as 60% (Megdal 2009). As a result, groundwater levels fall during droughts (Ruud et al. 2004). If groundwater is not replenished during wet years, long-term overdraft occurs. From 2005 through 2010, average annual overdraft in the Central Valley was estimated to be between 1.1 and 2.6 million acre-feet (Department of Water Resources 2015).

Two recent trends in California have tended to increase the rate of groundwater overdraft in agricultural regions.

First, over the past two decades, irrigation technologies have significantly improved water use efficiencies (Canessa et al. 2011; Howell 2001; Orang et al. 2008; Tindula et al. 2013; Ward and Pulido-Velazquez 2008). Where surface water is used for irrigation, a consequence of applying less water is that groundwater recharge is diminished because of a reduction in deep percolation of excess water.

Second, expanding worldwide markets have driven significant expansions of nut and wine grape acreage. For example, the almond acreage in California has doubled, to roughly 1 million acres, since 1994 (NASS 2014). Much of this expansion has occurred in the San Joaquin Valley where rates of rainfall and natural groundwater recharge are low. This shift in cropping systems to high value perennial crops reduces the flexibility of agricultural water demand because the economic costs of not irrigating are severe. Inflexible demand has made agriculture even more reliant on groundwater during dry periods when surface water resources are curtailed.

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n02p75&fulltext=yes

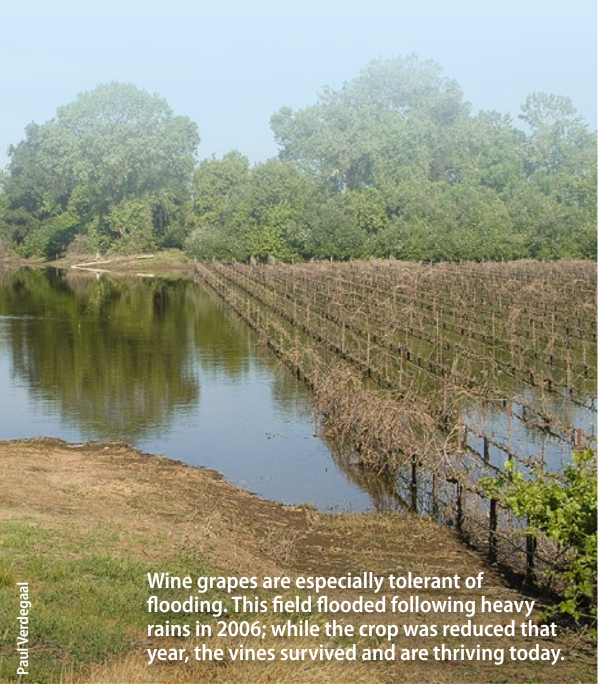
doi: 10.3733/ca.v069n02p75

During fallow or dormant periods, agricultural lands have the potential to serve as percolation basins for groundwater recharge.

David Doll

Five factors that determine the feasibility of groundwater recharge on agricultural land

1. **Deep percolation:** Soils must be readily able to transmit water beyond the root zone (1.5 m, 5 ft).
2. **Root zone residence time:** The duration of saturated/near saturated conditions after water application must be acceptable for the crops grown on lands under consideration for groundwater banking throughout the entire crop root zone.
3. **Topography:** Slopes that negatively influence the even distribution of water will be more difficult to manage.
4. **Chemical limitations:** High soil salinity may result in saline leachate (poor water quality) that must be avoided to protect groundwater quality.
5. **Soil surface condition:** Certain soils may be susceptible to compaction and erosion if large volumes of water are applied. Surface horizons with high sodium are prone to crusting that may contribute to decreased surface infiltration rates.



Paul Verdegaal

Wine grapes are especially tolerant of flooding. This field flooded following heavy rains in 2006; while the crop was reduced that year, the vines survived and are thriving today.

Groundwater recharge

Natural groundwater recharge is the predominant source of groundwater replenishment in almost all basins. It is typically unmanaged and can be slow. Water percolates into aquifers from a variety of surface water sources including precipitation, streams, rivers, lakes, surface water conveyance facilities — such as unlined canals — and applied irrigation water. Natural recharge also may occur from horizontal subsurface inflow from one part of a groundwater basin to another. Natural recharge requires no dedicated infrastructure or land.

Groundwater banking is a management strategy that stores surface water in aquifers for future withdrawal. It expands managed water storage capacity, which in California consists mainly of surface water reservoirs. Groundwater banking is achieved through the intentional application of surface water. During hydrologic cycles when surface water is abundant, extra surface water can be "deposited" in a groundwater bank by application to constructed percolation basins, through injection wells, or through joint management of rivers and groundwater to effect riverbed infiltration into underlying aquifers.

A key limitation to groundwater recharge is the lack of suitable percolation basins available for deliberate flooding. In this paper, we consider a new strategy for groundwater banking that involves applying water to agricultural lands outside of the usual irrigation season for the specific purpose of recharging a groundwater basin. Given the millions of acres of irrigated farmland in California, using agricultural lands as percolation basins has the potential to increase groundwater recharge during wet periods when surface water is available.

In California, one potential source of water for recharge on agricultural land is river floodwaters, because surface water rights may be easily re-negotiated (or may not apply) for the excess water. This floodwater approach has the dual benefit of withdrawing large amounts of water from a river that is at or near flood stage and reducing downstream flood risks (Bachand et al. 2011). The frequency and intensity of river flooding is difficult to forecast. For instance, flood flows on the Kings River from 1975 to 2006 had an average reoccurrence interval of 2 to 3 years, though flooding has not occurred in recent years (Bachand et al. 2011). As the climate warms, flooding may become more frequent and extreme as a result of episodic snowmelt events driven by warm winter rains. Recycled water (highly treated wastewater) is another potential source.

There are a variety of institutional and other barriers to widespread agricultural groundwater banking in California. Water rights for operation of aquifers as reservoirs are challenging to navigate; water conveyance infrastructure has limited capacity; regional planning to capture river flood waters may be difficult to organize; fields with high percolation rates at the surface may be underlain by low-percolation layers that slow or block the recharge of deeper aquifers; it can be difficult to assess how much capacity a given aquifer has to store banked groundwater; certain crops and certain stages of crop growth do not tolerate flooded conditions; and the quality of water recharged to an aquifer via agricultural land may be degraded due to excessive leaching of contaminants from soil such as pesticides and nitrates.

To date, few well-documented trials of groundwater banking have been conducted on agricultural land. Since nearly all agricultural land is privately owned and operated, participation in groundwater banking programs depends on cooperation from the landowner or land manager. Therefore, a clear understanding of the risks and best practices associated with this practice is paramount.

In this study, we take a first step toward better understanding opportunities to recharge groundwater using agricultural landscapes in California by identifying and mapping the soil and topographic conditions most conducive to groundwater recharge.

Groundwater banking index

This study developed a Soil Agricultural Groundwater Banking Index (SAGBI) that provides a composite evaluation of soil suitability to accommodate groundwater recharge while maintaining healthy soils, crops and a clean groundwater supply. The SAGBI is based on five major factors that are critical to successful agricultural groundwater banking: deep percolation, root zone residence time, topography, chemical limitations and soil surface condition (see sidebar, this page).

We modeled each of the five factors using U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) digital soil survey data. The suitability of each factor was expressed through a scoring system based on a combination of fuzzy logic functions and crisp ratings (see sidebar, this page).

Deep percolation factor. Successful groundwater banking depends on a high rate of water transmission through the soil profile and into the aquifer below. A high percolation rate is especially important if floodwaters are the water source used because floodwaters are available for diversion over a narrow time frame. The deep percolation factor is derived from the saturated hydraulic conductivity (K_{sat}) of the limiting layer (the soil horizon with the lowest K_{sat}). Saturated hydraulic conductivity is a measure of soil permeability when soil is saturated. Many soils in California have horizons (layers) with exceptionally low K_{sat} values that severely limit downward percolation, such as cemented layers (duripan, petrocalcic), claypans (abrupt increases in clay content) and strongly contrasting particle size distributions. Soils with these horizons were given crisp scores of 1. For other soils, a "more is better" fuzzy logic rating curve was applied to a soil profile's lowest K_{sat} to score the likelihood of deep percolation (fig. 1).

Root zone residence time factor. Prolonged duration of saturated or nearly saturated conditions in the root zone can cause damage to perennial crops, and in some cases, crop loss (table 1). About one-third of California's irrigated cropland is occupied by perennial crops and vines. Table 1 provides estimates of tolerance to saturation for some common tree and vine crops before and after budbreak compiled through a survey of UC ANR Cooperative Extension (UCCE) commodity experts. Annual crops were not included in the survey because we assumed that these fields generally would be fallow during times of excess surface water availability. In general, crops become prone to damage after budbreak and there is a range in tolerance among crops and rootstocks (table 1). For example, wine grapes and pears may be able to withstand more than two weeks of saturated conditions before budbreak, while avocados and citrus have no tolerance.

Our survey identified that many crops are unable to withstand long periods of saturated conditions in the root zone. To account for this potential adverse outcome, we included in the model a saturation residence time factor for soils. The root zone residence time factor estimates the likelihood of maintaining good drainage within the root zone shortly after water is applied. This rating is based on the harmonic mean of the K_{sat} of all horizons in the soil profile, soil drainage class and shrink-swell properties. The harmonic mean is typically used when reporting the average value for rates and tends to be lower than a standard average. Poorly drained soils and soils with high shrink-swell received the lowest scores with a crisp rating of 1. All other soils were

TABLE 1. Survey results of tree crop vulnerability to saturated conditions

Crop	Rootstock	Tolerance to saturation before budbreak	Tolerance to saturation after budbreak	Recommended N fertilizer rate
				lbs N/ac/yr
Almonds	Peach; peach x almond hybrid	1	1	250
Almonds	Plum; peach x plum hybrid	2–3	1	250
Avocados	—	0	0	150
Cherries	—	1	0	60
Citrus	—	0	0	100
Wine grapes	—	4	2	15–30
Olives	—	?	?	<100
Pears	*P. betulaefolia*	4	4	100–150
Pears	*P. communis*	4	3	100–150
Pears	*Cydonia oblonga*	3–4	2–3	100–150
Pistachios	—	?	?	200
Plums/prunes	Peach	1	1	150
Plums/prunes	Plum; peach x plum hybrid	2–3	1	150
Pomegranate	—	?	?	100
Walnuts	—	2–3	1	200

The following scores were used to estimate vulnerability: 0 - No tolerance for standing water; 1 - tolerant of standing water up to 48 hours; 2 - tolerant of standing water up to 1 week; 3 - tolerant of standing water up to 2 weeks; 4 - tolerant of standing water > 2 weeks; ? - tolerance unknown.

Tolerance to saturated conditions is based on expert opinion and has not been supported by controlled experimentation.

Fuzzy logic and crisp scores

Fuzzy logic is a method by which membership to a class or condition can be partial (maybe) rather than discrete (true or false; or A or B). Thus, fuzzy logic allows reasoning to be approximate rather than fixed and exact. Variables are evaluated via fuzzy logic scores that range between 1 and 100, reflecting the degree of vagueness of a membership being completely false (1) or completely true (100). Fuzzy logic is appropriate for this model analysis because in agricultural landscapes, the above five factors are relative as opposed to absolute, which poses challenges in quantifying them using the raw data.

We used fuzzy logic statements such as (1) "more is better" where the score increases with higher factor values; (2) "less is better" where the score increases as factor values decrease; and, (3) "optimum range" where the score is highest across a certain range of factor values and decreases above and below that range. Using the suitability of root zone residence time as an example, the fuzzy logic statement "less is better" enables the suitability of that factor to vary between 1 and 100 (from unsuitable to optimally suitable) rather than having to choose between absolutes, e.g., suitable (true) or not suitable (false). Crisp ratings are defined scores that apply to a well-understood system, and hence do not require fuzzy scoring. For example, slope classes as reported in soil surveys reflect limitations of common practices such as irrigation and cultivation practices and are scored in our model with crisp ratings.

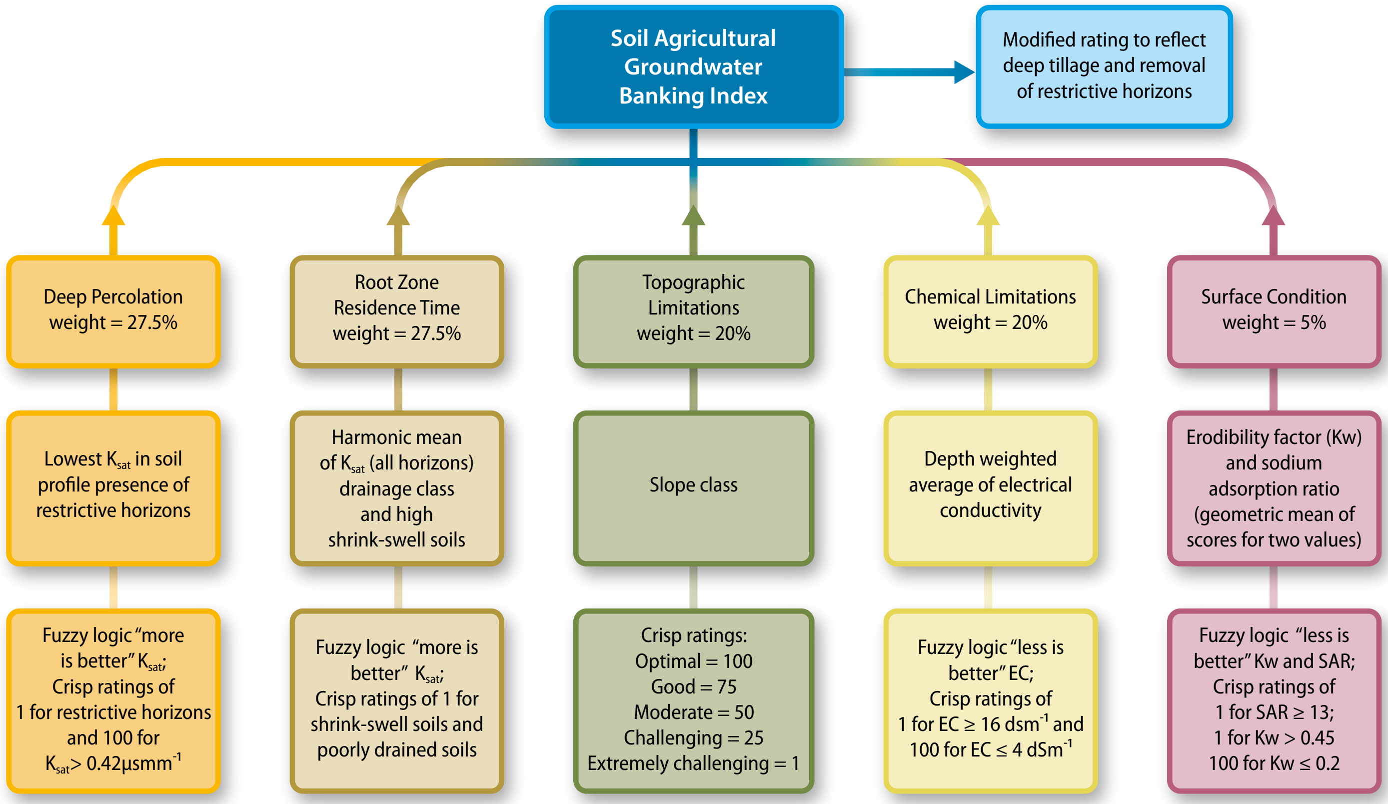


Fig. 1. Schematic of the Soil Agricultural Groundwater Banking Index.

scored using a fuzzy logic rating curve of "more is better" for K_{sat} (fig. 1).

Topographic limitations factor. Agricultural groundwater banking will likely be implemented by spreading water across fields. Level topography is better suited for holding water on the landscape, thereby allowing for infiltration across large areas, reducing ponding and minimizing erosion by runoff. Ranges in slope percent were used to categorize soils into four slope classes: Optimal (slope classes 0%–1% and 0%–3%), good (slope classes 0%–5% and 2%–5%), moderate (slope classes 0%–8% and 3%–8%), challenging (slope classes 5%–8%, 3%–10% and 5%–15%), and extremely challenging (slope classes 10%–30% and 15%–45%) (fig. 1). Topographic limitations were scored using crisp ratings that generally reflect the USDA-NRCS slope classes because these classes were designed in consideration of limitations for standard agricultural management practices (Soil Survey Division Staff 1993).

Chemical limitations factor. Salinity is a threat to the sustainability of agriculture and groundwater in California, especially along the west side of the Central Valley (Kourakos et al. 2012; Schoups et al. 2005), where sediments are derived from marine sediments in the Coast Range. The chemical limitations factor was quantified using the electrical conductivity (EC) of the soil, which is a measure of soil salinity. A fuzzy logic rating curve "optimum and less is better" was used to score chemical limitations. The "less is better" statement implies that soils with low salinity score high and soils with high salinity values score low. Soil profiles with EC < 4 dS/m were considered optimal (score of 100). Beyond this threshold, scores decreased with increasing EC. Soils with EC values above 16 dSm^{-1} received a score of 1 (fig. 1). A variety of other contaminants such as pesticides and nitrate are also present in agricultural soils. However, because this type of contamination is dependent on management history, the USDA-NRCS soil survey does not document it and we were unable to evaluate it.

Surface condition factor. Groundwater banking by flood spreading can subject the soil surface to changes in its physical condition. Depending on the quality of the water and depth of water, standing water can lead to the destruction of aggregates, the formation of physical soil crusts and compaction, all of which limit infiltration (Le Bissonais 1996). We used two soil properties to diagnose surface condition, the soil erosion factor and the sodium adsorption ratio (SAR). The surface condition factor was calculated by the geometric mean of fuzzy logic scores from these two properties. A geometric mean is a way to identify the average value of two or more properties that have different ranges in value. SAR values greater than 13 indicate that the soil is prone to crusting. A "less is better" fuzzy logic curve was used to evaluate SAR, where values greater than 13 were assigned a crisp rating of 1, and values of 0 were assigned an optimal rating of 100. Soil surface horizon Kw, the soil erodibility factor of the Revised Universal Loss Equation, was used to estimate the potential soil susceptibility to erosion, disaggregation and physical crust formation (USDA-NRCS 2014). A fuzzy logic rating curve, "optimum and less is better," was used for scoring the surface condition factor. Kw values < 0.20 were considered ideal (score = 100); beyond this threshold, factor scores decreased with increasing Kw values.

SAGBI calculation. Each of the five model factor scores was assigned a weight based on its significance to groundwater banking (fig. 1). The SAGBI score was calculated by the weighted geometric mean of the scaled factors. The factors were weighted as follows: Deep percolation (27.5%), root zone residence time (27.5%), topographic limitations (20%), chemical limitations (20%) and surface condition (5%). Factor weights were applied based on expert opinion. Factors with greater relevance to groundwater recharge were weighted more heavily, while factors that may be modified by management, such as surface condition, were given a lower weight. SAGBI scores were categorized into six groups: Excellent, Good, Moderately Good, Moderately Poor, Poor and Very Poor based on the natural groupings of the dataset.

Soils modified by deep tillage. In recent decades, high value orchard and vineyard crops have expanded onto soil landscapes that contain restrictive horizons. A standard practice for tree and vine establishment on these soils is deep tillage up to a depth of 6 feet to destroy restrictive layers that impede root penetration. This practice increases deep percolation rates and drainage conditions compared to naturally occurring soils. Soils with root- and water-restrictive horizons in California have been altered to the point that they are now considered endangered in the Central Valley (Amundson et al. 2003).

As a result, soil surveys of much of the region — many of which were conducted decades ago — are outdated with respect to alterations by deep tillage. To address this problem, we created an updated soil disturbance map using geospatial analysis. A map of orchard and vineyard crops was created using California Department of Water Resources land use maps (issued between 2001 and 2011) and aerial imagery from the National Agricultural Imagery Program (NAIP) and Google Earth (2012 to 2014). This file was overlain in a geographic information system with a map of soils with water-restrictive horizons. We assumed that all tree and vine cropland with restrictive soil layers (based on soil survey data) has been modified by deep tillage, generating an updated map of modified soils.

To reflect the mixing of soil horizons in the calculation of the deep percolation factor, the depth-weighted average of K_{sat} for the entire soil profile was used in place of the lowest K_{sat} for each profile. We reduced the deep percolation factor rating for soils with claypans by 20% to reflect the risk that modified claypans will reform, which can occur in as little as four years in soils with weak structure (White et al. 1981). Cemented layers (not including bedrock) were assumed to have been removed by deep tillage and were not included in the weighted average. Data below the restrictive horizon was included in the depth-weighted average if populated in the database. The depth-weighted average of K_{sat} was used in place of the harmonic mean to estimate hydraulic conductivity for the root zone residence time factor.

Map unit aggregation. SAGBI scores were calculated for most agricultural soils populated in the USDA-NRCS Soil Survey Geographic Database (SSURGO). Soil survey delineations represent map units, which often contain more than one soil type. The map units range in size from 5 acres to roughly 500 acres. To create a regional map, each map unit was scored with the SAGBI value using the soil component that comprised the largest percentage of the map unit area. If there was a tie (i.e., one map unit containing two components of equal area), the most limiting (lowest) SAGBI score was chosen for the map unit.

Spatial patterns of SAGBI

Our study area included over 17.5 million acres of agricultural land (irrigated and non-irrigated) as identified by the state Farmland Mapping and Monitoring Program. Based on our initial modeling, which did not initially consider the effects of deep tillage, soils in the Excellent, Good and Moderately Good suitability groups comprised over 5 million acres, or 28% of the study area (fig. 2 and table 2). These highly rated soils were most abundant on broad alluvial fans on the east side of the Central Valley stemming from the Mokelumne, Stanislaus, Merced, Kern and Kings rivers (fig. 2). Excellent, Good and Moderately Good ratings are also found throughout much of Napa, Salinas and Santa Maria valleys and in patches

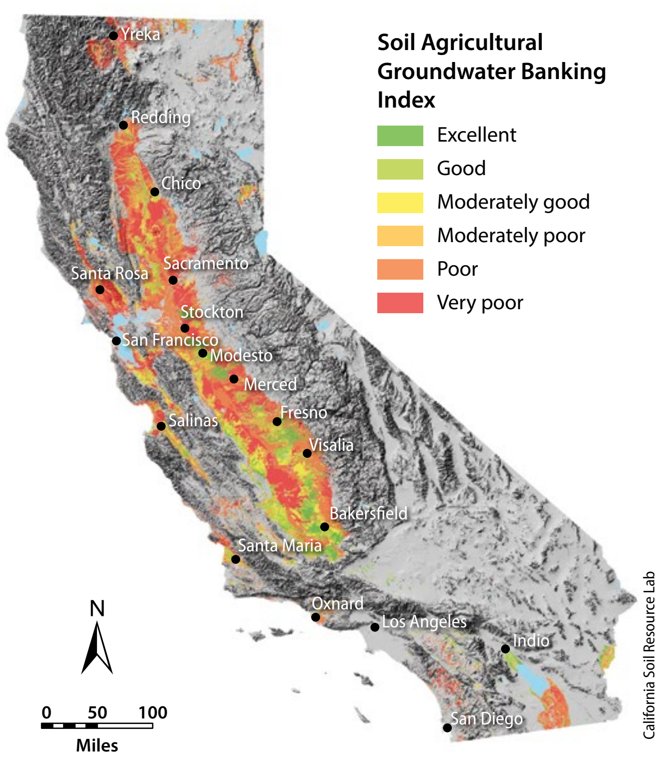


Fig. 2. Spatial extent of Soil Agricultural Groundwater Banking Index suitability groups when not accounting for modifications by deep tillage.

TABLE 2. Summary of the areal extent of Soil Agricultural Groundwater Banking Index groups generated from soil survey data

SAGBI group	Original SSURGO data		SSURGO modified by deep tillage	
	acres	*%**	*acres*	*%**
Excellent	1,477,191	8	1,557,035	9
Good	1,747,712	10	2,020,921	11
Moderately Good	1,786,972	10	1,984,414	11
Moderately Poor	1,343,250	8	1,364,066	8
Poor	4,866,942	28	4,586,645	26
Very Poor	6,375,277	36	6,084,142	35
Total†	17,597,345		17,597,222	

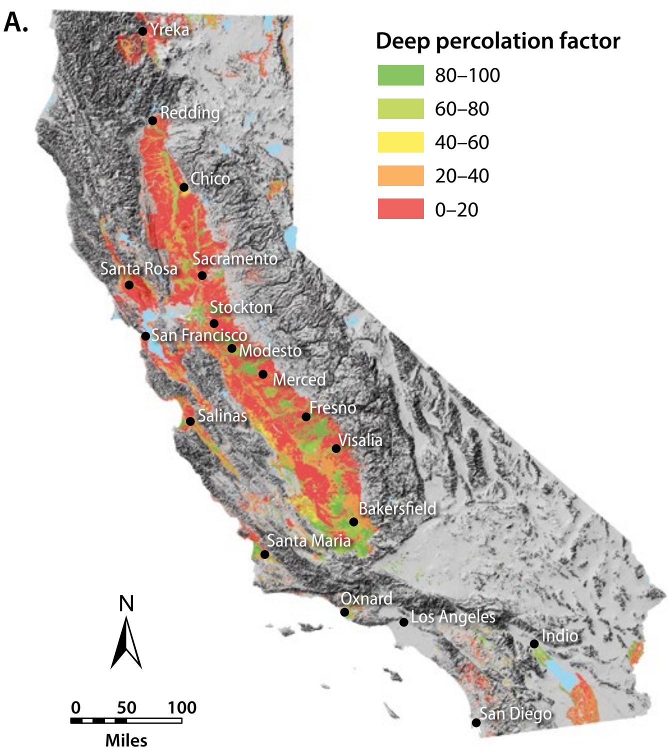
* Percent of total study area.
† Modified SAGBI ratings had 123 fewer acres because two soils lacked sufficient data to adjust.

along the Russian River in Mendocino and Sonoma counties and the northern parts of the Coachella Valley. The best soils — the Excellent and Good groups — occupied about 3.2 million acres, representing 18% of the study area (fig. 2 and table 2). Some areas of Good and Excellent ratings were found on sandy floodplains of rivers and streams, especially along the Sacramento and Feather rivers.

Floodplains may not be ideal locations for groundwater banking because of the potential for applied water to flow, by subsurface transport, into rivers and streams. Thus, these systems should not be prioritized for groundwater banking unless it is known that the surface water bodies are losing streams — that is, surface water bodies that discharge to groundwater. Most major streams that traverse the San Joaquin Valley, for instance, are known to be losing streams.

Extensive Moderately Good areas were mapped on the western margins of the San Joaquin and Sacramento valleys where soils tend to be finer textured and sometimes salt-affected (saline). Moderately Good groups were also mapped in basin alluvium where low energy flood events have deposited fine sediments. Moderately Good groups occupied 1,786,972 acres or 10% of the study area. These areas may require careful consideration for groundwater banking.

The majority of land in the study area (72% or ~12.6 million acres) was classified as Moderately Poor, Poor or Very Poor SAGBI groups (fig. 2 and table 2). Soils with low SAGBI scores were abundant throughout the basin margins of the Sacramento and San Joaquin valleys as well as across land interstratified between recent alluvial fan deposits of



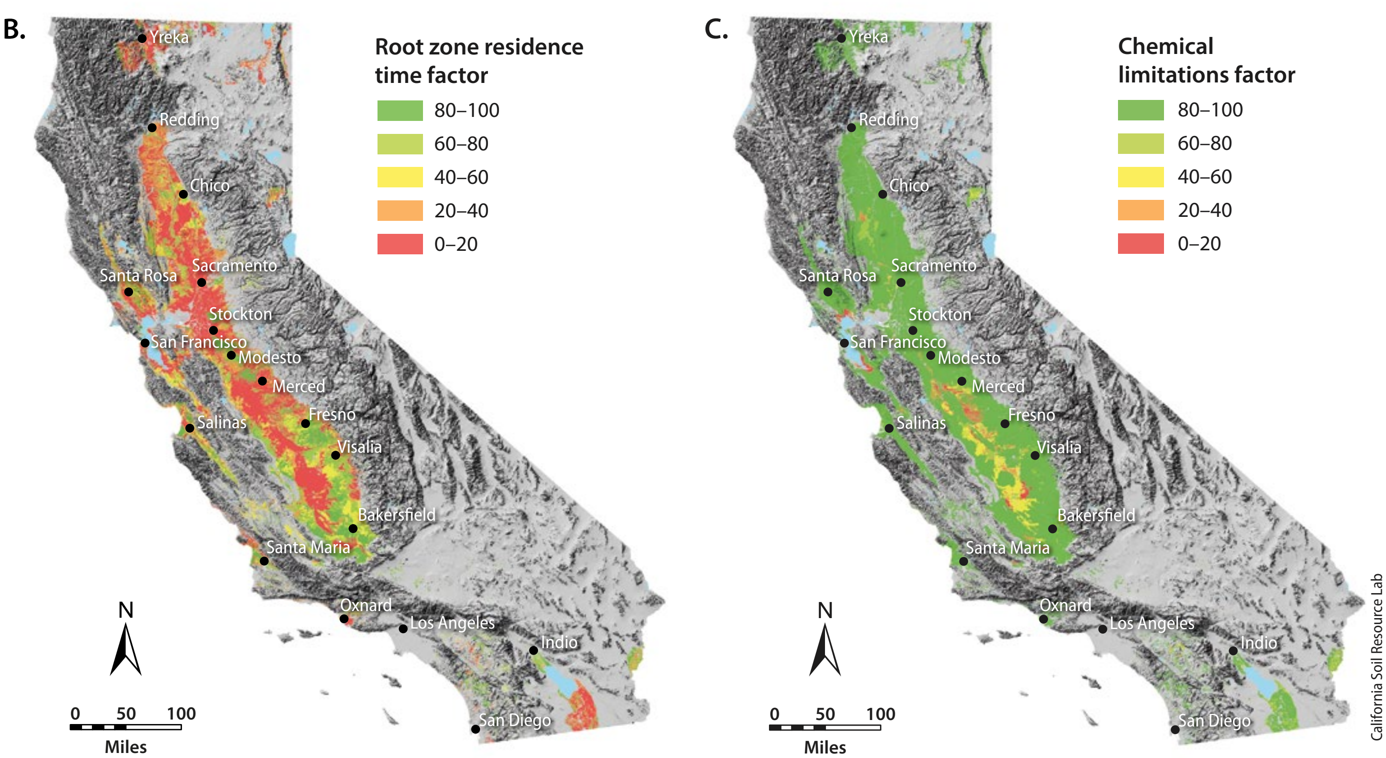


Fig. 3. Spatial extent of Soil Agricultural Groundwater Banking Index factors (A) deep percolation, (B) root zone residence time and (C) chemical limitations.

the Mokelumne, Tuolumne, Stanislaus, San Joaquin, Kings and Kern rivers. Very Poor and Poor ratings are also found on the northern portions of the Salinas and Santa Maria Valleys and throughout most agricultural regions in Sonoma County and southern parts of the Coachella Valley.

Of the SAGBI components, the deep percolation factor was limiting over the greatest area (fig. 3A). These limiting conditions arise from different characteristics of soils. For example, old, highly developed soils found along the margins of the Central Valley contain water-restrictive horizons (either cemented hardpans or claypans). The center of the valley contains young soils with fine (clay-rich) texture throughout the soil profile. Both of these soil landscapes contain at least one soil horizon with low permeability. In contrast, high deep percolation scores were found on coarse-textured soils derived from recent (e.g., < 80,000 years) alluvial fans with drainages sourced in granitic terrain of the Sierra Nevada and the Salinian block within the Coast Range.

Areas limited by the root zone residence factor typically had soils with uniformly fine texture throughout the soil profile and poor drainage. Poorly and very poorly drained soils have properties or conditions that promote saturation in the upper parts of the soil profile, such as high clay content, water restrictive layers or regionally shallow water tables. The least suitable soils in this factor were those with poor drainage or high shrink-swell properties. Low scores for root zone residence factor were widespread along the west side of the San Joaquin and Sacramento valleys in soils weathering from Coast Range alluvium (fig. 3B). Poor drainage and fine textured soils were also found in the basin alluvium towards the center of valleys. Low scores for this factor were also found on alluvial fans that have drainages confined to the metamorphic portions of the Sierra Foothills such as the Calaveras River fan, which tend to have fine textured sediments compared to fans sourced in granitic terrain in the high Sierra Nevada.

Chemical limitations had a localized influence on the distribution of SAGBI ratings. Most of the salt-affected soils are present along the west side of the San Joaquin Valley and to a lesser extent along the western margin of the Sacramento Valley (fig. 3C). The distribution of salt-affected soils results from a combination of the salt-rich nature of the marine sediments within the Coast Range and poor drainage conditions on the west side that prevent salts from leaching out of soil. There are other chemical limitations of soils we could not evaluate that would influence groundwater banking, most notably the concentration of residual nitrate in soil. Crops with high nitrogen demand or high residual nitrate in soil in the fall after harvest may not be suitable for groundwater banking (table 1).

The surface condition factor was weighted lowest among all other factors because compaction from standing water can be fixed with tillage and amendments. Low surface condition factor ratings were abundant in soils with loamy surface textures or high SAR and were located throughout the study area but tended to be concentrated on the west side of the Central Valley where sodium-affected soils are common (fig. 4A).

Soil landscapes with low slope factor ratings were limited to the margins of the valleys (fig. 4B). This sloping terrain is a result of uplift by the Coast Range and Sierra Nevada over geologic time scales, which increased slope gradients and accelerated erosion. The natural erosion of the valley margins has created gentle to

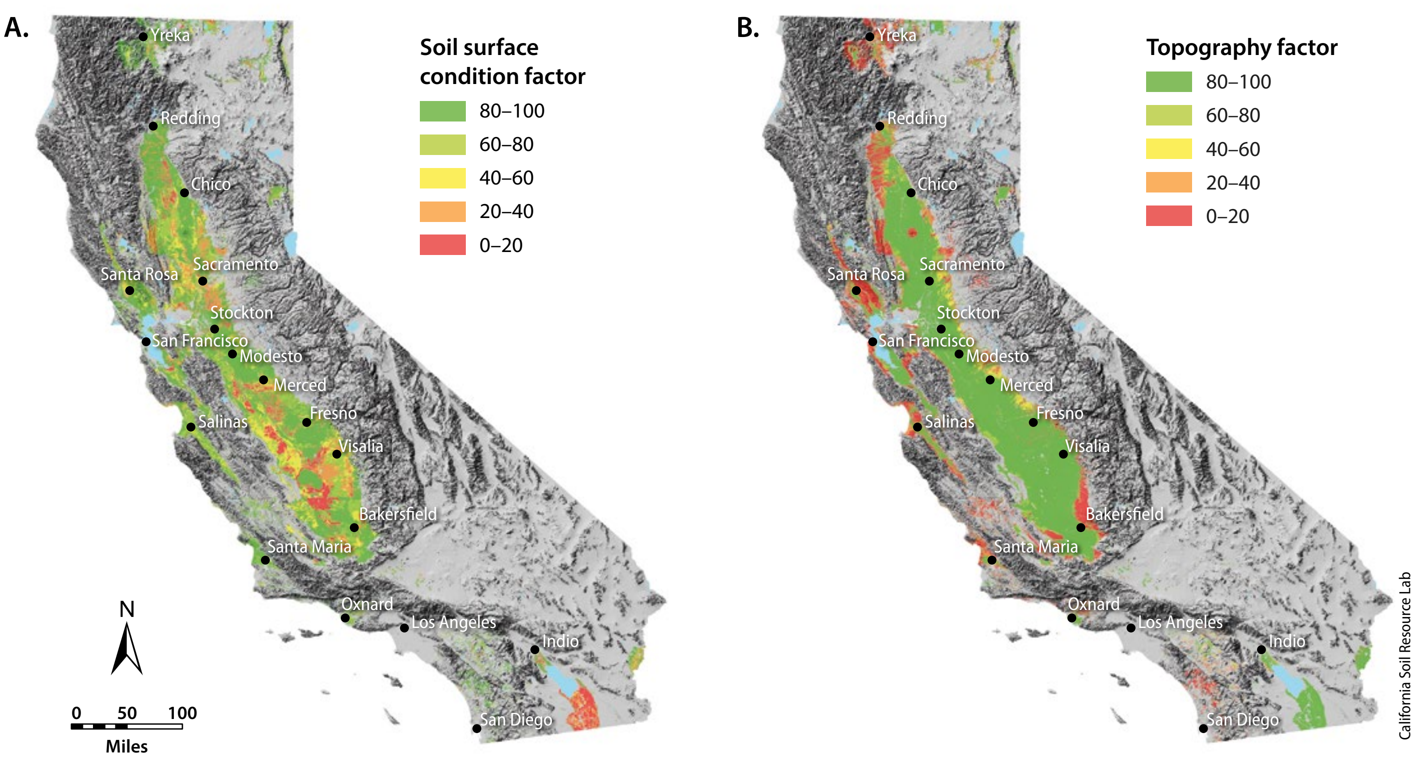


Fig. 4. Spatial extent of Soil Agricultural Groundwater Banking Index factors (A) surface condition and (B) topographic limitations.

steeply undulating landforms (see photo, below).

Modified SAGBI scores to reflect deep tillage

When deep tillage on orchard and vineyard croplands was incorporated into the model, the Excellent, Good and Moderately Good SAGBI suitability groups increased from 28% to 31% of the land area, adding 550,494 acres of suitable agricultural land for groundwater banking (table 2). A majority of improved SAGBI scores were located in the eastern San Joaquin Valley and Tulare Basin, where soils with restrictive horizons are common (fig. 5). It is possible that over time, more suitable land for groundwater banking will become available as marginal soils continue to be developed and modified for agricultural purposes (Charbonneau and Kondolf 1993).

The final SABGI that accounts for deep tillage represents the best estimate of soil suitability for groundwater banking. Over 12 soil survey areas are classified as out-of-date in agricultural regions of California (USDA-NRCS 2014) and do not accurately document the extent of soil modification by deep tillage. These modified SAGBI ratings provide an updated assessment of the current state of soils in the study area.

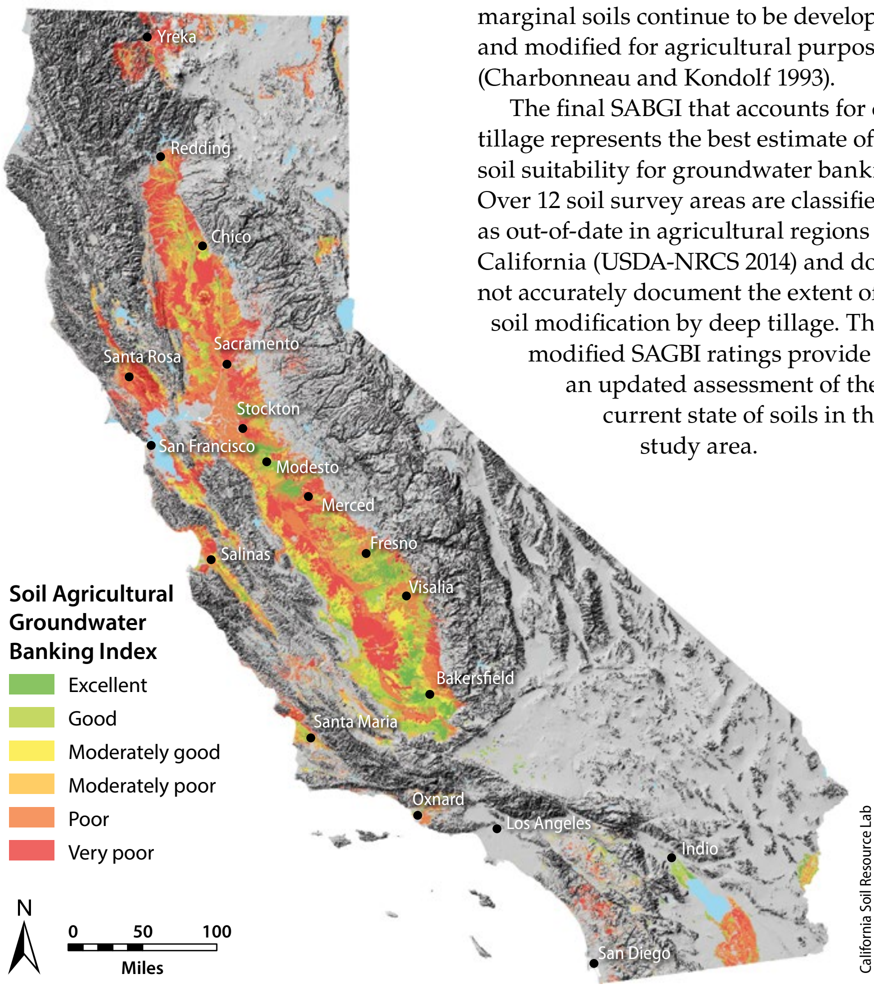


Fig. 5. Spatial extent of Soil Agricultural Groundwater Banking Index suitability groups accounting for modifications by deep tillage.

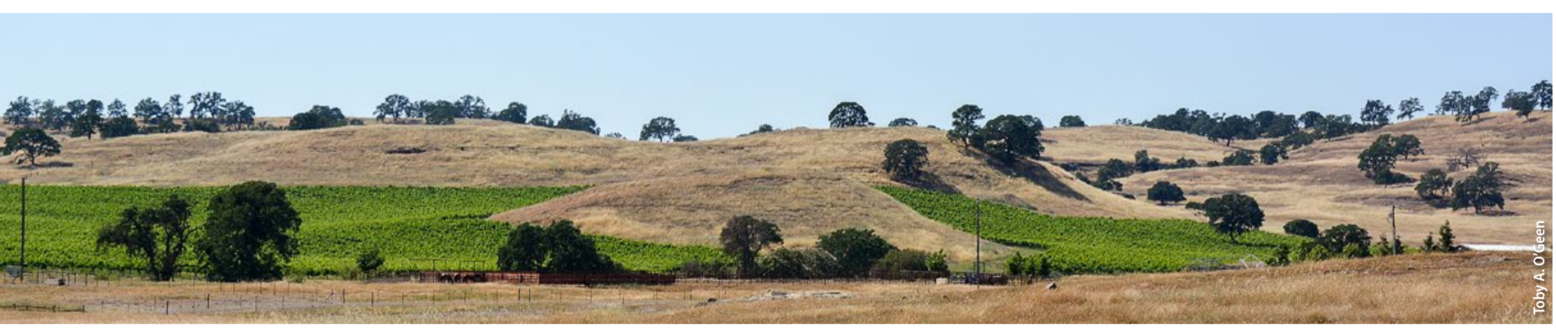
Implications

There are approximately 5.6 million acres of land with soils in Excellent, Good and Moderately Good SAGBI suitability groups, a significant amount of agricultural land capable of accommodating deep percolation with low risk of crop damage or contamination of groundwater by salts. Most suitable soils for agricultural groundwater banking occur on or near alluvial fans created by rivers draining the Sierra Nevada. Perhaps not coincidentally, these are also the areas that have California's most successful groundwater banking programs (Water Association of Kern County 2014).

Our preliminary survey of UCCE perennial crop experts suggests that pears, wine grapes and some rootstocks of various *Prunus* species (i.e., almond, peaches and plums) are best suited for groundwater banking if planted on suitable soils and managed appropriately, especially after budbreak. While extensive in acreage, almonds may be less ideal because of the trees' sensitivity to saturated conditions and high nitrogen demand (table 1). Walnuts may be an option given that budbreak typically occurs in late April. Wine grapes may be the best option because of the extensive acreage planted, low nitrogen demand and tolerance to standing water (table 1). Almonds with plum rootstocks may also be suitable; however, currently almonds with water tolerant rootstocks are generally planted in soils that are poorly drained and thus less likely to be suitable for groundwater banking.

Recharge potential

A preliminary calculation based only on soil properties and crop type shows that landscapes rated Excellent or Good could be used to bank as much as 1.2 million acre-feet of water per day. This



The undulating agricultural land found along many valley margins in California is poorly suited to groundwater banking because application of floodwater or waste water would be difficult to apply at these sites, which are typically drip irritated.

estimate assumes 1 foot per day of water infiltration on lands in the Excellent and Good categories that are planted with grapes (460,000 acres) or alfalfa (300,000 acres), or fallowed (440,000 acres). There are significant limitations to this estimate. Most importantly, California lacks the infrastructure to accommodate and route such large volumes of water to the fields in such a short time (presuming that floodwater is the source of the water). Plus, the heterogeneity in precipitation across the state makes this estimate improbable (that is, it is unlikely that floodwater availability would be geographically close to the best lands for recharge). Offsetting these limitations to some degree are other crop types that would be suitable for recharge (i.e., annual crops) but were not included in this estimate.

Agricultural groundwater banking must be approached with caution. The financial risk associated with crop loss may exceed the potential benefits of water savings. Perennial crops carry particular risks and uncertainties. For instance, while trees and vines are generally more tolerant of saturation before budbreak than after (table 1), determining a reliable cutoff date for this increased tolerance is difficult. Tree and vine roots generally start to grow several weeks before budbreak, so damage from waterlogging can occur well before budbreak. Moreover, budbreak for a given species varies by location across the state. In addition, standing water on trunks can lead to aerial *Phytophthora* or other diseases. Investigating this opportunity in less valuable cropping systems, such as alfalfa, irrigated pasture and annual crops may be more promising until further research on tree crop sensitivity to standing water has been conducted.

If groundwater banking on agricultural lands becomes a priority, coordination at the policy, market and planning levels would be needed to provide an adequate land base ready to opportunistically capture floodwaters. Adoption of this practice would likely require some form of support to mitigate or protect growers from the risks of crop failure. For example, growers who make their land available for floodwater capture and groundwater banking could receive credits from municipalities or irrigation districts. They could also receive credits from irrigation districts for enrolling in a long-term program. Long-term commitments from growers likely would be needed for basin-scale planning purposes.

Josh Viers, UC Merced

David Doll

Orchards of walnuts (above) and almonds (below) may be viable sites for groundwater recharge, though the potential for water damage to such high-value crops adds risk.

Although not included among the crops listed in table 1, alfalfa may be an ideal crop for groundwater banking because it requires little or no nitrogen fertilizer, reducing the risk that groundwater recharge would transport nitrates into aquifers. Alfalfa is sensitive to flooding and saturated conditions; thus the timing of flooding should coincide with older fields (typically 4 to 5 years old) slated for replanting. Because the financial risk associated with crop damage is lower in alfalfa than in tree and vine crops, the financial incentive needed to drive grower participation in groundwater banking programs likely would be lower as well.

Most annual cropping systems would be suitable for groundwater banking if water is applied when land is fallow. The major risk in annual crops is leaching of residual pesticides or fertilizer in the soil. Appropriate management practices for groundwater banking with specific annual crops would need to be developed. If agricultural groundwater banking becomes an important water security practice, the SAGBI may provide valuable information to guide future changes in cropping systems.

SAGBI can be a powerful aid to decision makers and stakeholders when considering the tradeoffs associated with the implementation of groundwater banks utilizing agricultural land for direct recharge. It was also developed with the intention of informing growers of the potential hazards associated with this practice. As is the case with any model, and with soil survey information in particular, ground-truthing at the field scale is necessary to verify results.

If agricultural groundwater banking becomes an important water security practice, the SAGBI may provide valuable information to guide future changes in cropping systems.

We acknowledge limitations to our model. It does not consider proximity to a surface water source, which is an issue especially in areas that are irrigated solely from groundwater wells and are not connected to conveyance systems that supply surface water. The SAGBI also does not consider characteristics of the vadose zone (the unconsolidated material below soil and above the groundwater table) or depth to groundwater. In arid regions, deep vadose zones may contain contaminants such as salts or agricultural pollutants that have accumulated over years of irrigation and incomplete leaching. These deep accumulations of contaminants could be flushed into the water table when excess water is applied during groundwater banking events. Furthermore, deep sediment likely contains hydraulically restrictive horizons that have not been documented, creating uncertainty as to where the water travels. An understanding of the depth to the groundwater table is also needed.

Given these issues, SAGBI may be most useful when used in concert with water infrastructure models and hydrogeologic models — which generally do not incorporate soil survey information in a comprehensive way — to develop a fuller assessment of the processes and limitations involved in a potential groundwater banking effort.

Information delivery

Our goal is to make SAGBI an interactive, web-based app. The decision support tool will display SAGBI groups as a map in Google Maps. Users will be able to navigate via standard map interface operations such as zoom tools and panning, or by entering a location in a search field to obtain SAGBI ratings. Users will also be able to query and display the individual ratings of each SAGBI factor for any location that has a SAGBI rating, illustrating the transparency of the model and allowing for further investigation of individual factors. CA

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This research was conducted with funding from the UC ANR Competitive Grants Program. We also thank the anonymous reviewers for their helpful feedback.

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Regional identity can add value to agricultural products

by Bradley C. Christensen, Martin Kenney *and* Donald Patton

Regional identity creation is being recognized for its economic benefits and as a strategic resource for producer communities. A regional identity is not a brand; it is built through a complicated process of developing cohesion and sharing in the industry community and communicating outside the industry community to opinion-makers and consumers. The California fine wine industry has built successful regional identities and leveraged them to add value to their wines. As regional identities in the wine industry have strengthened, so has the industry, and a symbiotic relationship with other local value-added industries, such as tourism and hospitality, has emerged. Other agricultural producers can learn from the identity creation experiences in the wine industry. With the many challenges faced by California agriculture, identity formation may offer producers new ideas for adding value to their products and finding larger markets.

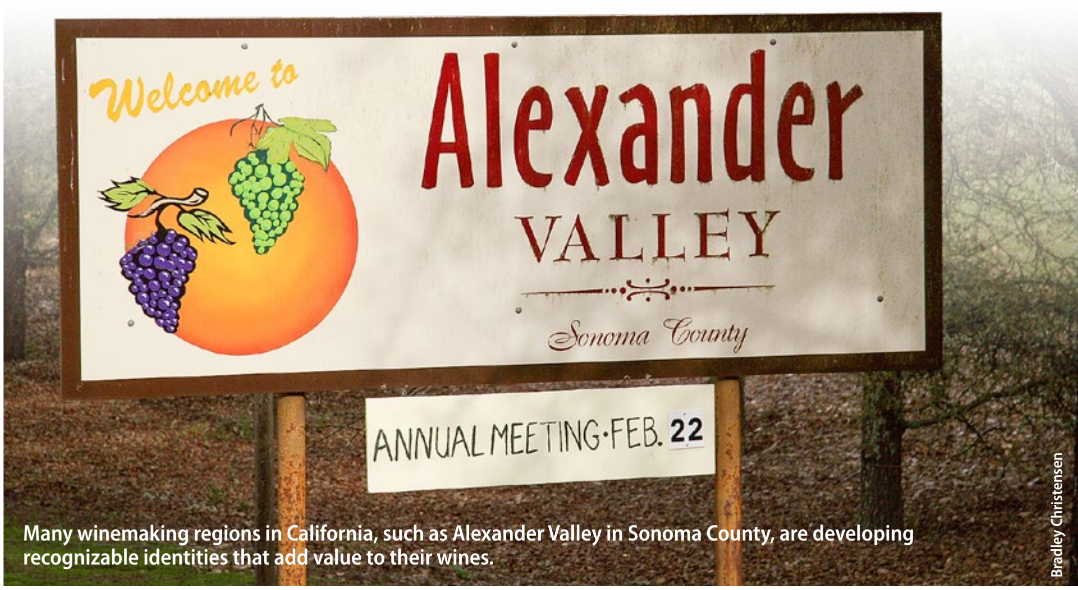
Identity can be an important factor for the success of regional economies. It can send strong signals of positive traits to consumers and the business community. In agriculture, many regions, such as Bordeaux, Champagne, Islay, Speyside, Parma and Tuscany, are identified with excellence and quality. A successful regional identity adds value to the products made there. Industries, often including tourism, grow in response to a region's identity. The region may also become a knowledge center, where producers share information and experts gather, which further contributes to its reputation of excellence and quality. As consumers, we are familiar with the regional identities of agricultural products, but there has been little research on the creation of regional identities. Here we draw upon our research (Beebe et al. 2012) on the creation of identity in the Paso Robles American Viticultural Area to interrogate the larger question of the dynamics of regional identity creation and how it can add value for agricultural producers.

The quintessential example of an agricultural industry that has a strong place identity is the California wine industry, in particular the Napa Valley industry. As a region, Napa Valley has firmly established itself as a world leader in wine. From its start, in partnership with UC Davis it has been at the forefront of innovation in both the technical sense (i.e., stainless steel fermenters, temperature-controlled tanks, etc.) and in the social sense of creating innovative networks of producers to share knowledge (Lapsley 1996; Peters 1984). The early pioneers, such as Louis M. Martini, Robert Mondavi and John Daniel Jr., who shaped Napa's industry created an industrial structure and an identity that in many ways codified what the U.S. wine industry would look like. Today, the U.S. wine industry is known for its varietal focus (as opposed to Europe's focus on regional blends), and it has shown the wine-drinking public that the United States can produce top-quality fine wines (Lapsley 1996).

Though the Napa Valley is the premier example, other winemaking regions, such as Paso Robles in San Luis Obispo County and the Alexander and Russian River Valleys in Sonoma County, are also developing recognizable identities. In all these areas, a sophisticated, high-value-added hospitality industry has emerged, which is synergistically contributing to strengthening the local identity.

Learning from Paso Robles

Winemaking in the Paso Robles region dates back to 1797, when Franciscan missionaries planted the Mission grape, but its long history of winemaking wasn't sufficient to earn it a regional identity for quality wines. Not until the 1970s did a group of winemakers and grape growers in Paso Robles begin the process of creating the identity for which it is known today. Growers in the Paso Robles area were selling their grapes into other regions for blending into top-tier wines and were confident the region could produce its own high-quality wines — and



Many winemaking regions in California, such as Alexander Valley in Sonoma County, are developing recognizable identities that add value to their wines.

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capture more of the value of their production — but they realized that this view of the region's wines was not validated by consumers or outside opinion-makers. To build a validated reputation and receive higher prices, they would have to organize and create an identity.

The first step was to secure federal government recognition as an American viticultural area (AVA), which would enable growers within the area to take actions that would have a collective benefit. A few visionary winemakers, winery owners and vineyard owners petitioned the federal government and in 1983 created an AVA that encompassed 614,000 acres (Federal Register 1983). The same year, the group held the first Paso Robles wine festival, which proved to be an impactful event because it convinced local growers that there was an opportunity to build a regional identity.

With relatively inexpensive land, an increasing level of coordinated organization and a growing reputation, the Paso Robles wine industry expanded rapidly. From 1986 to 1993, two new wineries on average opened each year. From 1994 to 2001, 11 new wineries on average opened each year. The owners came from a variety of backgrounds and brought new talent and financial resources. The expansion and attention being paid to the region attracted well-known winemakers from outside the region, which in turn attracted the attention of key opinion leaders, such as Robert Parker at *The Wine Advocate*.

In 1992, the emerging community became official with the formation of the Paso Robles Vintners and Growers Association (VGA). The association's goals were to educate and inform growers about new techniques and raise the reputation of local grapes in order to bring in higher prices for all growers. The VGA's goals were inward focused, but the VGA also presented a unified face to the outside.

As the reputation of Paso Robles wine improved and the region began receiving national media attention and a substantial increase in favorable wine ratings (Beebe et al. 2012), key local wine industry leaders recognized that the next step to strengthen the regional identity was to integrate into the group other businesses, such as those in the hospitality industry, whose success depended on the wine industry doing well. In 2005, the VGA changed its name to the Paso Robles Wine Country Alliance (WCA). It continued to include the growers and winemakers but now was open to hoteliers, restaurateurs and other wine-related tourism firms.

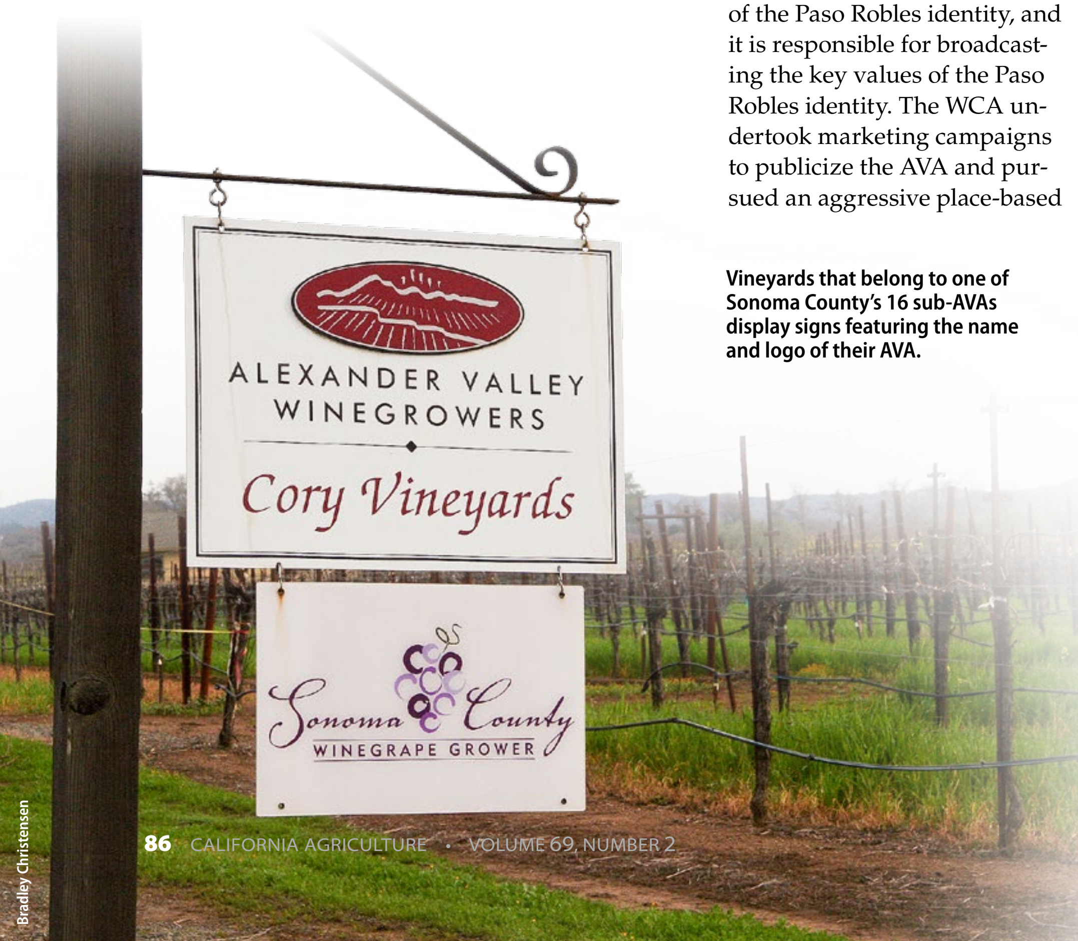
The WCA is effectively an expression of the Paso Robles identity, and it is responsible for broadcasting the key values of the Paso Robles identity. The WCA undertook marketing campaigns to publicize the AVA and pursued an aggressive place-based marketing campaign to promote Paso Robles as a *fine* wine region. The WCA is funded by members, and, among region-based wine groups in the United States, its budget is second in size only to that of the Napa Valley Vintners Association. This identity was not a random outcome, but rather was the result of a vision developed by the early entrepreneurs.

The creation and preservation of shared identities is not always easy. As the value of the Paso Robles identity increased, a group of winemakers located west of Highway 101, which bisects the region, decided that they would be better served with their own AVA, believing that their region produced higher-quality wines. This idea to secede from the larger group was serious because it threatened the value of the hard-won regional identity connected to the Paso Robles AVA label. As the threat grew, the local social networks that had been built earlier defused the controversy, and key Westside winemakers who had initially supported the division withdrew their support. They understood that a new AVA would cause confusion amongst consumers, and, more importantly, the identity that they had established might be perceived as incoherent and inauthentic by outsiders (Beebe et al. 2012). The social networks that had formed and the strength of the identity had become so strong that the notion among Westsiders that they could secure higher prices for their wines with a separate identity was outweighed.

Although most winemakers recognized the power of the Paso Robles identity, there was still a desire for wineries to be able to differentiate themselves within it, acknowledging the differences (e.g., microclimates, soil) that affect wine characteristics within the region. To achieve this, a coalition of winemakers and vineyard owners (emulating the Napa Valley model) successfully proposed to keep the Paso Robles AVA but create sub-AVAs, known as districts. A conjunctive labeling law was passed that stipulates a wine produced in a sub-AVA can feature that district's name but must also feature Paso Robles AVA in equal or greater significance (e.g., Paso Robles AVA, Adelaida District).

Creating regional identities

Like Paso Robles, many recognized regional identities began with a key leader



Vineyards that belong to one of Sonoma County's 16 sub-AVAs display signs featuring the name and logo of their AVA.

or group of leaders initiating a process of organizing and working together to improve joint outcomes. The resulting regional identity is a collective good with shared ownership amongst the members. It cannot be managed as if it belonged to a single firm. Developing internal coherence and community commitment among members is vital for establishing and maintaining the identity; the process is about cooperating with others and establishing a shared vision for the region. The knowledge that is created and the value added to businesses develop the identity into a common resource available to members of the community; in this way, managing a regional identity is like managing a common natural resource, but the challenge is maintaining quality rather than not overusing the resource (Ostrom 2000).

The knowledge that is created and the value added to businesses develop the identity into a common resource available to members.

Creating a geographical area with legally delineated boundaries defines those having a collective interest in the success of the area's identity. For wine, the AVA circumscribes the area and requires growers using the AVA label on their product to ensure 85% of the grape content is grown in the area. This is very different from French wine regions, in which boundaries as well as production practices are strictly regulated. For example, in Bordeaux, a red wine may use the AOC Bordeaux label only if it is made from Cabernet Sauvignon, Cabernet Franc, Carmenère, Merlot, Malbec or Petit Verdot grapes; the minimum sugar content must be 178 grams per liter; the vineyard must have a minimum of 2,000 vines per hectare and a maximum of 60,000 buds per hectare after pruning; and the resulting wine must be tasted and approved by an appointed committee (INAO 1936).

In the United States, instead of strict production rules, quality is maintained by social pressure, a collective interest in protecting the investment in the vineyards and wineries and increases in the value of the region's wines due to the perception of the AVA by outsiders. Members cannot impose direct sanctions on a member winery, but social pressure may be applied (e.g., not exchanging knowledge, not recommending the winery to visitors, criticizing certain wineries in the media or refusing to provide assistance in times of crisis).

These two approaches represent very different tactics: the French system honors tradition and cultural legacy — the classification system originated from an attempt to differentiate wine produced by aristocrats from wine made by commoners (Fourcade 2012) — while the U.S. system spurs innovation while protecting intellectual property rights (Lapsley and Sumner 2014). The remarkable result in the California fine wine AVAs is that even after an identity has been created there has not been a dilution of quality from free riders; rather, the identity dynamics have been so powerful that quality has increased.

Industry clusters

A regional cluster of businesses producing the same or similar products creates an advantageous environment for individual businesses. It also gains external significance beyond the fact of it being a collection of similar businesses in geographical proximity to one another. The significance is evident in the identity of Silicon Valley, not just a number of tech companies, or Hollywood, not just a number of filmmakers, or Napa Valley.

Scholars have observed that, in general, industry clusters have two key characteristics. The first is largely economic and refers to the horizontal structure of colocated competitors and vertical structure of proximate suppliers or customers. This arrangement ensures the constituent firms can attract skilled labor, and educational institutions are encouraged to produce specialized employees and to undertake relevant research.

The second key characteristic of clusters is the knowledge creation and network sharing that emerge. For example, while sitting in a café in the Napa Valley one is likely to hear discussion of wine and grape plant varieties, while in Silicon Valley the overheard discussion is likely to be on the newest Internet social media startup. These are indicators of the vitality of the information flow and, while untraded in a market, they have real economic value (Storper 1995).

Wineries are located in the Napa Valley for the climatic and physical attributes of the area, but knowledge sharing has significant economic value and attracts other, related industries. In industries with a high level of innovation-based value creation, having access to that knowledge means being on the cutting edge of new products and technology (Gertler 2003). In industries such as agriculture, where craft knowledge is important, effective

The Russian River Valley Winegrowers group has an online database of its winegrape growers and has installed signs at all of its member vineyards.

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institutions and mechanisms for sharing knowledge are important; in particular, the knowledge disseminated person to person is of great significance.

Much has been written about the formation and maturation of local industries into globally recognized clusters (Porter 1998). It is now accepted that the growth of these clusters changes the local environment physically, socially and economically (Porter 1998). It is remarkable how they become a magnet for talent, a foundation for the development of public good specialization and the basis of regional pride and cooperation.

Social and business interactions in an industry cluster do not simply generate a regional identity. Identity may emerge through social dialogue among interested local parties and be developed by strong social ties, but purposive action is involved; parties must decide on the key characteristics they want signaled by the shared identity. Regional identities are important because they "affect economic investments, including individuals' decisions about where to locate their talents, entrepreneurs' decisions about where to locate their organizations, and investors' decisions about where to target financial resources" (Romanelli and Khessina 2005).

Brand versus identity

It is commonly believed that identity is synonymous with brand. However, several features differentiate the two. A brand is a form of intellectual property that has significance to consumers and, to at least a certain degree, can be created through advertising alone. Branding does not require the collective activities of the producer community, which is the source of the internal coherence necessary for identity creation. Most often, brand creation is a one-sided process of communicating to external audiences. Brands can certainly have a reputation for quality but when the brand is connected to a regional identity, it has a much greater ability to signal attributes about the region, both literal — producer of fine wines — and ephemeral — place to experience "the good life"— as can be found in the Napa Valley identity (Lapsley 1996). The Napa Valley name has much more meaning than simply producer of excellent wine.

Branding efforts absent this organic, community-derived effort have difficulty appearing authentic because they are perceived as simply the result of marketing. Some wineries have a number of brands, which they market differently. When they sell generic California wine, there is no strong identity associated with the wine and, not surprisingly, it has only weak meaning to consumers and garners a relatively low price in the market. In the traditional branding literature, a brand is often more or less placeless; it is not rooted to a geographic area. In contrast, the fact that the wine is from the Napa Valley AVA or the Alexander Valley AVA signals that the grapes are of high quality, and this has meaning to consumers.

In the United States, some agricultural regions have attempted to create regional brands that include a number of the area's products. Because such a brand is spread across items with diverse characteristics, uses and standards of quality, it is much harder to establish its unique value to consumers, and therefore it is more difficult to charge premium prices. For example, products from a large diverse agricultural county might include marmalade, lamb, peppers, firewood and Christmas trees; a regional brand on all these products delivers a diffuse message. In contrast, a regional industrial identity offers a focused message: for example, not just a wine, but a particular type of wine. In wine regions with well-established identities, members of the industry could recommend what to taste in order to understand the aspects of that region — if you want to taste the Napa Valley, get a cabernet sauvignon, the Russian River Valley, get a pinot noir.

Clear signage can be an important tool for fostering tourism and demonstrating regional cohesion.

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Identity and reputation

To be successful, an identity must be legitimated. Legitimacy accrues in a two-sided process: the identity creation and maintenance by the industry community, which is the internal side of the process; and validation of that identity by key intermediaries and critics, and eventually consumers, on the external side (fig. 1). The success of the identity, its accumulation of legitimacy, is dependent on the interactions between the sides. For example, a region may believe that it produces an excellent bottle of cabernet sauvignon, but if that belief is not shared by significant outsiders, such as wine critics, consumers will perceive the wine as overpriced. Or, if consumers recognize the regional identity, they confer value on the product; but if the product disappoints the consumer, then the regional identity also suffers.

From this mutual dependence between internal and external parties flows one of the most powerful aspects of creating the identity, namely, the community interest in upgrading and investing in quality — further developing the knowledge, skills and technical ability to create higher-quality, higher-value products. In ideal cases, the dynamics between the internal and external parties enable the formation and growth of yet other activities, such as agritourism, that leverage the region's high-quality products as a springboard for further economic development.

In the wine industry, the *Wine Spectator, Wine Enthusiast, Saveur, Food & Wine* and restaurant sommeliers validate

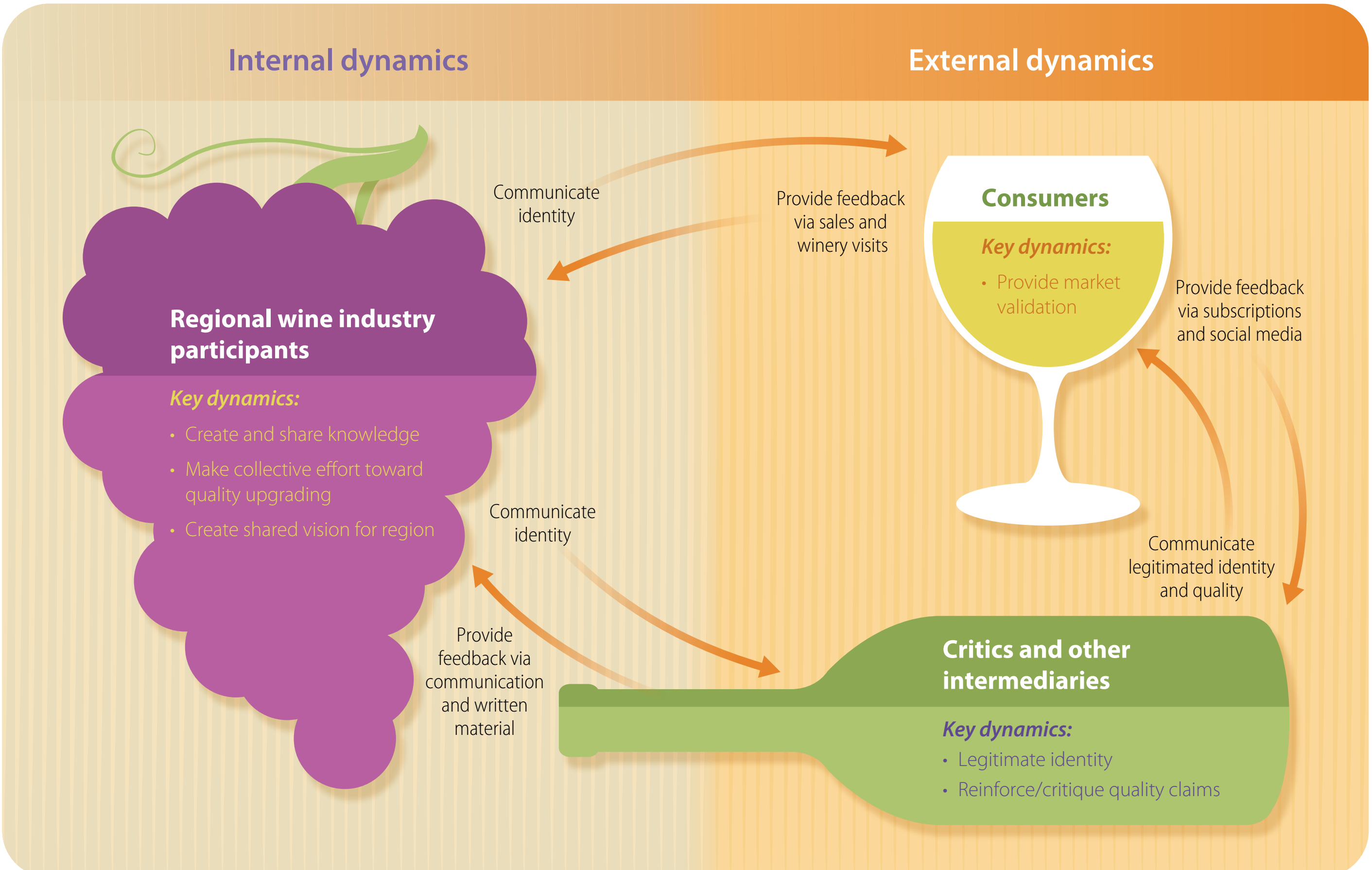

Fig. 1. Identity formation in the wine industry. The first stage of identity creation is for regional wine industry participants to work together to create a shared vision of the region, which includes creating and sharing knowledge that can promote quality upgrading at the regional level. This identity is then communicated to critics and other key intermediaries, who legitimate the identity and quality claims in communications to consumers and back to wineries. Consumers provide validation to the regional wine industry through market sales and winery visits.

a regional identity by informing and educating consumers about it. For other agricultural producers aiming to create an identity, the cultivation, or establishment, of such intermediaries should be a central goal. Conversely, in areas where intermediaries for a product already exist, the product is ripe for identity creation. Intermediaries who can speak to large, dispersed consumer audiences provide an important validating function, more important than direct marketing.

Other strategies for increasing external visibility, and validation, include establishing events such as festivals. The Paso Robles Wine Festival was very effective at garnering external attention, especially in its largest primary market, Los Angeles. As the festival expanded each year, the external awareness of local wines increased. Local winemakers cultivated informal relationships with the Los Angeles entertainment industry, encouraging filmmakers to make films or television programs in the region. This media attention helped validate Paso Robles as a fine wine region with attractive tourist locations. Nearby, in the Santa Barbara area, filmmakers featured local wines in several films, including *Sideways*, which significantly increased sales for the region's wines.

U.S. versus European models

As mentioned previously, the U.S. and European models for creating and legitimizing agricultural identities differ. AVAs and French appellations, such as AOC Bordeaux, are geographical indications (GIs) formalized by the World Trade Organization in 1994 in the Agreement on Trade-Related Aspects of Intellectual Property Rights. Both provide intellectual property rights to agricultural producers, protecting producers from fraudulent products made outside of the region or with nonconforming ingredients. GIs are a form of legitimization by governments; they signal that a group of producers has organized and created a petition for why their products are unique and should be protected. The presence of a GI may indicate that an agricultural identity exists for a region, but it does not guarantee that one exists. There has been much research on the potential for GIs to promote economic development and increase added-value, but the results are mixed and depend on the socio-political structure of the region (Parasecoli and Tasaki 2011), or as we argue, the presence of identity creation dynamics.

The strong identities associated with the GIs of Champagne, Parma and Bordeaux are built around the cultural heritage and traditions of the regions. In general, U.S. producers cannot draw upon deeply embedded regional cultural traditions. Napa Valley, the most famous wine region in the country, has been known for its distinctive wines only since the 1970s. Regional agricultural identity in the

United States must be based instead on a pursuit of quality. This freedom from cultural tradition allows the development of innovative products, but producers must adhere to a perception of quality that is more rigorous and highly contested because the power to determine quality is spread out amongst a variety of actors throughout the supply chain as opposed to one small group of experts (Murdoch and Marsden 2000). How actors in the supply chain define quality and how they effectively create institutions to support their notion of quality is an area of research that we are currently pursuing.

Sonoma County

As recognition of the importance of identity increases, agricultural regions are trying to sort out what their identity should be. The identity formation process undertaken by one region may significantly differ from the process in other regions, depending on local social, geographical and product characteristics. Sonoma County has wrestled with how to build its identity. Should it follow Napa, which has an identity as a county (only a few areas of Napa County are not part of the Napa Valley AVA), or should it be like Paso Robles, which is part of San Luis Obispo County?

Sonoma County encompasses a large area with a mix of landscapes and climates, very different from the more homogeneous geography of Napa or Paso Robles, and it has 16 AVAs ranging in size and reputation. As in Paso Robles, producers enacted a conjunctive labeling law; all wine made in the county must have the words "Sonoma County" on the label. However, the law was much more contentious in Sonoma than in Paso Robles, and numerous growers, wineries and other industry participants are opposed to it.

The salient question is which identity will be legitimated and drive a collective upgrading process? Is there countywide sharing and solidarity, with strong ties binding the whole county together; or do the different regions in Sonoma County have their own character, industry organization, information flow patterns and cultures? From the external perspective, will key opinion-makers recognize the Sonoma County identity, or will they insist on referring to the various AVAs separately? Or alternatively, might there be a hierarchy of identities, with the individual AVA identity nestled within the county identity? The answers to these questions will determine whether conjunctive labeling is successful or obscures the current AVA identities.

Potential for other industries

Identity has long had a role in the wine industry. A strong regional identity could help expand the sales of other agricultural products, even globally. Many agricultural products in California are produced at a scale that far outstrips local demand; for example, the Bay Area foodshed, the growing area within a 100-mile radius of San Francisco, produces annually around 20 million tons of food, yet the local population consumes only 5.9 million tons (Thompson et al. 2008). Cultivating strong regional identities could upgrade, and add value to the region's products for export sales.

Outside of California, products such as coffee and tea have an identity component (e.g., Kona coffee, Darjeeling tea), though there has been little active effort to build strong identities for most of them. Scotch, Calvados and, more recently, Kentucky bourbon whiskies have such identities. Agricultural industries differ significantly from the wine and beverage industries, but regional leaders should still consider whether a regional industry identity could be built. While not all agricultural products can be transformed from commodity products into unique cultural goods that have other values embedded in them, thus making them more economically valuable, the task is to think creatively about possibilities and work collectively to bring them into existence.

Olive oil, hops, cheese. The California olive oil industry is certainly ready for regional identity creation, and boutique olive oil tasting rooms in and around production areas, as well as in San Francisco, could communicate the qualities of the oils and reinforce the identity. Regional hops organizations could partner with the many California breweries emerging throughout the state. The artisan cheese industry in Northern California continues to grow and gain recognition; many opportunities exist for cheese tasting rooms and an organized effort to highlight regional cheese specialties. Above all, these regional industries must communicate to consumers and opinion-makers the internal cohesion and collective effort among the producers to upgrade quality.

Organic products. Often mentioned is the possibility of developing regional identity on the basis of organic production, but most regions produce a large

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An Alexander Valley vineyard near Healdsburg in Sonoma County.

number of crops, making it hard to create a crisply focused identity. Further, the producers may see themselves almost entirely as competitors and thus be unwilling to share information and knowledge. Also, there may not be agreement on the goal — for example, to produce organic foods or high-quality foods? Does an organic tomato from the region have meaning that is resonant with consumers? Does an organic potato have a similar meaning? Using organic production as a way to get to higher quality might be a useful approach, but consumers' associating organic with quality is different than their associating a region with quality. If another region focuses on organic production, these regions are then competing in the organic market instead of creating a market niche for each region.

Local products. Locally produced food is one of the fastest-growing market segments within agriculture, but California produces more food than it can consume, so proximity of production is unlikely to work as the basis for an economically successful regional identity. Local production captures local dollars; whereas identity-laden products are focused on high-value markets external to the region. Also, for relatively durable goods, such as olive oil, distinctions of quality are hard to embed solely within notions of proximity and freshness.

Apples. Apple Hill in El Dorado County has built some level of external recognition for its apple production, though mostly only in the Sacramento area. There has been limited evidence of — but also little research on — internal information sharing and cooperation among producers to improve quality. At this point, Apple Hill is a seasonal destination during the apple harvest; the production of less perishable apple-derived products extend the season and further add value. A significant opportunity exists for apple growers to take advantage of the growing interest in alternative alcoholic beverages by producing regionally distinct hard ciders or Calvados-like apple brandies. Some apple-growing regions, such as around New Berlin, Wisconsin, have focused a regional identity on antique apple varieties and connected the flavor profiles of the apples to the terroir of the land; these apples can be found in many of the high-end restaurants throughout the Midwest.

Adding value through identity

We have argued that a regional industry identity, though often not considered a significant economic variable, could, on the contrary, be of great significance for producers of distinct agricultural products. Developing identity is not a panacea for the difficulties of increasing income from agricultural products, but it has the potential to create new ideas for adding value. Improved communication and information sharing within the region could increase industry solidarity and, of particular importance for creating higher value, improve quality.

A regional identity may also benefit other industries and increase rural income. The Napa Valley has become one of the largest tourism destinations in the United States; Paso Robles also is developing an increasingly significant hospitality industry. Lastly, for producers increasingly pressured by low-cost imports, environmental demands and labor cost increases, identity development ideas can offer a basis for changing current income trajectories. CA

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The agritourism industry in Apple Hill (El Dorado County), initially based on apple production, has expanded to include wineries and Christmas tree farms.

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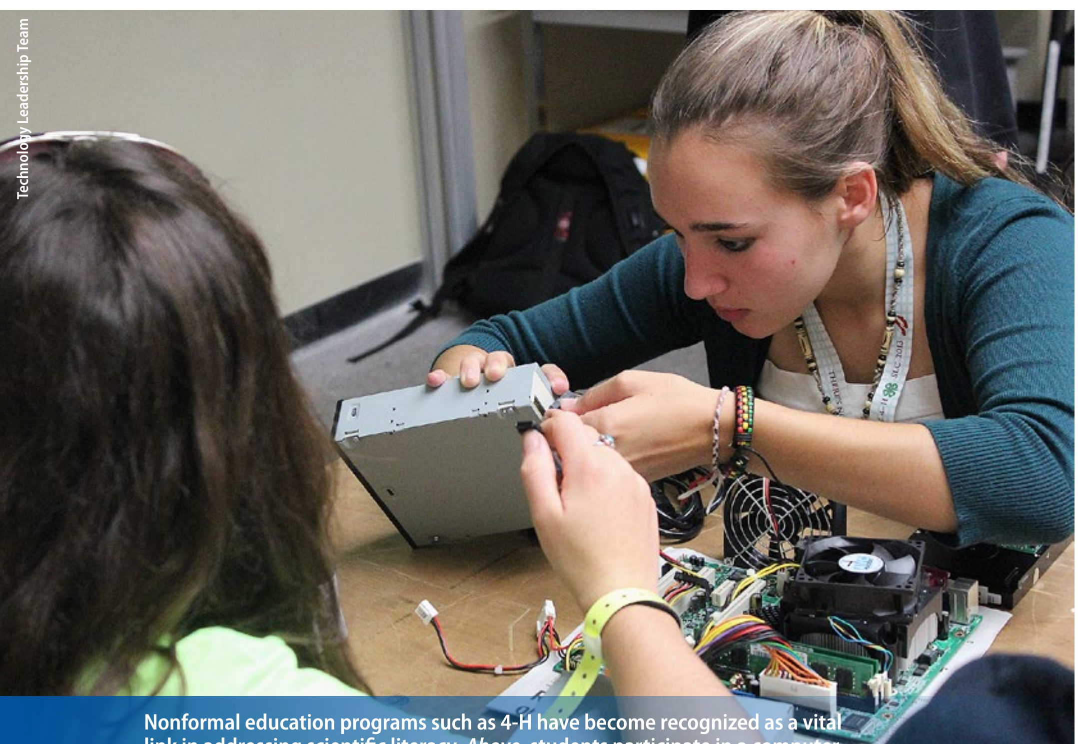
Research Article

Scientific literacy: California 4-H defines it from citizens' perspective

by Martin H. Smith, Steven M. Worker, Andrea P. Ambrose *and* Lynn Schmitt-McQuitty

Scientific literacy is an important educational and societal goal. Measuring scientific literacy, however, has been problematic because there is no consensus regarding the meaning of scientific literacy. Most definitions focus on the content and processes of major science disciplines, ignoring social factors and citizens' needs. The authors developed a definition of scientific literacy for the California 4-H Program from the citizen's perspective, concentrating on real-world science-related situations. The definition includes four anchor points: science content; scientific reasoning skills; interest in and attitudes toward science; and contribution through applied participation. The definition provides the California 4-H Science, Engineering, and Technology Initiative with a framework for future science curriculum and program development and implementation, educator professional development, and evaluation.

It is widely agreed that scientific literacy is an important educational and societal goal (e.g., NAS 2007). Scientific literacy targets socially responsible and competent citizenry in that it enables individuals to participate in and contribute to a society that is shaped ever more by advances in science and technology (NAS 2007). However, scientific literacy is low among U.S. youth; poor achievement in science among K-12 students on large-scale assessments (e.g., NCES 2011) has raised national concerns (NAS 2007). Youth who lack foundational knowledge and skills in science will neither be able to pursue science careers nor participate fully in helping to address challenges such as climate change, future energy resources and consumer food choices (NAS 2007).



Technology Leadership Team

Nonformal education programs such as 4-H have become recognized as a vital link in addressing scientific literacy. *Above*, students participate in a computer hardware workshop at the California 4-H State Leadership Conference.

Addressing scientific literacy was identified as a Strategic Initiative of the 21st Century in the UC Agriculture and Natural Resources (UC ANR) Strategic Vision 2025 (Regents of UC 2009), a vision statement to help guide UC ANR research and extension programs through the early part of the 21st century. Advancing scientific literacy is described there as critical to "our collective future." Strategies outlined to help increase scientific literacy through UC ANR included the development, evaluation and extension of science education programs for youth that use effective pedagogy and increase civic engagement.

While there is agreement that advancing scientific literacy among K-12 youth is important, measuring it has been problematic since there is no consensus about the meaning or component parts of scientific literacy (DeBoer 2000; Roberts 2007). Although "a veritable deluge of definitions" (Roberts 2007, 729) have been developed, most have focused principally on the content and processes of major science disciplines while ignoring "the social aspects of science and the needs of citizenship" (Lang et al. 2006, 179). Furthermore, strategies used to assess scientific literacy have operated traditionally from a deficit-based viewpoint of what individuals should know about key science concepts considered to be important by scientists (Falk et al. 2007; Laugksch 2000).

Falk et al. (2007) postulate that science learning is contextualized; persons within a community have unique science knowledge bases due to the fact that each

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n02p92&fulltext=yes
doi: 10.3733/ca.v069n02p92

individual develops "an understanding of a specific area of science because of his or her unique, personal set of needs and desires to know about this area of science" (458). They argue further that an asset-based approach to assessing science understanding is more appropriate than a deficit-based strategy. In this scenario, measurements of scientific literacy focus on individuals' science understanding and abilities within relevant contexts (Falk et al. 2007). Referred to also as a sociological approach to assessing scientific literacy, this type of measurement involves small-scale contextualized studies rather than large-scale investigations that require representative samples from populations (Laugksch 2000).

Defining scientific literacy or describing its component parts is critical in order for the work of science program development to progress. The absence of a definition or agreed-upon understanding makes it challenging to develop and compare science programs, evaluate pedagogical strategies and perform outcome evaluations (Roberts 2007). However, because science learning is a function of context, attempting to reach consensus on a universal definition is imprudent (Roberts 2007). Therefore, any definition of scientific literacy "should be conceptualized broadly enough . . . to pursue the goals that are most suitable for [a given] situation" (DeBoer 2000, 582).

Learning environments

Science learning environments may be classified into three types: formal, nonformal and informal. Formal science education programs are classroom based, occurring in K-12 schools during school hours, with instruction facilitated by trained teachers (Carlson and Maxa 1997). Nonformal science education programs (e.g., 4-H, Girl Scouts, summer science camps) occur during out-of-school time and are normally led by adult staff or volunteer educators (Carlson and Maxa 1997; Walker and Dunham 2002). Informal science education programs (e.g., museums, zoos, technology centers and aquaria) occur outside of a school setting during out-of-school time and learning is typically self-directed (Carlson and Maxa 1997).

4-H science education

Nonformal education programs have become increasingly recognized as a vital link in addressing scientific literacy (Falk et al. 2007; National Research Council 2009). The 4-H Youth Development Program is a nonformal youth education program administered through the national Cooperative Extension system. Grounded in positive youth development practices that are focused on helping youth reach their fullest potential, 4-H offers curriculum projects and activities through county-based programs in all 50 states, the District of Columbia and internationally. With a diverse array of science-based curricula and resources ranging across multiple disciplines (UC ANR 2013), 4-H science programming is facilitated by staff and volunteers through hands-on experiential learning and inquiry strategies (Enfield et al. 2007).

In 2008, National 4-H strengthened its commitment to science education by introducing the 4-H Science Mission Mandate (4-H Science). This national effort provided strategic direction to improve science curricula and resources, professional development of staff and volunteers, partnerships with local, state and national organizations and agencies, fund development and evaluation. In response, the California 4-H Youth Development Program established its 4-H Science, Engineering and Technology (SET) Initiative (UC ANR 2008). The primary goals of the initiative are to improve youth scientific literacy through effective programming and advance the research base of nonformal youth science education (Worker and Smith 2014). During the 2013–2014 program year, 82,545 youth participated in SET projects in California (California State 4-H Office 2014).

4-H science programming is grounded in effective science pedagogy and positive youth development practices. Individuals develop an understanding of subject matter and advance their abilities through interactions with their environment that include youth-led investigations, active questioning, facilitated reflection

The Sacramento County 4-H Children, Youth and Families at Risk project focuses on science and technology literacy in its afterschool program.

Marianne Bird

and the application of knowledge and skills in ways that address real-world issues (Carver and Enfield 2006). Specific youth development practices are adapted from the National Research Council and Institute of Medicine (NRC/IOM) (2002), which include physical and psychological safety, supportive relationships, youth engagement, community involvement and opportunities for skill building. The targeted youth development outcomes are the six C's of positive youth development — caring, contribution, confidence, competence, character and connection (Lerner et al. 2010).

Citizens' perspective

Historically, as mentioned above, most definitions of scientific literacy have focused on generalized knowledge related to major science disciplines, principally content and processes germane to scientists as opposed to unique contexts or situations where science is of relevance to individual citizens (Roberts 2007). These "within science" definitions represent what Roberts (2007) referred to as a Vision I perspective of scientific literacy that is situated within the disciplines of science. In contrast, a Vision II perspective focuses on situations whereby scientific literacy is positioned from the viewpoint of the citizen and concentrates on science-related situations individuals may encounter in their lives (Roberts 2007). Although elements of both Vision I and Vision II are typically incorporated into definitions of scientific literacy in what Roberts (2007) refers to as "a kind of mating dance wherein they complement one another" (730), starting from a Vision II perspective is important when viewing science learning as a contextualized phenomenon.

A Vision II perspective is essential to define scientific literacy within the context of the California 4-H Youth Development Program. California 4-H educational programming is guided by environmental, social and economic issues (e.g., water conservation, quality and security; alternative energy; food safety and security) outlined in the UC ANR Strategic Vision 2025. A Vision II perspective allows the component parts that comprise scientific literacy to be specified broadly enough that they address these diverse societal issues yet also provide opportunities to develop 4-H science programming that is culturally relevant and specific to individual county-based 4-H programs.

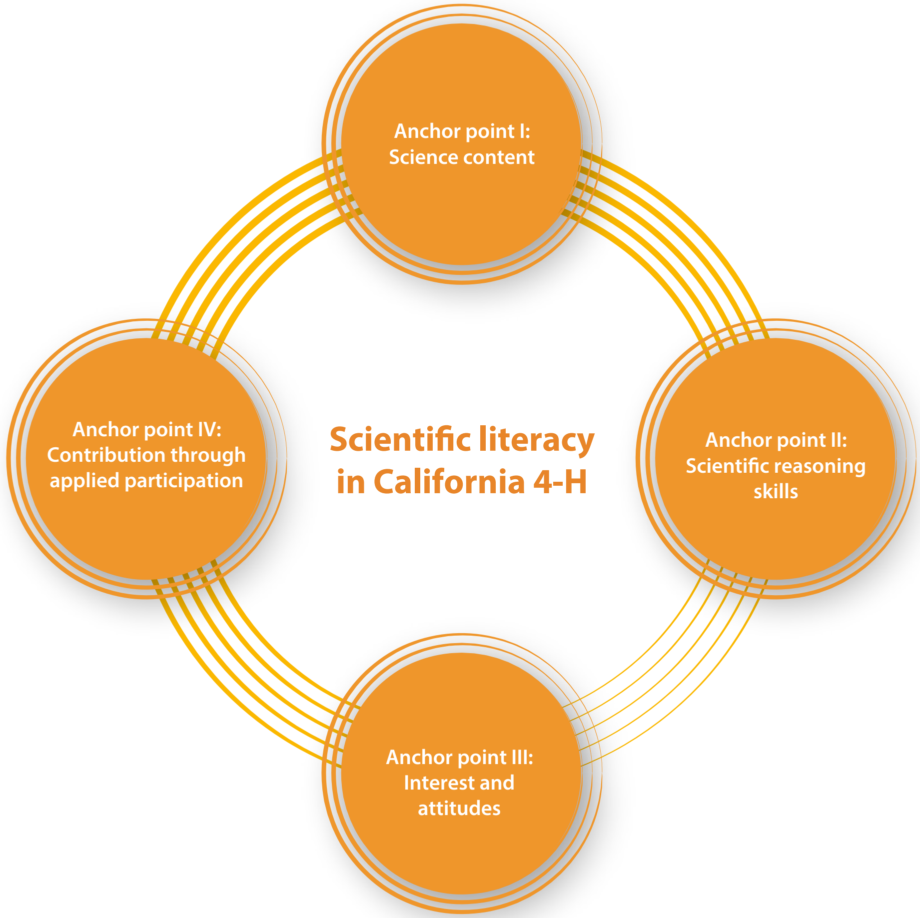


Fig. 1. Anchor points for youth scientific literacy in California 4-H.

Despite the importance of a Vision II perspective, however, elements of Vision I cannot be ignored. The issues facing California outlined in the UC ANR Strategic Vision 2025 require science- and research-based solutions. Thus, specific science content and practices (Vision I) remain critical to developing scientific literacy within California 4-H and must be incorporated effectively into science programming.

Anchor points

For the purpose of connecting a definition of scientific literacy within the context of California 4-H to previously published work, the authors completed a systematic, analytical literature review (Steward 2004). Specifically, the literature review synthesized key themes from relevant, peer-reviewed resources to help develop new ideas and understanding. Informed by this literature review, the authors identified four anchor points to define scientific literacy within the context of California 4-H: science content; scientific reasoning skills; interest and attitude; and contribution through applied participation (see fig. 1). These anchor points provide guideposts for curriculum and program development, teaching and evaluation, and are flexible enough for adaptation to local needs and situations.

Anchor point I: Science content. Content understanding is a key component of scientific literacy (Roberts 2007). However, rather than viewing scientific content as a generalized body of knowledge from the perspective of what scientists need to know (Vision I), the focus of this anchor point is on science-related content associated with issues relevant to citizens of California (Vision II) that were identified in collaboration with stakeholders from throughout the state (Regents of UC 2009). Specific examples include water resource management; sustainable food systems; sustainable natural ecosystems; food safety and security; management of endemic and invasive pests and diseases;

energy security and green technologies; and nutrition education and childhood obesity.

Anchor point II: Scientific reasoning skills. Scientific reasoning includes, generally, the cognitive skills needed to understand and evaluate scientific information (Giere et al. 2006). More specifically, it includes skills necessary to engage in the practices of science, such as asking questions, collecting data, analyzing and interpreting evidence, developing and using models, planning and carrying out investigations, making inferences and constructing explanations based on data, engaging in argumentation from evidence and communicating results (National Research Council 2012). Scientific reasoning skills are linked closely to the development of scientific knowledge. To make sense of scientific content, learners require reasoning skills so they can critique their knowledge claims and the claims of others (Ford 2008).

Anchor point III: Interest and attitudes. Enhancing interest in and attitudes toward science is essential to advancing scientific literacy among youth and the general population (National Research Council 2009). The authors included this as a third essential component for scientific literacy within the context of California 4-H, and it can be considered from both Vision I and Vision II perspectives: (1) education- and career-related choices are shaped by interest and attitudes (Else-Quest et al. 2013) and therefore can improve the likelihood that individuals will pursue careers in science (Vision I); and (2) interest and attitudes influence individuals' motivation, behavior and responses to science-related situations they encounter in their everyday lives (Bybee and McCrae 2011). Improved motivation can enhance willingness to engage in science-related issues as citizens in meaningful ways (Vision II) (Bybee and McCrae 2011). Furthermore, improving interest in and attitudes toward science is particularly relevant to women and ethnic minorities, groups that have more limited educational opportunities in science and are underrepresented in science-related careers (e.g., Else-Quest et al. 2013).

Anchor point IV: Contribution through applied participation. The authors identified the authentic application of knowledge and skills — application to real-world issues — as the fourth critical component for advancing scientific literacy within California 4-H. In order to enhance understanding and appreciation of context-specific science, Falk et al. (2007) advocate engaging the public in science by offering authentic, community-based opportunities related to the science they need or that interests them. The application of knowledge and skills in real-world contexts helps youth advance their critical thinking skills, gain a deeper understanding of science content (Jones 2012) and begin to identify with a larger scientific community (e.g., National Research Council 2009). Furthermore, community engagement in science promotes lifelong learning, allows for authentic participation at multiple levels (Lave and Wenger 1991), favors autonomous thinking and is a key element of experiential learning (Kolb 1984). In 4-H, community engagement is frequently carried out through service learning whereby youth apply knowledge and skills to address authentic community needs (e.g., Smith et al. 2010).

Advancing 4-H science

Emphasizing a "focus-on-situations approach" (Vision II) within the context of California 4-H provides opportunities for the systematic advancement of the 4-H SET Initiative using an asset-based approach to understanding science. This strategy emphasizes relevant science knowledge that individuals learn for different reasons, including interest, need and curiosity. The anchor points will be implemented by the California 4-H SET Initiative beginning in 2015. They will help California 4-H administrators, academic staff and program staff to: frame the development and adaptation of curriculum materials; shape the content and design of professional development for 4-H staff and volunteers; and use consistent outcome goals for program evaluation.

Curriculum development and adaptation. Deng (2011) describes three levels of discourse regarding curriculum development: institutional, "that which is valued and sought after by members of a society" (46); programmatic, which refers to the translation of institutional goals into curriculum documents and materials; and classroom, that, when viewed broadly, refers to the implementation of curriculum activities by educators with their target audiences. By defining scientific literacy using a Vision II perspective, the institutional and programmatic levels of discourse concerning curriculum development in California 4-H will be driven by issues and situations important to citizens of California outlined in the UC ANR Strategic Vision 2025. Furthermore, all curriculum materials, regardless of science content area, will attend to anchor points II (scientific reasoning skills), III (interest and attitudes) and IV (contribution through applied participation). The classroom level of discourse — curriculum implementation — will be determined by the needs and interests of youth in individual county-based 4-H programs. This will allow each county-based program to work collaboratively with internal and external stakeholders and focus on specific issues within their county or region.

Professional development. The knowledge and skills of science educators have a demonstrated positive effect on learner outcomes; therefore, professional development to build educators' capacity is

Enhancing interest in science is essential to advancing scientific literacy among youth. *Right*, San Mateo County 4-H members feeding goats.

Steven Worker

Applying knowledge to real-world issues is a critical component of scientific literacy. *Above*, planting the millionth tree in the 4-H Million Trees Project, which was created by a 4-H member to reduce atmospheric carbon dioxide.

an essential investment to advance science learning (Stiles and Mundry 2002). In California 4-H, effective professional development is needed to build the capacity of staff and volunteers to understand the 4-H SET Initiative and implement effective nonformal science programming (Schmitt-McQuitty et al. 2014; Smith and Schmitt-McQuitty 2013).

Utilizing a Vision II approach to defining scientific literacy will help in designing professional development opportunities for 4-H staff and volunteers that incorporate specific features considered critical to advancing the knowledge and skills of science educators: emphasis on subject matter knowledge (e.g., Penuel et al. 2007); and linking professional development to broader organizational goals (e.g., Loucks-Horsley et al. 2003). For 4-H, the subject matter and organizational priorities will be the science-related issues of importance to California citizens.

Evaluation. The evaluation of nonformal science learning involves members of the target audience demonstrating “how they understand science concepts and make connections between concepts and skills and their lived experiences” (Cox-Petersen and Olson 2002, 105), their attitudes towards science (Osborne et al. 2003) and interest in science learning activities (Krishnamurthi et al. 2013). When viewing evaluation in this manner, the four anchor points provide a framework for consistent, measurable learning goals that can be used for formative (program and activity improvement) and summative (outcome) evaluation of California 4-H SET programming. Formative assessment using the four anchor points will be used to provide data-driven improvements with respect to the development and adaptation of curriculum materials, state and county-based science programming, and educator professional development. Summative evaluation will target the four anchor points through the use of appropriate evaluation methods. Specifically, the assessment of content understanding (anchor point I) and contributions made by learners through applied participation (anchor point IV) will be designed around the specific environmental, social and economic issues outlined in the UC ANR Strategic Vision 2025 that are being addressed through 4-H SET programs. Scientific reasoning skills (anchor point II) and interest and attitudes (anchor point III) will be measured in all content areas and will provide the opportunity for comparisons across 4-H SET programs.

Benefits to California. Most aspects of 21st century life are impacted by science. Associated political and economic challenges are complex and related decisions require sound choices made by a scientifically literate populace (NAS 2007; Regents of UC 2009). From this perspective, scientific literacy can be viewed as an essential form of human capital, one that is critical to developing an informed and economically competitive societal infrastructure with a productive and efficient workforce (McEneaney 2003). Accordingly, increasing scientific literacy can help advance economic prosperity, enhance environmental sustainability, develop energy technologies and improve human health (NAS 2007; Regents of UC 2009).

Increasing scientific literacy can help advance economic prosperity, enhance environmental sustainability, develop energy technologies and improve human health.

When viewing scientific literacy from the perspective of societal infrastructure, it is important to acknowledge the intersection between science and society and the changing relationship between science and the public. By emphasizing a focus-on-situations approach to scientific literacy (Vision II) (Roberts 2007), the intersection between science and society involves citizens in framing and resolving scientific issues as opposed to the previous social contract science had with society that was based on a degree of separation between scientists and the public (Gibbons 1999). Gallopín et al. (2001) and Gibbons (1999) discuss the importance of developing a new contract between science and society, one where science has a more pragmatic aim that involves the public in identifying and addressing relevant issues, works within real-world contexts and produces new knowledge, products and processes that address specific societal needs.

Improving youth scientific literacy through a Vision II approach can help strengthen California’s economy by building the capacity of the future workforce and advancing a new social contract between science and society. By focusing on science-related situations youth may encounter in their daily lives, educators can help advance their scientific literacy in a manner that enables them to address relevant issues related to agriculture, the environment and human resources outlined in the UC ANR Strategic Vision 2025. According to Feinstein (2011), this is the fundamental usefulness of scientific literacy: Helping individuals address “meaningful problems in their lives, directly affect their material and social circumstances, shape their behavior and inform their most significant practical and political decisions” (169).

Beyond California 4-H. The definition of scientific literacy using four anchor points developed for the California 4-H Youth Development Program is adaptable for use by other state 4-H programs. Since the National 4-H Youth Development Program includes, by its nature, 50 context-specific state programs, each addressing particular needs relative to the youth populations they serve, the focus-on-situations approach (Roberts 2007) used for California 4-H could be modified and positioned around issues relevant to circumstances in each state.

Specifically, anchor points I (science content) and IV (contribution through applied participation) provide for adaptability within different contexts. Individual state 4-H programs could identify relevant content and associated service learning projects that provide youth opportunities for applied participation. For example, science-related issues around marine ecology could be a subject matter and service learning focus for 4-H programs in some coastal states, whereas sustainable agriculture might be a concern germane to citizens in crop-producing states in other parts of the country. In comparison, anchor points II (scientific reasoning skills) and III (interest and attitudes) are broad constructs that could remain consistent across diverse subject matter areas within different contexts.

Implications for 4-H science

The four anchor points identified as the component parts to scientific literacy will provide California 4-H with a consistent framework for science curriculum and program development and implementation; educator professional development; and evaluation. More specifically, this focus-on-situations perspective (Roberts 2007) will center science education programming on science-related issues to California as defined by the UC ANR Strategic Vision 2025 and measurements of scientific literacy will utilize an asset-based approach grounded in individuals' understanding and abilities within areas of science germane to their needs and interests. Additionally, further work will focus on the extent to which the four anchor points support the evaluation of scientific literacy. Lastly, the definition of scientific literacy developed for the California 4-H Youth Development Program is broad enough that it can be adapted for use in other contexts. CA

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WIC fruit and vegetable vouchers: Small farms face barriers in supplying produce

by Shermain Hardesty, Penny Leff, Aziz Baameur, Jose Luis Aguiar, Manuel Jimenez, Yelena Zeltser *and* Lucia Kaiser

By October 2009, all 50 states had implemented a revised WIC program with produce vouchers for millions of eligible families. USDA economists had projected the vouchers would raise net farm revenues by $76 million. In response to such a significant policy change and market opportunity, a UC Agriculture and Natural Resources Cooperative Extension team of researchers conducted a pilot project to test the ability of small farms to market produce locally to WIC-authorized stores known as A-50 vendors. They also interviewed store owners and produce distributors to determine how produce was entering the supply chain to the A-50 vendors. The pilot project was not successful in helping small growers enter the supply chain. The analysis indicates that it is improbable that small farms will be selling much produce to A-50 vendors; growers' price expectations are unlikely to be met since these vendors are competing with large retailers. And although the vouchers can be redeemed at farmers markets, very few are because the process is cumbersome for growers and shoppers.

As of October 2009, all 50 states had introduced produce vouchers as part of a federal food assistance program that was projected to generate significant increases in fruit and vegetable sales and new opportunities for growers. The federal Special Supplemental Nutrition Program for Women, Infants and Children (WIC) began distributing monthly fruit and vegetable vouchers (F&V vouchers) to program clients. The cash-value vouchers were originally $6 per child between 1 and 4 years old and $10 per woman; in June 2014, the voucher for children increased to $8 (USDA FNS 2007). The cost of adding F&V vouchers to the specific foods and amounts that may be purchased with vouchers each month was offset by reducing monthly allowances for infant foods, milk, cheese, infant formula and other dairy products, as well as for juice and eggs.

The F&V vouchers had been long awaited by the produce industry (Karst 2009). WIC serves about 9 million low-income women, infants and children each month, including about half of the infants in the United States (USDA ERS 2012). In their analysis of the potential impact of the policy changes on WIC expenditures, U.S. Department of Agriculture (USDA) economists projected a net increase of $76 million in farm revenues from the F&V vouchers (Hanson and Oliveira 2009).

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A-50 vendors play a significant role in the distribution of fresh produce to WIC clientele in California, handling 28% of the redeemed fruit and vegetable vouchers.

Early findings

In a pilot study conducted in California in 2001 using cash-value vouchers for fruits and vegetables, 90.7% of the farmers market vouchers and 87.5% of the supermarket vouchers were redeemed by WIC participants (Herman et al. 2006). A California study that involved cross-sectional telephone surveys in September 2009 and March 2010 reported small but significant increases in fruit and vegetable intakes by WIC clients and their families (Whaley et al. 2012). Similar findings were obtained in a Connecticut study by Andreyeva et al. (2012); they determined that the availability of fresh fruits and vegetables increased significantly at A-50 stores, but there was no increase at other stores that accepted the vouchers, such as supermarket chain stores. (An A-50 vendor is a WIC-authorized store with more than 50% of its food revenues generated from sales of WIC foods.)

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n02p98&fulltext=yes

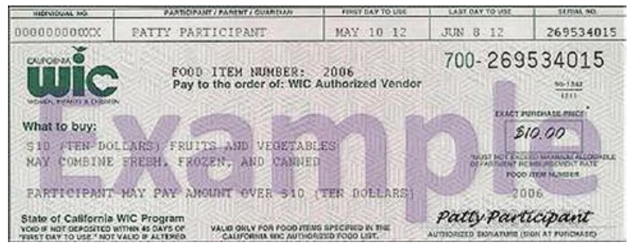
doi: 10.3733/ca.v069n02p98

In a 2010 telephone survey of 52 managers of small WIC-authorized stores in eight major cities, most perceived their increased sales of fresh fruits (75%) and vegetables (69%) as due to the F&V vouchers; no changes in sales were reported for processed (canned and frozen) fruits and vegetables (Ayala et al. 2012). Managers who reported a daily delivery of fruit to their stores were more likely to perceive a greater increase in sales, implying that the freshness and higher quality led WIC clientele to purchase more fruit. This is consistent with earlier findings from our project — interviews in 2010 of ethnically diverse WIC participants in Tulare, Alameda and Riverside counties indicated that the key factors determining their produce purchase decisions were produce quality and freshness (Kaiser et al. 2012).

The F&V voucher program

California's Department of Public Health administers the state's WIC program. Federal regulations set the parameters for the amounts and types of foods allowed to be distributed to different categories of WIC participants: pregnant, nursing or postpartum women; infants (0 to 11 months); and children (12 to 60 months) (USDA FNS 2007). States are required to offer at least two fruits and two vegetables — fresh, canned, frozen and dried fruits and vegetables are all allowed — but states may impose more stringent requirements. WIC-approved vendors in California must offer at least five varieties each of fresh fruits and vegetables, in addition to fresh bananas. Twelve states allow only fresh fruits and vegetables; California is one of 24 states that also allows canned and frozen fruits and vegetables. The produce items not allowed are listed by Kaiser et al. (2012).

WIC clientele can redeem food vouchers at various types of retail outlets (states have the option of allowing participants to redeem vouchers at farmers markets also; California does allow redemptions at farmers markets). Only F&V vouchers have a stated cash value. The other WIC food vouchers are redeemable for allowable products in the food product category; for example, the cereal voucher is redeemable for a package of cereal that is on the list of approved brands, is at least 51% whole grain and weighs between 12 to 36 ounces. The entire F&V voucher must be redeemed in a single transaction. If the purchase value is less than the voucher amount, no change is given. If the purchase value is more than the voucher amount, the WIC client must pay the difference or charge it against her food stamp benefits.



In California, WIC produce vouchers may be used to purchase fresh, frozen or canned fruits and vegetables.

Giving a cash value to the F&V vouchers introduced an element of price sensitivity to WIC clients' shopping practices that had not existed before, and created competition among vendors for WIC shoppers. Each retail chain or store owner determines the quantity and quality of produce that can be purchased with the F&V vouchers. Until F&V vouchers were added, A-50 vendors competed only on nonprice factors, such as brand selection and location (McLaughlin et al. 2013).

There were 42,651 WIC vendors nationwide in 2010, with WIC redemptions totaling $4.1 billion (Mantovani 2012). In California, there were 5,426 WIC-authorized vendors as of June 19, 2012. The overall redemption rate for F&V vouchers during 2011 was 90.7% in California. Redemptions totaled $87.7 million in both 2011 and 2012 (amounting to roughly 1.7% of total retail produce sales in the state); they are displayed by vendor type in table 1.

A-50 vendors play a significant role in the distribution of fresh produce to WIC clientele in California, handling 28% of the redeemed F&V vouchers. In 2004, 15 states had A-50 vendors, and of those 1,180 vendors, 715 were in California (US General Accounting Office 2006). A-50 vendors include small food markets that serve primarily WIC participants and WIC-only stores, which carry only WIC products. California now has approximately 900 A-50 vendors; they constitute 15% of the state's authorized WIC vendors and account for more than one-third of the state's total WIC redemptions (McLaughlin et al. 2013).

UCCE farm-to-WIC project

In 2010, our team of UC Agriculture and Natural Resources Cooperative Extension (UCCE) academics initiated a pilot project to test the ability of small

TABLE 1. California F&V voucher redemptions by vendor type, 2011 and 2012

	2011*			2012†		
Vendor type	Vouchers redeemed	Value	Total redemption dollars	Vouchers redeemed	Value	Total redemption dollars
		$	%		$	%
Chain store (7+ stores)	6,658,218	45,057,890	51.37	6,664,185	45,573,451	51.96
WIC A-50 vendor	3,586,749	24,809,745	28.28	3,479,719	24,359,392	27.77
Neighborhood store (2 to 6 stores)	1,552,662	10,505,582	11.98	1,598,669	10,913,381	12.44
Independent (single store)	1,070,429	7,296,406	8.32	995,148	6,828,755	7.79
Farmers market	5,376	36,403	0.04	4,979	33,923	0.04
Total	12,873,434	87,706,026	100.00	12,742,700	87,708,902	100.00

* Source: Tawny Cowell, California Department of Public Health, pers. communication.
† Source: Paula Griffin, California Department of Public Health, pers. communication.

farms to market produce to WIC clients. The project tried to connect small-scale growers with local A-50 vendors in three counties: Alameda (highly urbanized), Tulare (largely rural) and Riverside (mixed) (Kaiser et al. 2012). It had two objectives: (1) to enhance small growers' financial viability and access to new markets and (2) to provide WIC clients with better access to more nutritious, high-quality, culturally preferred produce and expanded nutritional knowledge. As noted by Campbell et al. (2013), this is a challenging undertaking; their literature review describes the tension between the prices needed to support small-scale growers and the affordable healthy food sought by low-income consumers. Our interviews in 2010 revealed the same tension: "small stores in low-income urban and rural neighborhoods find it challenging to supply a variety of high-quality produce at affordable prices" (Kaiser et al. 2012).

The UCCE team first conducted market research with WIC clients in the three counties to identify preferred vendor partners and produce items to target in the project (Kaiser et al. 2012). The farm advisors narrowed the proposed produce list to those crops that could be produced locally (in the same county) by small-scale growers. The UCCE project team prepared a pamphlet for store owners in each county, highlighting the results from the WIC client interviews. We contacted the preferred vendors, provided each manager with a county-specific pamphlet and requested a meeting with the manager to discuss logistics for purchasing WIC-popular crops from small local growers.

In July and August 2010, the UCCE team initiated contact with buyers from the stores (including regional grocery chains) preferred by the WIC clients. Only the produce buyers from A-50 vendors were interested in the project. It would have been cumbersome for regional grocery chains to develop separate produce procurement programs for their WIC clients. In each of the three counties, we met with the owners of at least three A-50 stores that had been identified by some WIC clients as preferred vendors.

Our meetings in Alameda and Tulare counties included one small grower identified by the UCCE farm advisor as being interested in supplying produce directly to the A-50 vendors. In Alameda County, the farm advisor worked with a small grower to prepare a list of crops and facilitated a meeting at the grower's farm with the buyer from an A-50 store chain, Prime Time Nutrition. The grower had investigated packaging options and was ready to package the produce as requested by the buyer. The buyer was impressed with the small farm; there were rows of sweet corn and various other vegetables, staked heirloom tomatoes, patches of watermelons and ripe strawberries. At the end of the farm tour, the conversation turned to quality, quantity, price and delivery logistics. The grower and buyer planned to continue price negotiations, with the prospect of a delivery within 2 weeks. There were a few brief follow-up phone calls to clarify certain points, but then the communication stalled. Unanswered phone messages from the grower and the buyer piled up, and finally contact between the two parties ceased.

FRUITS and VEGETABLES

CAN BUY

Fresh Fruits and Vegetables
Any brand, type, or combination of:

- Any variety of whole or cut fruits and vegetables
- Sweet potatoes and yams are the only potatoes allowed
- Bagged fruits and vegetables
- Bagged or packaged salad mixtures
- Garlic, onion, ginger, jalapeños, peppers, and chilies are allowed
- Organic is allowed

CANNOT BUY

- Any potatoes other than sweet potatoes or yams
- Any food or product from the salad bar or deli, party trays, fruit baskets, decorative vegetables and fruits, such as chilies or garlic on a string or painted pumpkins
- Nuts or fruit-nut mixtures
- Edible blossoms, such as squash blossoms
- Bagged salad, vegetable, or fruit kits with added ingredients, such as dressing, croutons, cheese, dips, or sauces
- Dried vegetables
- Herbs and spices, such as parsley, basil, cilantro, and mint

CAN BUY

Dried Fruits
Any brand, size, and type of container or bulk, if printed on the check:

- Any variety of dried fruits without added fats, sugars, or oils, such as raisins, prunes and/or dried plums, figs, dates, and apricots
- Freeze-dried is allowed
- Pitted or with pits are allowed
- Organic is allowed

CANNOT BUY

- Dried fruits with added fats, sugars, or oils
- Dried or freeze-dried vegetables
- Trail mix
- Dried fruits with added artificial or natural flavors, including essences

Effective July 5, 2011 15

This guide from the California WIC Program shows authorized fresh and dried produce options. In addition to fresh bananas, WIC-approved vendors in California must offer at least five varieties each of fresh fruits and vegetables.

In Tulare County, the farm advisor introduced a small grower to the owner of three A-50 stores. The grower agreed to sell watermelons from his 4-acre farm to the store owner. When the store owner asked for just two bins of melons to supply his three stores, the grower decided that it was not cost effective for him to load and deliver them to the stores; instead, he sold the entire harvest at one time to a wholesale buyer.

The farm advisor in Riverside County offered to take the purchasing manager of Fiesta Nutrition, a small A-50 chain, and the buyer for Fiesta Nutrition's distributor on a tour to meet local growers who could supply produce to the 15-store chain. Despite repeated attempts, the store purchasing manager never responded to the invitation. No individual growers in Riverside County communicated with WIC store buyers.

Based on these experiences, we realized that connecting individual small growers with A-50 vendors directly would be very difficult due to problems of pricing, communication and the economics of delivering small quantities of individual crops to individual vendors. We then decided to evaluate the feasibility of linking small growers and A-50 vendors through distributors, and identified several regional produce aggregators and distributors that purchased from local small growers.

To supply the Prime Time Nutrition stores in Alameda County, we contacted ALBA Organics, a regional produce distributor based in Monterey County that distributes for organic farms in the region, including four new small-acreage growers who had transitioned from being farmworkers through ALBA's farmer training program. In March 2011, Prime Time Nutrition's buyer purchased 160 cases of lemons from ALBA Organics, which had been bought from a small organic citrus grower in the San Joaquin Valley. In May 2011, during the peak of strawberry harvest, ALBA Organics sold 500 boxes of strawberries from small growers to Prime Time Nutrition for their Northern California stores. For both transactions, the buyer's truck picked up the boxes at ALBA Organics' cooler facility in Salinas. These two purchases totaled just over $10,000, of which slightly less than $5,000 went to the growers. ALBA Organics' manager was satisfied with these sales and was willing to negotiate on price to secure future business from Prime Time; however, Prime Time's buyer did not return his calls.

In Tulare County, the farm advisor attempted to contact the head buyer for a regional produce distributor that made direct deliveries twice each week to the three targeted Tulare County A-50 vendors. He did not get any response from the buyer.

In Riverside County, the owner of the three targeted A-50 vendors in the Coachella Valley contacted a project team member in 2011, seeking assistance in locating a full-line produce distributor that would deliver to his desert stores. The UCCE team located a nonprofit food security organization, which had plans for a campaign to encourage local farmworkers to eat local produce. The organization's director said she was willing to purchase produce from local growers and deliver to the A-50 vendors, but she was unable to package the produce as needed and deliver it for a price that the store owner was willing to pay. The store owner was left delivering produce from San Diego to his stores in the Coachella Valley.

Thus, in this distributor-focused phase of the project, we were generally unable to facilitate sales between small farms and stores serving WIC clients because the parties could not agree on prices. To better understand why it was so difficult to connect small growers andA-50 vendors, we examined supply chains that were successfully providing produce to WIC clients. Table 1 shows that large store chains are the dominant suppliers of produce to WIC clients in California. These stores include large grocery chains, such as Safeway and Savemart; box stores such as Food4Less and FoodMax; and general merchandise stores, such as Walmart and Target. These chains have a diverse client base and had significant sales of produce before the introduction of WIC F&V vouchers in 2009, so the impact of the vouchers on their produce sales and supply chain is likely to have been minimal. Therefore, we focused our examination on new produce supply chains that were developed at A-50 stores when F&V vouchers were introduced. To this end, we interviewed owners and managers of A-50 stores as well as produce distributors that serve such stores.

Survey of A-50 store owners

In 2012, we interviewed five owners or managers of A-50 stores in the three counties in our pilot project regarding their experience in transitioning to F&V vouchers, including how they sourced the new produce they had to carry, the financial investments needed and the price competition they faced. The five stores were part of retail chains that ranged from four stores to 100 stores. (More than 230 A-50 vendors in California are chain stores.)

The store owners reported that the introduction of F&V vouchers had led to either an increase in or had no impact on the number of WIC shoppers in their stores. However, even those whose sales volume increased did not report increased profits. Milk, egg, cheese and juice vouchers were reduced when the F&V vouchers were added, and those products tend to have higher margins than produce.

Additionally, major changes had to be made in the stores to prepare for fruit and vegetable sales, including installing coolers and reconfiguring counter space and shelving to display produce. Product mix, pricing and packaging had to be determined to allow customers to maximize variety with their vouchers, staff had to be trained and produce suppliers located. The owners faced challenges related to these changes, such as obtaining financing to purchase the refrigeration and display equipment, and obtaining information regarding proper produce handling. A companion article in this issue (Kaiser et al. 2015, page 105) describes our project's educational activities with staff at A-50 stores.

Four of the store owners rely on produce distributors. The fifth owner, who operates four stores, decided that it was more cost effective to buy directly from farms and packinghouses around Fresno and Bakersfield, as well as from produce terminals, and to have a staff member pick up and deliver the produce in a 24-foot box truck.

The store owners mentioned their increased costs due to packaging requirements. A-50 vendors sell at least some, if not all, of their produce prepackaged, priced most commonly in 50-cent increments up to $3 so customers can easily determine how many items they can purchase for the $6 and $10 vouchers. Three of the five stores do some or all of their own packaging, while two stores purchase products prepacked by distributors or processors.

All the store owners stressed the importance of good quality and reasonably priced produce when competing for customers, because WIC shoppers are not likely to visit more than one store to spend their vouchers. Four of the five said that they priced their produce very

After the introduction of F&V vouchers, some A-50 vendors experienced increased costs due to packaging requirements; some or all of their produce is sold prepackaged.

Farmers Market Nutrition Program vouchers are issued once a year for use between May and November at WIC-approved certified farmers markets.

competitively to attract customers and give them the greatest variety possible for their F&V vouchers. Most of the store owners noted that high-quality, reasonably priced produce brings in new non-WIC customers. One owner estimated that 10% to 20% of produce sales are to non-WIC customers. Another now stocks specialty produce items, such as plantains and yucca, requested by the neighborhood's non-WIC customers who have started shopping at the store. Another owner mentioned that pricing the produce aggressively encouraged WIC customers to spend more, using the F&V vouchers for some of their purchases.

These interviews revealed several reasons why it was unlikely that the store owners would purchase a few select product items for their stores from small farms. Four of the five store owners identified distributors' lower prices, broad product mix and preference for prepackaged produce as reasons for using produce distributors. The fifth owner found it more cost effective to purchase produce direct from farms and produce terminals, which growers often utilize if they have excess produce that they need to sell quickly at reduced prices.

Survey of produce distributors

Most A-50 vendors do not have the facilities, staffing, expertise or volume to source their produce direct from packer/shippers or processors. Instead, they rely on regional produce distributors, many of which sought out the larger A-50 chains as customers when the F&V vouchers were introduced.

We interviewed two large regional produce distributors about their experiences supplying A-50 vendors. They did not make any major capital improvements when they took on the vendors as customers. However, they did provide merchandising guidance and limited handling advice to store chain management and staff. One distributor sold refrigeration and display units to the store chains; in some cases, the distributor paid for part or all of the cost of the equipment. These distributors reported that their sales to A-50 vendors represented between 15% and 20% of their firm's revenues.

One distributor noted the low volumes of produce to some A-50 vendors were too costly to deliver in 40,000-pound trailers; consequently, deliveries are made to only some of the stores, and the store chain uses its own trucks to distribute the produce to its smaller stores. The other distributor determined that the sales volumes of some A-50 vendor accounts were too small to be profitable, so these accounts were relinquished to a smaller distributor.

Both distributors commented that the A-50 vendors they supply face stiff price competition from Walmart and the box stores, so small growers interested in supplying produce to the distributors must also have competitive prices. Both distributors require their suppliers to have food safety certification from a third party and liability insurance. One distributor requires its suppliers to provide prepackaged products to be sold at specific prices; the other distributor does the prepacking.

Our interviews with produce distributors confirmed the small farms' inability to compete with them on price, product mix and services when supplying the WIC A-50 vendors. Many large regional distributors were ready to supply A-50 vendors when the F&V voucher program was implemented, but one of these distributors found that sales to some A-50 vendors were too low to be profitable and relinquished these accounts to a smaller distributor.

WIC vouchers in farmers markets

In 2010, the California WIC program piloted the acceptance of WIC F&V vouchers at a small number of certified farmers markets. However, grower participation in California in the current F&V voucher program has been low. The first farmers market authorization occurred in May 2010. As of March 4, 2015, there were only 31 farmers markets and 149 growers authorized for F&V vouchers, compared with 371 farmers markets and 1,018 farms authorized for USDA Farmers Market Nutrition Program (FMNP) vouchers in California (CDPH 2015). The total value of WIC F&V vouchers redeemed at farmers markets in California during 2011 and 2012 (table 1) represented less than 0.05% of the total WIC F&V redemptions.

USDA's Food and Nutrition Service introduced FMNP vouchers in the 1990s, enabling growers to provide fresh, nutritious and locally grown fruits and vegetables to WIC families at farmers markets. Each eligible family receives $20 in vouchers once a year to redeem between May and November for fresh fruits, vegetables and cut herbs at WIC-approved certified farmers markets in California. In 2010, program participants included 149,200 WIC families, 1,100 certified growers and 430 certified farmers markets (CDPH 2014).

The FMNP is popular with most small direct-marketing growers because the vouchers can be redeemed only at certified farmers markets, thus increasing the markets' customer counts and raising the growers' revenues. Redemptions of FMNP vouchers increased from 57.2% in 2005 to 66.2% in 2012 (McDonnell et al. 2014) and 68% in 2014 (CDPH 2015). Transportation to farmers markets was commonly identified by WIC clientele as a barrier to participation in the FMNP. Some local WIC agencies have set up new farmers markets close to the offices where they distribute vouchers. At many California farmers markets in low-income neighborhoods, nonprofit organizations and private funders provide matching funds that allow WIC shoppers (as well as food stamp and Social Security recipients) to double the value of their vouchers (Roots of Change 2012); this has contributed significantly to the program's success.

To be able to accept F&V or FMNP vouchers, both the grower and the market where he or she is selling must be authorized by California's WIC program; the authorization requirements are essentially the same for both voucher programs. However, the F&V vouchers are more difficult for the grower to redeem than the FMNP vouchers. The grower must check the F&V voucher to ensure that it is being used within the required 30-day redemption period; FMNP vouchers are valid for 6 months. Tessman and Fisher (2009) noted that California is one of only two states that require growers to call in the numbers on each redeemed F&V voucher. Growers must deposit the vouchers in the bank within 45 days of the "first day to use" indicated on the voucher. Banks may charge a fee for depositing a large number of vouchers. The vouchers can get damaged if it is raining, and then they can be rejected by banks.

Using F&V vouchers at farmers markets is also problematic from the WIC client's perspective. Since the entire F&V voucher must be spent at one time, a grocery store with a wide selection of produce is more appealing than an individual grower at a farmers market. Additionally, grocery stores have extended hours of operation and are more convenient to shop at than farmers markets.

Occidental's farm-to-WIC program

Occidental College's Urban and Environmental Policy Institute (UEPI) initiated a farm-to-WIC program in 2009 to improve the health and vitality of local communities. Similar to the UCCE pilot project, it strives to provide WIC families with high-quality seasonal produce while expanding market opportunities for small local farms. Starting with four participating A-50 stores in Los Angeles, it now includes 12 flagship stores in Los Angeles County selling produce from a dozen local growers (Y. Zeltser, unpublished data). Its purchases from small local farms in the first 3 years totaled over $500,000. Two of the store partners, Mother's Nutritional Center and Prime Time Nutrition, each operate more than 50 A-50 stores in California; they are the two largest A-50 store chains in California. Fewer than 30% of Prime Time Nutrition's stores are in Southern California; all the Mother's stores are located there.

UEPI's program initially involved sourcing one local product each month — a Harvest of the Month model. The turnaround period proved too short for stores struggling with packaging and handling issues; it was also less convenient for growers, who do not want to sell their product for just 1 month. Thus, the program shifted to a seasonal model, which limits the number of items but provides more opportunity for store employees and customers to become familiar with the products.

The success of UEPI's program can be partially attributed to its unusual product offerings from local farms, including Cuyama Crimson Gold crabapples and Ojai Pixie tangerines, both of which are only about 1 inch in diameter. Many of the products offered in UEPI's program are too small to be desirable to conventional grocery stores, but they are a perfect snack size for young eaters. These small fruit, along with UEPI's marketing program, have helped its A-50 store chain partners differentiate themselves from large retailer competitors. Growers benefit financially from UEPI's program because it provides them with a niche market that probably would not exist otherwise.

Supply chain barriers

The UCCE pilot project demonstrated that small farms face several barriers to gaining access to the WIC produce supply chain and providing WIC clients with F&V vouchers for local produce. These barriers are particularly evident when considered with the transitions the A-50 WIC store owners have had to make and their relationships with produce distributors; they are evident also in the successes of the UEPI project and FMNP voucher program. The A-50 vendors are competing with established large retailers that operate with very small margins. Small farms lack economies of scale in production; therefore, they cannot provide competitive pricing when selling direct to A-50 vendors or through produce distributors.

ALBA Organics succeeded in making a few sales transactions with an A-50 store chain, but ALBA Organics had several assets that individual small growers usually lack: familiarity with produce industry standards; a cooler facility and equipment to store and load the buyer's trucks; and third-party food safety certification and liability insurance (Berkenkamp 2011; Feenstra et al. 2011; Tropp and Barham

Individual small farms offering limited volumes of high-quality product are not set up to meet the demands of these A-50 vendors.

Penny Leff

2008). Significantly, the sales occurred at peak season when prices were low and product supply exceeded what the growers could sell directly themselves.

The success of UEPI's program is similarly attributable to a particular set of circumstances, especially the expertise and facilities provided by its produce consultant, who helped develop a streamlined process for placing orders and communicated quality or delivery problems between the vendors and growers. The program involves a limited selection of products that are well suited to young children. UEPI's A-50 store chain partners are small customers in the wholesale produce market compared with their large retail chain competitors. As they strive to aggregate their purchasing to gain market power and improve their distribution efficiency, these A-50 vendors need high-quality produce, a steady supply and competitive prices. Individual small farms offering limited volumes of high-quality product are not set up to meet the demands of these A-50 vendors. However, they could adapt UEPI's small fruit program — sort out small fruit, bag them and offer them as special kid-sized packs — to other A-50 vendors, farmers markets or farm stands.

Farmers markets participating in the FMNP provide small growers a means of entry into the WIC produce supply chain, but few WIC shoppers are using their F&V vouchers at farmers markets. FMNP redemptions increased significantly when private matching funds essentially doubled the vouchers' value. If USDA could raise the value of the FMNP vouchers, WIC clients could be expected to increase their purchases at farmers markets. However, reductions in congressional allocations for food security programs reflected in the 2014 Farm Bill make increased funding for FMNP vouchers unlikely. Since most WIC shoppers tend to spend their vouchers in one place, increasing redemptions of F&V vouchers at farmers markets may be a slow process. However, USDA is implementing an electronic benefit program for WIC (USDA FNS 2013), which could make the payment process less onerous for growers and increase F&V voucher use at farmers markets.

The results of the pilot project and the very low redemption rate of WIC F&V vouchers at farmers markets in California raise questions about the role of small farms in food security programs. Should their participation in these programs be a priority, and, if so, how can their ability to participate best be enhanced? Can small farms collaborate or organize themselves to provide reliable supplies of produce to local A-50 vendors, food banks, schools and businesses and also enhance their profitability? These questions raise many policy issues that need to be addressed by policymakers, and they warrant further research on the marketing challenges and constraints faced by small growers. CA

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This project was partially funded by a California Department of Food and Agriculture specialty crop block grant.

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UCCE efforts improve quality of and demand for fresh produce at WIC A-50 stores

by Lucia L. Kaiser, Cathi Lamp, Chutima Ganthavorn, Lucrecia Farfan-Ramirez, Maya Behar, Marita Cantwell *and* Shermain Hardesty

In 2005, the Institute of Medicine recommended major revisions in the food packages provided by the federal Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), leading to new regulations that allow participants to purchase a wide variety of fruits and vegetables with their vouchers. In support of this policy change, UC Agriculture and Natural Resources Cooperative Extension (UCCE) developed educational materials to promote fresh produce among WIC participants and offered postharvest handling training at WIC-only stores, known as A-50 vendors, in order to improve produce quality. A survey conducted after the educational sessions found that WIC participants had increased knowledge of produce and A-50 vendors showed improved postharvest handling after the education sessions. This research demonstrates that combining nutrition education with postharvest handling curriculum can lead to a successful educational program that supports increased demand among WIC participants for fresh produce.

In support of the revised federal policy on WIC fruit and vegetable vouchers, UC ANR Cooperative Extension researchers created posters and fact sheets to promote nutrition education and increase demand for fresh produce among WIC participants.

In 2005, the Institute of Medicine (IOM) recommended major revisions in the food packages provided by the federal Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) (IOM 2005). These recommendations resulted in the first comprehensive changes since 1980 in the foods provided by WIC, a food assistance program that serves low-income pregnant, breastfeeding or postpartum women; infants; and children up to 60 months of age with a nutritional risk (USDA 2007). Revisions to the WIC food packages (the specific foods and amounts that may be purchased with vouchers each month) were needed to help this vulnerable group of participants achieve dietary intakes in accordance with the Dietary Guidelines for Americans (USDHHS and USDA 2011).

Based on evidence that WIC populations do not consume sufficient amounts of fruit and vegetables (IOM 2005), interim federal regulations were implemented to allow WIC to issue cash-value produce vouchers for $10 a month in the women's packages and $6 a month in the children's packages (USDA 2007). WIC vendors are required to stock a minimum of two different types of fruit and vegetables, although the intent is that WIC participants will have access to a wide variety of fruit and vegetables. The expectation is that participants will receive nutrition education at WIC sites on how to shop for produce to get the maximum nutrition for their WIC vouchers.

By October 2009, WIC agencies in all 50 states, tribal lands and U.S. territories had implemented the revised WIC food packages. The impact of this policy

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n02p105&fulltext=yes
doi: 10.3733/ca.v069n02p105

Fact sheets developed by UCCE researchers provide nutrition information and tips on how to choose, store, prepare and serve different fruits and vegetables.

change on the retail environment where WIC shoppers use their vouchers appears to be positive, albeit modest — A-50 vendors, for example, installed coolers and began to carry a wider variety of produce (Hardesty et al. 2015). One study has published data on the revised policy's impact on dietary intake of WIC participants. In that study, small but significant increases in fruit and vegetable intakes were documented among WIC participants, as determined by cross-sectional phone surveys conducted in California in September 2009 and March 2010 (Whaley et al. 2012).

About half of the more than 5,500 WIC-authorized vendors in California are large grocery stores that already carry a variety of produce and therefore are not affected by the federal requirement of stocking a minimum of two different types of fruit and vegetables. The other half includes smaller stores as well as the WIC vendors that have over 50% of their food sales from WIC items, known as A-50 vendors. Prior to the implementation of the new WIC produce vouchers, the A-50 vendors were not required to carry any fresh produce except carrots.

In 2010, a team of researchers from UC Cooperative Extension (UCCE) exploring the feasibility of a farm-to-WIC program conducted a survey in three California counties (Tulare, Alameda and Riverside) to determine interest among WIC clientele in purchasing locally produced fruits and vegetables, as well as the factors influencing produce choices (Kaiser et al. 2012). WIC participants reported a preference for fresh, good-quality produce, demonstrating the demand-side viability of a farm-to-WIC program. A companion paper in this issue discusses the challenges of meeting this demand through small-scale local farmers (Hardesty et al. 2015, page 98).

In this paper, we examine UCCE efforts to increase the demand for fresh produce among WIC participants through point-of-purchase education and to improve the quality of produce offered by A-50 vendors through postharvest handling training. In addition, we review the results of a small qualitative study we conducted in 2012 on WIC clientele shopping behavior to assess the WIC population's purchasing needs. The protocol for this study was approved by the UC Davis Institutional Review Board under exempt status.

Educational materials

The UCCE nutrition researchers developed educational materials primarily for use at the point of purchase (i.e., the cash register or counter where customers pay) in A-50 stores, but also for use in reinforcing nutrition education delivered at WIC offices. Based on the findings of the 2010 survey, the UCCE team identified the following 18 produce items to target for promotion and nutrition education via single-page fact sheets in English and Spanish: bell peppers, broccoli, cabbage, cactus leaves (*nopales*), cantaloupe, carrots, collard greens, grapes, green beans, lettuce, mustard greens, oranges, spinach, strawberries, sweet potatoes, tomatillos, tomatoes and watermelon.

TABLE 1. What WIC participants in Tulare and Riverside counties learned from the fact sheets

Theme	No. of comments	Examples of participants' comments*
Preparation	40	"I didn't know spinach could go in a sandwich. I've never eaten spinach." "Oranges can be added to salad. It looks good." "How to cook it (mustard greens). You can stir-fry it."
Storage	25	"Strawberries need to be used within 3 days." "How long *nopales* (cactus leaves) last — they need to be used in 1 week." "Store watermelon in the refrigerator if it is cut."
Nutritional value	21	"Vitamin C — I didn't know that broccoli had it." "The nutrition cantaloupe has — it is good for you!"
Serving	17	"Different ways to serve grapes, like freezing them." "Mix puree (tomatillo) with sweet potatoes for babies." "Steam (green beans) until soft and serve with a little bit of butter."

* n = 14–21 participants for each of the 18 fact sheets.

Each fact sheet is designed for a limited-literacy audience and features a single fruit or vegetable with tips on how to choose, store, prepare and serve the food in ways that appeal to young children (ucanr.edu/sites/comnut/mothersyoungchildren/Fact_Sheets/). UCCE researchers and assistants conducted cognitive testing of the fact sheets at the WIC sites in Tulare and Riverside counties, interviewing in person, one-on-one, between 14 and 21 different WIC participants in English or Spanish for each of the 18 fact sheets. UCCE staff used open-ended questions to probe for understanding of the words, concepts and pictures used in the fact sheets and to determine what new information was gleaned. During the interviews, participants shared their ideas and provided additional kid-friendly tips for preparing or cooking the vegetable or fruit.

Table 1 shows what the participants learned from the fact sheets (in rank order) about preparation, storage, nutritional value and serving of the produce items. Most participants found the fact sheets useful, especially the nutrition information and the tips on how to choose, store and prepare produce. Most said they learned something new from the fact sheets; in particular, several people were surprised at the differences in the shelf life of various fruits and vegetables. Many participants mentioned that they had never eaten the vegetable before (collard greens, mustard greens, cactus leaves, sweet potatoes and spinach) but liked the tips on how to prepare them. Some were surprised that the fruits or vegetables can be served to infants, particularly bell peppers, green beans, collard greens, tomatillos and watermelon.

Like the California WIC program, UCCE has found that a learner-centered approach (one in which instructors use a variety of teaching methods to facilitate student learning) is more effective in improving fruit and vegetable intake (Gerstein et al. 2010; Kaiser et al. 2007) than a traditional lecture-oriented approach. The produce fact sheets can be used to provide information that is immediately useful to a WIC participant who expresses interest in introducing that food to her child. The "What's In Season Now?" poster, another educational resource created by the UCCE project team, is a colorful visual showing produce available during each season. It can be used as an activity for WIC participants to pair up and brainstorm how they can use seasonally available fruits and vegetables to prepare meals for their families.

Postharvest handling training

Since produce quality is an important factor affecting WIC customer purchases, and handling perishable fresh produce was a new task for many A-50 store employees, UCCE gave produce-handling trainings to WIC distribution center personnel and A-50 vendors. Between 2010 and 2012, a UCCE specialist visited 15 A-50 vendors in Alameda, Tulare and Riverside counties to assess the need for employee training. Based on the specialist's observations and discussions with A-50 store personnel, the project team developed workshops that focused on produce handling scenarios and how to minimize losses. Although the main focus was on handling the produce received by the stores, the trainings also addressed produce handling from harvest through distribution to the stores. UCCE staff covered topics such as temperature management with limited cold room space available in the stores, control of water loss, compatibility issues with a focus on ethylene-sensitive produce (those damaged by exposure to ethylene gas, such as lettuce and carrots), minimizing decay, managing product turnover and maintaining postharvest conditions to retain nutrients, among others.

The one-day workshop trainings at WIC distribution centers involved mostly female employees. Multiple trainings were held: one session with five employees, two sessions with 25 employees each, and a final session involving over 70 employees, with some attending via remote access. At the trainings, UCCE staff distributed photos with examples of good and poor handling practices occurring in the A-50 stores and facilitated discussions with store employees. For these sessions, PowerPoint presentations, handouts and thermometers were provided. To stimulate problem solving and discussion, the presentations incorporated some of the photos taken during the UCCE specialist's store visits.

Proper fruit and vegetable storage is an example of the type of challenges faced by A-50 vendors that UCCE staff addressed in the trainings. In most of the

Marita Cantwell

As a result of the new policy on WIC produce vouchers, many A-50 vendors in California began to carry a wider variety of fruits and vegetables.

A-50 stores, there are two temperature options: refrigerated shelf space at about 41°F (5°C) or holding at room conditions, 59°F to 86°F (15°C to 30°C), depending on the season and the store's location. The proper option for cool season vegetables and packaged salads and other fresh-cut products is the refrigerated cabinet. But for chilling sensitive products, such as tomatoes, there is no single correct option, as ripeness, time and ambient temperature will be considerations. Another problem for stores is that fruit may arrive at the store mature, but not ripe or ripened and ready to eat. Managing the ripening process if needed, and then holding ripe fruit in refrigerated shelf space, was discussed as a strategy to prevent fresh produce losses. Limes, which do not require ripening, can be problematic for a different reason: in refrigeration they turn brown due to chilling injury, while at ambient conditions they turn yellow. The UCCE specialist suggested that employees use a technique of intermittent warming, or switching the limes back and forth between the two temperature options. These examples illustrate some of the problems that were discussed with the objective of finding workable solutions to minimize fresh produce losses.

Over the 2-year period, an increased level of knowledge was noticeable among employees who participated in repeat discussions at the stores or the formal training offerings. Their questions about fresh produce handling became more detailed and specific as their experience and understanding grew. The UCCE specialist prepared four narrated PowerPoint presentations using A-50 vendor produce examples and answers to common postharvest handling questions for continuing employee trainings (postharvest.ucdavis.edu/libraries/video/PHVideosWIC/).

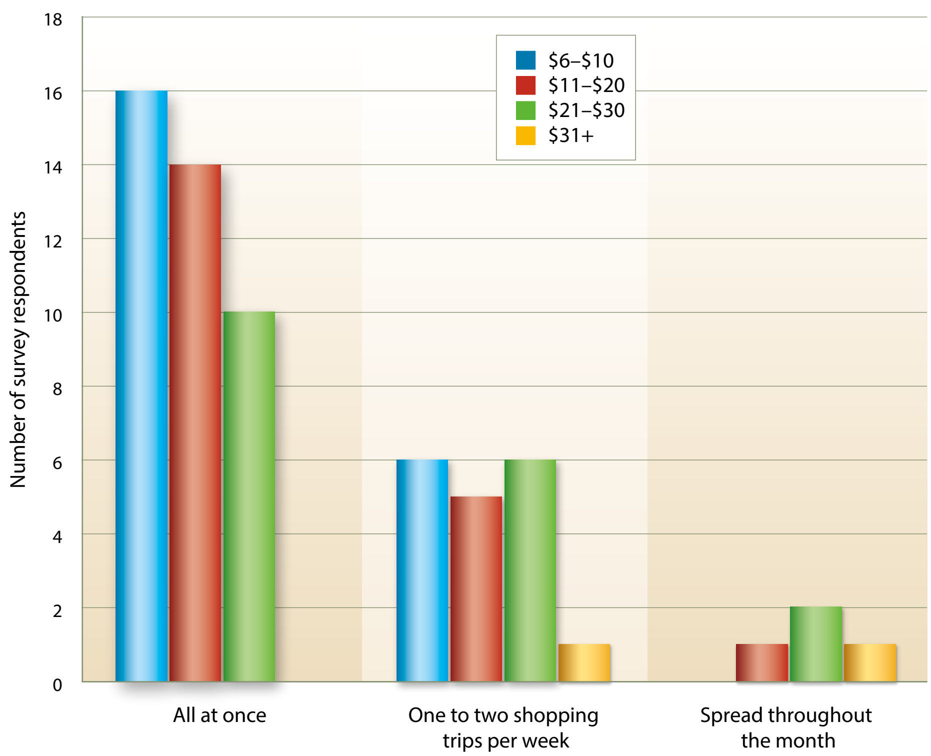

Fig. 1. Frequency of WIC fruit and vegetable voucher spending in Alameda, Tulare and Riverside counties based on dollar value of vouchers received the previous month (n = 62).

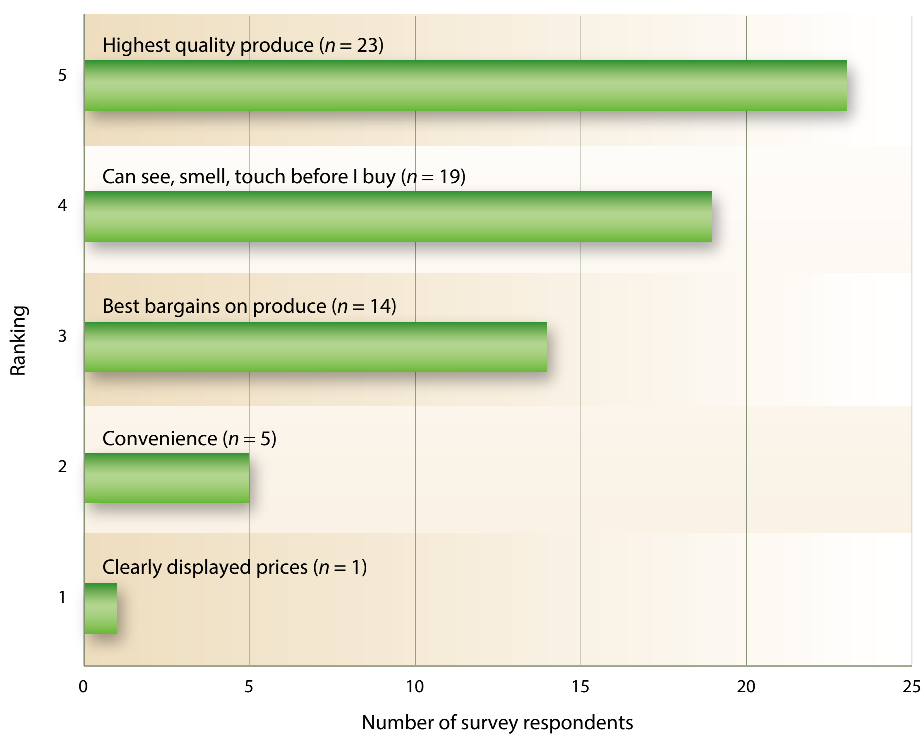

Fig. 2. WIC participants' ranking of factors affecting their purchasing decisions.

Survey of produce purchasing habits

To assess the need for future WIC education sessions, UCCE researchers conducted a qualitative survey in March and April 2012 on the spending habits of WIC shoppers. Data was collected from WIC participants in Alameda, Riverside and Tulare counties, who were recruited while they waited to pick up WIC vouchers. Inclusion criteria were having at least one child aged 12 to 47 months currently enrolled in WIC; being the main WIC shopper in the household; and being sufficiently fluent in Spanish or English to complete the study. UCCE staff members read aloud the surveys, which lasted 15 to 20 minutes, to participants in the waiting areas of WIC offices or in a closed WIC classroom, depending on the preferences of the participant. Surveys conducted in Spanish were translated into English and qualitatively analyzed for purchasing trends.

The sample included a total of 62 WIC participants. Of the 62 respondents, five identified as white/non-Hispanic and 56 identified as Latino/Hispanic (missing data on one participant). In California as a whole, roughly 80% of WIC participants report Hispanic ethnicity (Whaley 2012). The mean age of respondents was 29.2 years. A trend was observed towards a positive relationship between the dollar value of the produce voucher and frequency of spending: the smaller the dollar value of the voucher, the more likely that the entire voucher is spent in a single visit (fig. 1). For participants receiving between $6 and $10, this single point of spending suggests a peak period of fruit and vegetable purchasing and subsequent consumption. However, this is not dependent on when the vouchers are issued during the month. When participants were asked how soon they spent the vouchers after they received them, those receiving $6 to $10 (65% of survey respondents) most frequently replied, "it varies." Eighty-five percent of participants reported spending their fruit and vegetable vouchers at the same store where they spend other WIC vouchers.

Based on their observations of the store layout of the local A-50 vendors and conversations with WIC staff, UCCE nutrition researchers generated a list of

Over the 2-year period, an increased level of knowledge was noticeable among employees who participated in repeat discussions at the stores or the formal training offerings.

five factors that might influence WIC participants' produce purchasing decisions. Participants were given this list and asked to rank the factors, with 5 being most important and 1 least important. Responses from a total of 62 participants were summed and the results show that quality of produce received the highest ranking and clearly displayed prices received the lowest (fig. 2).

Overall, the quality of fruits and vegetables consistently ranked as very important to WIC participants. When asked to list the five fruit and/or vegetable items bought for the family most weeks and used most often, participants reported that they spend WIC vouchers more frequently on fruits than on vegetables, with bananas (77%) and apples (66%) being more frequent than carrots (45%) and broccoli (37%) (table 2). Seven of the top 11 items purchased were produce items featured on the fact sheets.

Participants were shown examples of the fruit and vegetable fact sheets. When asked if they would like to receive this kind of information, all but three (92%) participants responded yes. Following a "yes" response, participants were asked in what format they would like to receive the sheets; 77% preferred paper handouts, while the rest preferred other formats such as Facebook, websites and mail.

TABLE 2. Fruits and vegetables purchased most often with WIC produce vouchers

Item	Respondents (*n* = 62) who reported this item as one of their five most common produce purchases	
	no.	*%**
Bananas	48	77.4
Apples	41	66.1
Carrots	28	45.2
Broccoli	23	37.1
Tomatoes	20	32.3
Oranges	18	29.0
Lettuce	16	25.8
Strawberries	13	21.0
Grapes	12	19.4
Mangoes	7	11.3
Summer squash	7	11.3

Bolded items are featured in the fact sheets.

* Items for which % < 10 are not shown.

Future education and research needs

The research described here demonstrates the success educational efforts can have in support of the revised federal policy on WIC produce vouchers. These educational approaches should be seen as individually effective and complementary. For example, availability of fresh fruits and vegetables has the strongest influence on where WIC participants decide to shop, and they reported spending fruit and vegetable vouchers where they spend other WIC vouchers. If produce in A-50 stores is unappealing due to poor handling, for example, WIC participants may avoid the store altogether. A-50 vendors would then lose both produce voucher and other WIC food voucher profits.

Additionally, the results of our survey on produce shopping habits show that many of those receiving limited fruit and vegetable vouchers spend them all at once, suggesting produce is not eaten immediately after purchasing, but rather may sit for days in the home. This highlights the necessity of postharvest handling training to maintain the highest possible quality at purchase to ensure needed shelf life in the home refrigerator or cabinet. If educational efforts continue or expand to other A-50 vendor locations, the distribution of the fruit and vegetable fact sheets should remain, combined with postharvest handling training.

To further support and evaluate implementation of the WIC produce voucher policy, additional research is needed in the following areas: (1) Examining fruit and vegetable purchasing behaviors in the WIC population with earned income; (2) determining the perceived value of different locally sourced produce items found in A-50 stores; and (3) identifying changes in produce purchasing habits and dietary intake attributable to enrollment in WIC.

Educational approaches should provide guidance specifically tailored to the needs of the target population. The point-of-purchase educational materials and postharvest training of WIC A-50 store employees in this study were designed to respond to the food preferences and dietary patterns of WIC participants in California. This project demonstrated that UCCE programs, specifically teaming up nutrition with postharvest handling, can lead to a successful educational program that supports increased demand for fresh produce. CA

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Network-smart extension could catalyze social learning

by Matthew Hoffman, Mark Lubell *and* Vicken Hillis

Social learning, learning from others, has value in extending knowledge about farm management through networks of growers. Exactly how much value depends on the structure of the networks. We employed social network analysis to study knowledge networks and social learning in three American Viticulture Areas in California: Central Coast, Lodi and Napa Valley. In a survey, growers confirmed that experiential and social learning are more useful for accessing information about farm management than formal learning. UC Agriculture and Natural Resources Cooperative Extension (UCCE) was found to be well positioned to access and spread knowledge through the grower networks but a bottleneck exists — many knowledge-sharing relationships and relatively few staff. We also found that grower participation in traditional outreach activities, e.g., meetings and demonstrations, is a strong predictor of their number of knowledge-sharing relationships, so UCCE and other agricultural support organizations have an important role to play in strengthening networks. Several network-smart extension strategies might help alleviate the bottleneck and rewire networks to more efficiently connect those with questions to those with solutions.

Agriculture is a knowledge-intensive industry. Therefore, developing new and innovative extension strategies is among the most pressing challenges facing contemporary agriculture (Pretty et al. 2010). Studies have highlighted the value of social learning (people learning from one another), and social learning is considered a critical pathway for extending knowledge about farm management (Pretty and Chambers 2003; Roling and Wagemakers 1998; Warner 2007a). Compared to when they were established in the late 19th century, today's extension systems are more complex, dynamic and networked, and the work of extension may benefit by capitalizing on the network structure of the modern knowledge system (Lubell et al. 2014).

Elsewhere, we have shown a positive relationship between growers' number of knowledge-sharing relationships and their adoption of beneficial management practices (Hoffman 2013). However, before Cooperative Extension and other agricultural support organizations (e.g., commissions, marketing orders, voluntary grower associations) can develop extension strategies that harness the natural process of social learning, we must first understand the structure of these knowledge networks and identify leverage points that can rewire the network to connect those with solutions to those with questions.

The objective of our research was to find a scientific basis on which network-smart extension strategies can be based. We employed social network analysis (Wasserman and Faust 1994) to study knowledge networks in three American Viticulture Areas (AVAs) in California: Central Coast, Lodi and Napa Valley. We compared the usefulness of social learning to that of two other learning pathways: experiential learning and formal learning. The three knowledge networks in the AVAs were modeled to identify growers and outreach professionals who are optimally positioned in the network to access and share information.

Matthew Hoffman

Lodi wine grape growers Craig Ledbetter (left) and Aaron Lange (right) share thoughts after observing a trial pass of a prototype multirow in-row cultivator, engaging in both experiential and social learning simultaneously. In a survey of growers, field research and trials (experiential) and interpersonal relationships with other growers (social) were ranked as highly useful sources for learning about vineyard management.

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doi: 10.3733/ca.E.v069n02p113

Howard walnut trees can be brought into bearing without annual pruning

by Bruce D. Lampinen, John P. Edstrom, Samuel G. Metcalf, William L. Stewart, Claudia M. Negron *and* M. Loreto Contador

In traditionally managed Howard walnut orchards, trees are pruned annually during the orchard development phase, an expensive operation in terms of labor and prunings disposal costs. Our observations and some prior research by others had suggested that pruning may not be necessary in walnut. In a trial of pruned and unpruned hedgerow trees over 8 years, beginning a year after planting, we documented canopy growth, tree height, yield and nut quality characteristics and also the effects of fruit removal. Pruning altered canopy shape but did not lead to increases in canopy development, yield or nut quality. Although fruit removal stimulated more vegetative growth in both the pruned and unpruned treatments, fruit removal did not result in an increase in midday canopy photosynthetically active radiation interception or cumulative yield when fruit removal was stopped after year 4. After 8 years, there were no significant differences in tree height, nut quality or cumulative yield among any of the treatments, which suggests that not pruning young Howard orchards could provide a net benefit to growers.

The recommended training to develop the tree structure of lateral-bearing walnut (*Juglans regia L.*) varieties such as Howard during the first 4 years after planting is to use a combination of heading and thinning cuts (Aldrich 1972; Hasey et al. 1998). After year 4, heading of scaffolds is continued until the tree has reached the desired size, which usually occurs by year 6 to 8. The costs associated with such pruning and disposal of prunings are high — around $1,134 per acre total for years 1 to 6 (UCCE 2012). Some research has indicated that no significant difference in yield results from pruning walnuts (Olson et al. 1990), but that trial was conducted on mature trees. Our observations on breeding program orchards at UC Davis and grower orchards in California have suggested that walnut trees can grow and produce well without pruning even in the early years, so we initiated a trial to gather data over 8 years in a developing Howard walnut orchard.

In traditional pruning, after the first dormant pruning, relatively few shoots below the terminal bud usually break dormancy and grow, but those that do, grow more vigorously than shoots in unpruned trees. With repeated heading cuts over time, pruned trees develop a dense canopy, which can lead to shading-related dieback of interior limbs by year 5 or 6. In contrast, branches of unpruned trees elongate and produce side shoots, which fill the space around the main branches. The elongation growth on individual branches tends to occur every other year. The result is a more open canopy structure since fewer branching points are generated.

The size of a fruit or nut tree canopy affects the amount of light intercepted, which affects yield. A curvilinear relationship has been documented between intercepted PAR (photosynthetically active radiation) and canopy dry matter accumulation in apple (Wunsche et al. 1996), peach (Grossman and DeJong 1998) and macadamia (McFadyen et al. 2004).

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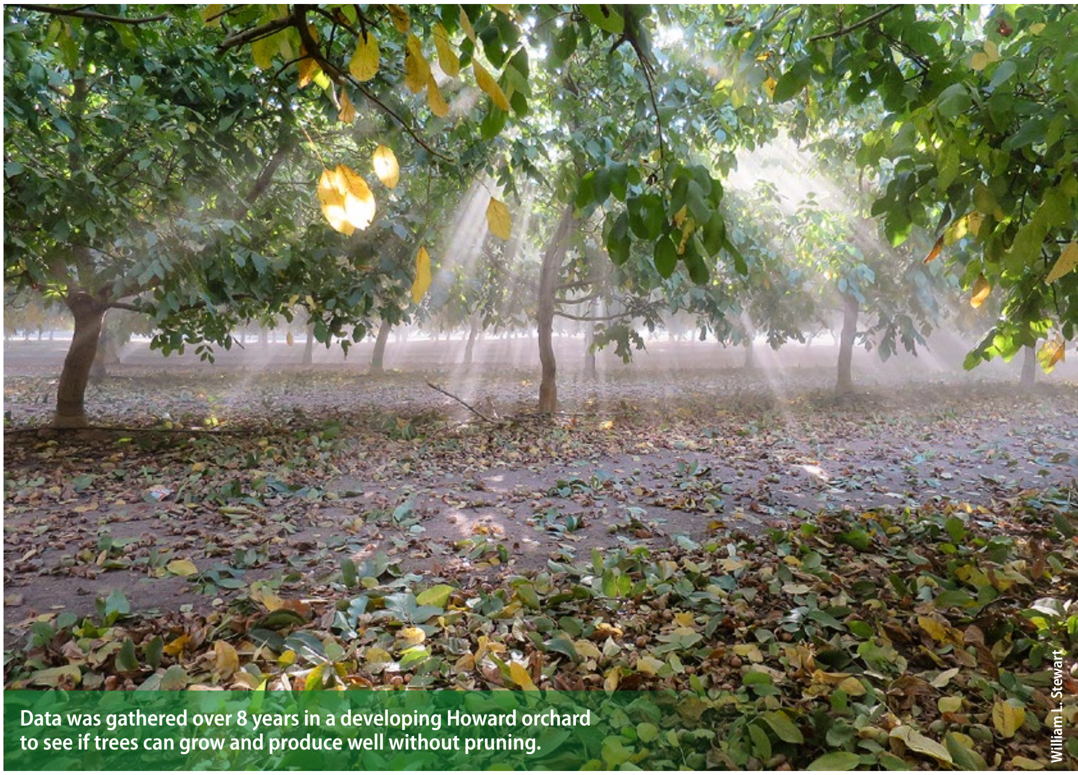
doi: 10.3733/ca.E.v069n02p123



William L. Stewart

Data was gathered over 8 years in a developing Howard orchard to see if trees can grow and produce well without pruning.

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Coming up in *California Agriculture*

Forests and bioenergy: Balancing energy, ecosystems and climate change

In April 2015, Gov. Jerry Brown issued an executive order with a new target of reducing the state's greenhouse gas emissions to 40% below 1990 levels by 2030. Utilizing woody biomass — residues from the logging, wood processing and agricultural industries, as well as materials removed in forest thinning treatments — as a source of electricity has the potential to contribute to shrinking California's carbon footprint while also lowering wildfire risk. However, the biomass energy industry faces many technological challenges and economic constraints as well as competition from other alternative energy technologies, especially solar power. The next issue of *California Agriculture* reviews recent developments in California's bioenergy sector and presents new research findings on the environmental and economic sustainability of energy production from woody biomass. CA

Forest residues are fed into a grinder located at a centralized grinding site and then loaded into a container pulled by a tractor (far right). Later, the containers will be transferred to chip vans for transport to the power plant.

Anil R. Kizhakkepurakal

Network-smart extension could catalyze social learning

by Matthew Hoffman, Mark Lubell *and* Vicken Hillis

Social learning, learning from others, has value in extending knowledge about farm management through networks of growers. Exactly how much value depends on the structure of the networks. We employed social network analysis to study knowledge networks and social learning in three American Viticulture Areas in California: Central Coast, Lodi and Napa Valley. In a survey, growers confirmed that experiential and social learning are more useful for accessing information about farm management than formal learning. UC Agriculture and Natural Resources Cooperative Extension (UCCE) was found to be well positioned to access and spread knowledge through the grower networks but a bottleneck exists — many knowledge-sharing relationships and relatively few staff. We also found that grower participation in traditional outreach activities, e.g., meetings and demonstrations, is a strong predictor of their number of knowledge-sharing relationships, so UCCE and other agricultural support organizations have an important role to play in strengthening networks. Several network-smart extension strategies might help alleviate the bottleneck and rewire networks to more efficiently connect those with questions to those with solutions.

Agriculture is a knowledge-intensive industry. Therefore, developing new and innovative extension strategies is among the most pressing challenges facing contemporary agriculture (Pretty et al. 2010). Studies have highlighted the value of social learning (people learning from one another), and social learning is considered a critical pathway for extending knowledge about farm management (Pretty and Chambers 2003; Roling and Wagemakers 1998; Warner 2007a). Compared to when they were established in the late 19th century, today's extension systems are more complex, dynamic and networked, and the work of extension may benefit by capitalizing on the network structure of the modern knowledge system (Lubell et al. 2014).

Elsewhere, we have shown a positive relationship between growers' number of knowledge-sharing relationships and their adoption of beneficial management practices (Hoffman 2013). However, before Cooperative Extension and other agricultural support organizations (e.g., commissions, marketing orders, voluntary grower associations) can develop extension strategies that harness the natural process of social learning, we must first understand the structure of these knowledge networks and identify leverage points that can rewire the network to connect those with solutions to those with questions.

The objective of our research was to find a scientific basis on which network-smart extension strategies can be based. We employed social network analysis (Wasserman and Faust 1994) to study knowledge networks in three American Viticulture Areas (AVAs) in California: Central Coast, Lodi and Napa Valley. We compared the usefulness of social learning to that of two other learning pathways: experiential learning and formal learning. The three knowledge networks in the AVAs were modeled to identify growers and outreach professionals who are optimally positioned in the network to access and share information. Next, we looked at the association between grower participation in extension activities and their number of knowledge-sharing relationships — where a positive association would suggest participation may increase their capacity for social learning. At the conclusion of our work, we were able

Lodi wine grape growers Craig Ledbetter (left) and Aaron Lange (right) share thoughts after observing a trial pass of a prototype multirow in-row cultivator, engaging in both experiential and social learning simultaneously. In a survey of growers, field research and trials (experiential) and interpersonal relationships with other growers (social) were ranked as highly useful sources for learning about vineyard management.

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Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.E.v069n02p113&fulltext=yes
doi: 10.3733/ca.E.v069n02p113

to suggest strategies for network-smart extension.

Viticulture partnership networks

The three AVAs in our study contain many active partnerships — intentional multiyear relationships among agricultural support organizations, scientists, other stakeholders and growers with the goal of extending practical knowledge about agriculture through applied research and outreach (Warner 2007a). The numerous partnerships in California viticulture have supported grower adoption of sustainable winegrowing practices across geographical regions (Broome and Warner 2008; Ohmart 2008; Shaw et al. 2011). According to Warner, "California's winegrape growers have undertaken more partnerships to greater effect than those of any other U.S. crop" (Warner 2007b). Partnerships that have had a positive influence on grower adoption of sustainability practices in the Central Coast, Lodi and Napa Valley AVAs include the Vineyard Team (formerly the Central Coast Vineyard Team), the Lodi Winegrape Commission and the Napa Valley Grapegrowers, respectively. The California Sustainable Winegrowing Alliance is a state-level partnership.

One of the defining characteristics of partnerships is their networked structure (Lubell et al. 2014; Warner 2007a). As opposed to the traditional Cooperative Extension model, which relies on vertical transfer of knowledge from universities to practitioners, partnerships are ordered horizontally and knowledge is created and shared among diverse groups of people (including those working within Cooperative Extension). Prence and Grieshop (2001) summarized the operational principles of the partnership model as local leadership, personal relationships, equal partnership, collaborative learning, responsive farmer outreach and voluntary practice adoption. The partnership model demonstrates that agricultural knowledge is extended most effectively through strategies that support learning from practical experience and from participating in a network of other growers and experts (Hassanein 1999; Roling and Wagemakers 1998; Warner 2007a).

Learning pathways

Agricultural knowledge is extended through three learning pathways: formal, experiential and social.

The defining feature of formal learning resources is that they transfer knowledge through text from expert to learner, where the learner is strictly the receiver of knowledge (Cofer 2000). The expert determines the content to be learned and the objective of the learning process. Formal learning resources we considered in our study include agricultural journals, industry magazines, text or reference books, Internet resources and self-assessment workbooks.

Experiential learning is learning by doing. Knowledge is acquired through experiences, observations and engagement with the surrounding environment (Kolb 1984). It is continually sharpened through a repeated cycle of engagement in practice, reflection on process and outcomes, and refinement of decision making. Kolb (1984) defines experiential learning "as the process whereby knowledge is created

UCCE San Joaquin County farm advisor Paul Verdegaal (right) discussing trellising systems with Lodi wine grape grower Joseph Spano (left). This boots-on-the-ground approach is a hallmark of traditional extension, but is becoming increasingly difficult to implement with low ratios of farm advisors to growers. Network-smart extension strategies may be useful for extensionists who are overloaded with inquiries.

Matthew Hoffman

through the transformation of experience." Experiential learning is meaningful to growers because it has direct and tangible implications in the practice of farming. Examples of experiential learning include growers' observations of their vineyard conditions, trial and error, on-farm research and written recordkeeping.

Social learning is learning from others, a social process of knowledge distribution among a network of individuals who share a common set of practices, knowledge and decision-making contexts (Wenger 1998). Knowledge networks are the social infrastructure that support social learning (Phelps et al. 2012). An individual's ability to engage in social learning activities such as the generation, access and spreading of ideas is either constrained or enabled depending on the structure of the network and the individual's position in that network. Examples of social learning considered in this paper include knowledge sharing between growers and pest control advisers (PCAs), UC Agriculture and Natural Resources Cooperative Extension (UCCE) staff, and vineyard sales representatives.

TABLE 1. Survey respondents' ratings of the usefulness of the three learning pathways

Rating	Learning pathway: Experiential	Social	Formal
	% of respondents		
Very useful	67.8	67.6	45.4
Somewhat useful	29.6	28.1	45.2
Not useful	2.7	4.3	9.5
	Mean usefulness score*		
	2.662	2.640	2.381

* Usefulness scores: Very useful = 3, Somewhat useful = 2, Not useful = 1.

Knowledge network theory

We couch social learning in three theoretical viewpoints: diffusion of innovation, cultural evolution and social capital (Lubell and Fulton 2008; Shaw et al. 2011; Tomich et al. 2011). These theories help explain human behavior as a function of one's position in the knowledge network. They provide a framework for understanding how and why information is or is not legitimized, vetted and ultimately adopted by individuals within a social network. These theories serve as a basis for designing network-smart extension strategies.

Diffusion of innovation theory argues that knowledge about the relative benefits and costs of innovations spreads through social networks over time (Rogers 2003; Rogers and Kincaid 1981). Early adopters of agricultural innovations bear the costs of experimentation and risk the chance of failure. Late adopters avoid these risks, but they may be slow to reap the rewards of successful innovations. The diffusion of innovation perspective sheds light not only on how new technologies and ideas are spread through a community but also on how their economic and practical worth is vetted among community members and on who benefits most from adoption of successful innovations. In the long run, the community adopts only successful innovations.

Cultural evolution theory posits that beliefs and behaviors spread in a network through social mechanisms, mechanisms such as an imitation of prestigious and successful individuals or a conforming to the most widespread behaviors in the network (Henrich 2001; Richardson and Boyed 2005). It suggests that social learning reduces the individual costs of knowledge development because lessons learned by one individual do not have to be learned personally by others in the network, leading to faster diffusion of innovations and understanding of their costs and benefits. These social processes of imitation and conforming have positive implications for extension when sound information and beneficial practices are spread through the network. However, they pose an extension challenge when prestigious or successful individuals, or a large group of people, in the network accept unfounded information or adopt ineffective practices. Hence, Cooperative Extension and other academic institutions have an important role in bringing science to bear on the ideas being spread through knowledge networks.

Social capital theory addresses the role and value of social connections in a community (Coleman 1990; Putnam 2000). Social capital among community members, and their shared trust, is key for solving collective action problems that require cooperation (e.g., reducing agricultural nonpoint source pollution requires adoption of proper irrigation and nutrition management practices from most growers in a watershed) (Ostrom 1990). Two types of social capital interest us. Bonding social capital, the tight social ties among locals, is important when community cooperation and information sharing are necessary for solving local problems. Bridging social capital, the loose social ties to individuals outside of a community, is key for accessing information to solve new or otherwise challenging local problems (Flora and Flora 1993; Flora and Flora 2008). Social capital theory helps explain why some agricultural communities are able to solve local problems by sharing information locally and accessing information globally while other communities fail (Flora and Flora 1993).

Data collection

We collected our data with a mail survey that we customized for each of the three regions of study: Central Coast, Lodi and Napa Valley. The Lodi survey was delivered during 2010 and 2011. The Central Coast and Napa Valley surveys were delivered during 2011 and 2012. An advisory committee of 25 growers and outreach professionals was consulted during all stages of the research process. We compiled lists of growers by using the 2010–2011 wine grape pesticide use reports from the 10 counties in the Central Coast region (Alameda, Contra Costa, Monterey, San Benito, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Ventura), the two counties in the Lodi region (Sacramento, San Joaquin) and the one county in the Napa Valley (Napa). As mandated by the California legislature, growers are required to report their use of pesticides, including those approved for organic certification, to their county agricultural commissioner office. Growers not applying any pesticides to their vineyards would not be captured by these reports; however, due to the pervasiveness of powdery mildew (*Erysiphe necator*) in wine grapes, few growers refrain from applying fungicides. These lists are therefore representative of our grower population. We supplemented these lists and corrected inaccuracies using Internet searches of publicly available information.

Following the Dillman method (Dillman 2007), we sent an invitation letter followed by a first survey, a reminder, a second survey, a second reminder and a final reminder. We collected a total of 822 completed surveys out of 2,085 eligible respondents, a response rate of 39.42%. By region, we achieved response rates of 32.52% in the Central Coast (358 collected of 1,101 eligible), 53.41% in the Lodi region (227 of 425) and 42.40% in Napa Valley (237 of 559). We calculated response rates using AAPOR guidelines (AAPOR 2009).

Most useful information resources

We asked survey respondents to rate on a scale of 1 to 3 the usefulness of 21 information resources for learning about vineyard management, with "not useful" equaling a value of 1, "somewhat useful" equaling 2 and "very useful" equaling 3. We subsequently grouped the information resources by learning pathway (experiential, social or formal) and examined the ratings of the individual resources and each pathway.

Table 1 reports the percentage of respondents who selected each rating within each pathway. A majority of respondents rated information resources in the experiential (68%) and social (68%) learning pathways as very useful. Noticeably fewer respondents rated information resources in the formal (45%) pathway as very useful. Only a small number of respondents rated the experiential (3%) and social (4%) pathways as not useful, but a larger number reported those in the formal pathway (10%) as not useful.

Table 1 also reports the mean usefulness scores for each learning pathway. The mean usefulness scores for information resources in the experiential and social learning pathways (2.66 and 2.64, respectively) were slightly higher than the average score of those in the formal pathway. The modal usefulness score (not shown) for each learning pathway was 3 (very useful).

Table 2 breaks down the learning pathway data to show the percentage of respondents who ranked each of the 21 information resources as being very useful. The resources are sorted in decreasing order of usefulness (as rated by all respondents in the three regions) and are color coded by learning pathway. The top 10 resources per region are listed.

Some standout regional differences were found among growers' preferred learning resources. First, pest control advisers (PCAs) were ranked much lower in Napa Valley (10th) than in the Central Coast (fourth) and in Lodi (second). The Napa Valley vineyards are frequently farmed by for-hire management companies, who may do their own pest monitoring and pesticide recommendations. In contrast, it is more common for Lodi growers to manage their own vineyards and hire a PCA. Another noticeable difference was that in Lodi, other growers were ranked as less useful (seventh) than they were in the Central Coast (second) and Napa Valley (third). One possible explanation is that Lodi growers rely less on other growers and more on PCAs and UCCE for advice, both of which were ranked as more useful in Lodi than in other regions. Overall, many of the same learning resources appeared in each region's top 10 list; though other growers (family) was absent in the Napa Valley list, viticulture consultants was absent in the Lodi list, and UCCE county farm advisors was absent in the Central Coast list.

The regional similarities in the data tell an interesting and useful story in terms of identifying network-smart extension strategies with universal application. Across the regions, respondents reported that observations of their own vineyard was the most useful learning resource, with 90% of respondents rating the resource as very useful (table 2), which points to the geographically universal power of experiential learning. PCAs, vineyard field crew and other wine grape growers (not family) — all social learning resources — were the second, third and fourth most useful learning resources, respectively, across the regions (table 2). The

TABLE 2. Survey respondents' ratings of the usefulness of 21 information resources

Pathway	Information resource	"Very useful" rating (% of all respondents)	Top 10 ratings by region: Central Coast	Lodi	Napa Valley
Experiential	Observations of own vineyard conditions	89.8	1	1	1
Social	Pest control adviser	72.3	4	2	10
Social	Vineyard field crew	71.2	6	5	2
Social	Other wine grape growers (not family)	71.1	2	7	3
Experiential	Trial and error	69.5	5	4	5
Experiential	Field research trials conducted in own vineyard	68.3	7	9	6
Social	Winery personnel	67.9	3	6	9
Experiential	Observations of others' vineyard conditions	67.2	8	10	4
Social	Other wine grape growers (family)	64.4	9	8	
Social	Viticulture consultant	63.5	10		7
Social	UC Cooperative Extension farm advisor	62.7		3	8
Formal	Internet resources	60.5			
Formal	University publications	58.7			
Formal	Viticulture text or reference books	58.5			
Experiential	Written records of vineyard performance	56.8			
Experiential	Field research trials conducted in others' vineyards	55.1			
Formal	Trade journals	47.2			
Formal	Lodi Winegrower's Workbook	44.4			
Formal	Sustainability in Practice (SIP) Workbook	42.5			
Formal	California Code of Sustainable Winegrowing Workbook	34.0			
Formal	Newspapers	17.2			

Color key: Social, Experiential, Formal

process of trial and error, and research trials conducted in a grower's own fields — experiential learning resources — were the next most highly ranked. All the top 10 resources across the regions were experiential or social. No formal learning resource appeared on any region's top 10 list.

These results validate the argument that grower learning is grounded primarily in personal experience and knowledge-sharing relationships, and the data is consistent with the findings of similar studies (Hood and Shearer 2001; Knapp and Fernandez-Gimenez 2009; Korsching and Malia 1991).

Position in network, knowledge agents

Since an individual's ability to access and spread knowledge is dependent on his or her position in the knowledge network, we modeled the networks in the three AVAs to identify how growers and outreach professionals are positioned in them. The three knowledge networks include growers and 12 types of outreach professionals: for-hire vineyard managers, PCAs, viticulture consultants, vintners, vineyard sales representatives, UCCE staff (farm advisors and specialists), winery representatives, labor contractors, research scientists, partnership staff, Natural Resources Conservation Service (NRCS) staff and county agricultural commissioners.

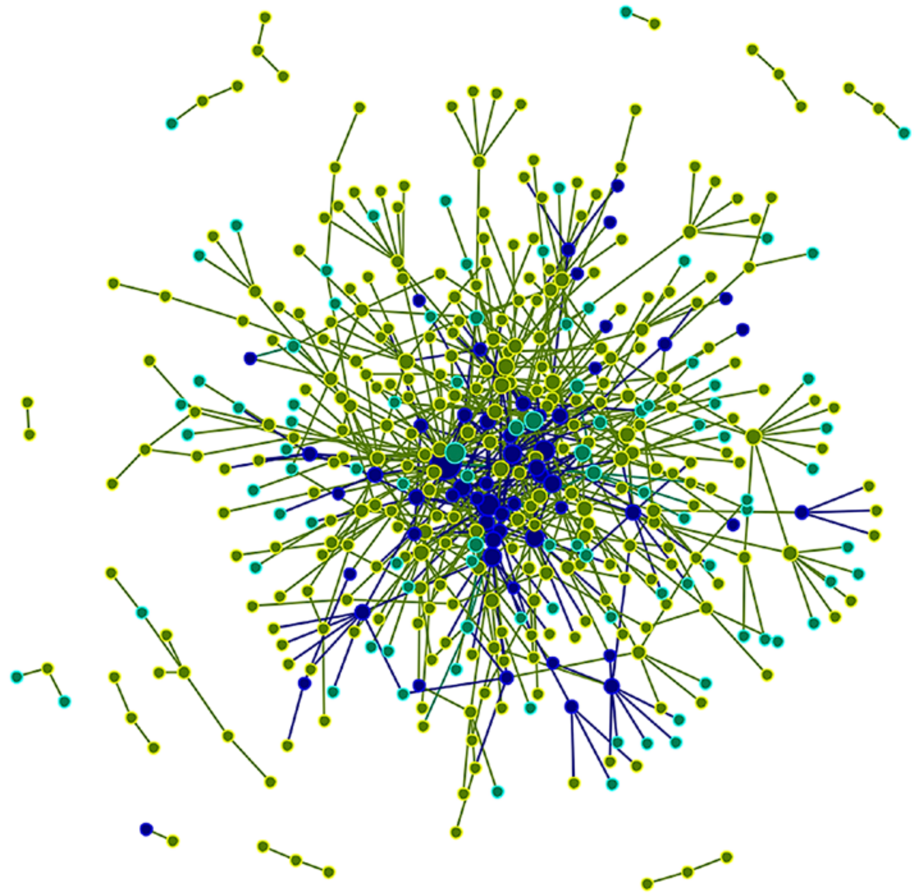

Fig. 1. Lodi's knowledge network. Nodes represent individuals and ties represent knowledge-sharing relationships. Green nodes represent individuals who are exclusively growers, aqua nodes represent individuals who are exclusively outreach professionals and blue nodes represent individuals who are both growers and outreach professionals (boundary-spanning professionals). Nodes are scaled by total degree centrality, with higher centrality represented by larger diameter nodes.

Using conventional network data collection methods that rely on survey respondents' recollection of their recent social interactions (Knoke and Yang 2008), we asked growers to provide the names of other growers and outreach professionals with whom they communicated for advice about vineyard management. Matrices of relational data were constructed from this survey question. The matrices were nondirectional. Even though survey respondents were asked only to nominate others with whom they communicated about vineyard management, we assumed that knowledge-sharing relationships were reciprocal.

Centrality. We calculated individuals' centrality in the networks. Centrality is a measurement of how connected an individual is to the rest of the network. Individuals with high centrality have great potential to be aware of others' opinions, insights or expertise and to rapidly spread information throughout the entire network because they are connected to many others who themselves are connected to many others.

In our analysis, we used total degree centrality, which represents the total number of knowledge-sharing relationships as reported by respondents (Wasserman and Faust 1994). Note that we are not claiming this is an exact measure of an individual's actual (i.e., real-world) number of knowledge-sharing relationships. We believe total degree centrality is an underestimate of knowledge sharing relationships. For example, our data shows UCCE staff have on average 6.44 knowledge-sharing relationships with growers and PCAs have an average of 3.45. The actual number of relationships these outreach professionals have is likely larger. What is important in this analysis is not an individual's actual number of knowledge-sharing relationships but his or her relative degree of connectedness to other individuals in a knowledge network.

Figure 1 visualizes Lodi's knowledge network. Nodes represent individuals and ties represent knowledge-sharing relationships. Nodes are color coded: Green nodes represent individuals who are exclusively growers, aqua nodes represent individuals who are exclusively outreach professionals and blue nodes represent individuals who are both growers and outreach professionals (boundary-spanning professionals). Nodes are scaled by total degree centrality, with higher centrality represented by larger diameter nodes.

The figure yields cursory insight into which types of individuals are best positioned to access and spread knowledge. Nodes that have high centrality measures tend to be located close to the center of the network. Boundary-spanning professionals clearly tend toward the center. The patterning of those who are exclusively outreach professionals and exclusively practitioners is more difficult to discern. The Central Coast and Napa Valley knowledge networks were qualitatively similar to the Lodi knowledge network and expressed the same general patterns.

Table 3 reports the mean total degree centrality for the three types of individuals (growers, outreach professionals, boundary-spanning professionals) by region. On average across the regions, boundary-spanning professionals reported 5.51 knowledge-sharing relationships, which was 2.19 times more than growers and 3.65 times more than outreach professionals. By virtue of their relatively high number of knowledge-sharing relationships, coupled with their practical and expert training, these individuals with dual professions are likely some of the richest resources of viticulture knowledge. They are likely aware of other growers' needs and challenges, are able to broker knowledge across the boundaries of science, industry and practice, and are well positioned to rapidly spread knowledge throughout the network.

Coverage. Outreach professional types, as groups (e.g., PCAs, farm advisors), have varying degrees of knowledge-sharing relationships relative to the number of individuals making up that group. Therefore, different outreach professional types have more or less potential coverage. Coverage is the average number of knowledge-sharing relationships of an outreach type (mean total degree centrality) multiplied by the total number of individuals within that type (*n*). Coverage represents the number of growers that a given outreach type, as a population, can potentially connect with.

Based on the measurement of coverage, we found a distinct set of outreach professional types who have high potential to efficiently access and spread knowledge throughout the networks. Across the three regions, the top outreach professionals in terms of coverage were for-hire vineyard managers (table 4). Vineyard managers are great in number and their relatively high centrality ranks them highest in terms of coverage. They engage in a broad scope of vineyard activities during the entire growing season and commonly do so for multiple vineyard operations. Consequently, vineyard managers are influential knowledge agents (individuals well positioned in the network to access and spread knowledge)

PCAs, viticulture consultants, vintners and sales representatives round out the top five (table 4). These outreach professionals are involved in vineyard management through advising growers on fundamental vineyard activities such as pest control, nutrient management, equipment selection, and wine grape quality and yield enhancement practices. They too work with multiple growers. Vintners are a special case because individually they communicate with a relatively small number of growers, but their large population size means they have significant coverage over the network.

These five types of outreach professionals constitute a core group of knowledge agents. Note that there is considerable overlap between those outreach professionals with high coverage and those whom a large number of growers reported as being very useful

TABLE 3. Mean total degree centrality of growers, outreach professionals and boundary-spanning professionals, by region

	Mean centrality			
Occupation	3-region average	Central Coast	Lodi	Napa Valley
Boundary-spanning professional	5.512	5.302	6.491	6.180
Grower	2.519	2.453	2.753	2.596
Outreach professional	1.511	1.417	2.137	1.252

TABLE 4. Mean total degree centrality, population size and coverage of 12 types of outreach professionals, by region

	3-region average			Central Coast			Lodi			Napa Valley		
Outreach professional*	Mean centrality	Size	Coverage†	Mean centrality	Size	Coverage	Mean centrality	Size	Coverage	Mean centrality	Size	Coverage
		no.			*no.*			*no.*			*no.*	
Vineyard manager	5.349	272	1,455	5.239	113	592	5.250	48	252	5.505	111	612
Pest control adviser	3.452	104	359	2.698	43	116	3.826	46	176	4.467	15	67
Viticulture consultant	2.879	99	285	2.596	47	122	3.000	9	27	3.163	43	136
Vintner	1.407	118	166	1.254	63	79	1.000	1	1	1.593	54	86
Sales representative	3.060	50	153	1.885	26	49	7.000	15	105	4.000	9	36
UCCE staff	6.438	16	103	4.000	9	36	21.05	2	43	4.800	5	24
Winery representative	1.744	43	75	2.000	6	12	1.800	25	45	1.500	12	18
Labor contractor	1.455	11	16	1.429	7	10	1.000	2	2	2.000	2	4
Research scientist	1.444	9	13	2.000	3	6	2.000	1	2	1.000	5	5
Partnership staff	1.857	7	13	1.000	5	5	4.000	2	8	—	—	—
County agricultural commissioner	2.000	3	6	1.000	1	1	—	—	—	2.000	2	4
NRCS staff	1.000	6	6	1.000	2	2	—	—	—	1.000	4	4

* Sorted in decreasing order by coverage for 3-region average.

† Refer to text for unit definition.

for learning about vineyard management (table 2). This suggests that growers are already doing a good job of identifying individuals capable of providing useful advice and are cultivating knowledge-sharing relationships with them. For the most part, the pattern in coverage was also expressed in each individual region (table 4).

UCCE bottleneck. UCCE faces a challenge in terms of its network coverage, which ranked sixth in our study (table 4). In California as a whole, UCCE staff had the highest mean centrality (table 4). Regionally, they had the highest mean centrality in Lodi, and in the Central Coast and Napa Valley they had the second highest. The highly central position of UCCE staff attests to the legacy of UCCE's traditional boots-on-the-ground approach. However, the population of UCCE county farm advisors and specialists is small, resulting in a coverage bottleneck — the large workload of sharing knowledge with many growers falls on a few UCCE staff. In Lodi, the bottleneck was unmistakable. The two UCCE staff in Lodi had, on average, 3.34 times more knowledge-sharing relationships than the 3-region average and 5.38 and 4.78 times more than their Central Coast and Napa Valley counterparts, respectively (table 4).

Velasquez et al. (2006) demonstrated that the ability to access and spread knowledge can be constrained by network bottlenecks. When outreach professionals are overburdened by too many requests for advice, as is increasingly the case with UCCE farm advisors (Cline 2003; Fruit Grower News 2007), the quality and quantity of their work may be compromised.

Our results suggest that UCCE, and therefore the interface between growers and UC Agriculture and Natural Resources, is presented with a unique extension challenge. UCCE is limited in its ability to access and spread knowledge through one-on-one social interactions such as farm calls. Our findings are consistent with UCCE's recent budget constraints (Cline 2003) and the historic trend of the decreasing number of farm advisors per number of growers (Fruit Grower News 2007). Distributing knowledge-sharing relationships over a larger population of outreach professionals could alleviate the bottleneck, and thus make the network function more efficiently.

Table 5. Summary of regression analyses for variables predicting grower network centrality, by region

	Central Coast		Lodi		Napa Valley	
Variable	β	SE β	β	SE β	β	SE β
Participation in events	0.209*	0.073	0.495*	0.116	0.237*	0.059
Acres	0.000	0.000	0.000	0.000	0.002	0.001
Age	−0.310	0.300	−0.102	0.300	−0.009	0.316
Education	0.406	0.240	−0.031	0.248	0.480	0.259
Generations	0.571*	0.215	0.221	0.198	−0.032	0.120
Income	0.387	0.239	0.252	0.232	0.724†	0.247
Years of experience	0.031	0.278	−0.031	0.021	0.008	0.256
R^2		0.141		0.256		0.338
F		5.558*		6.780†		12.610*
Cases		246		146		181

* $P < 0.1$.
† $P < 0.05$.

Strengthening a knowledge network

Participation in outreach opportunities helps growers build knowledge-sharing relationships — for example, by attending workshops or by reading a newsletter (a referral for future interaction). Using a simple linear regression model, we tested the hypothesis that growers' position in the knowledge network is a function of their participation in outreach activities. We conducted three separate regression analyses with data from each AVA.

The outcome variable used for this analysis was total degree centrality. The primary predictor variable was the total count of outreach events that survey respondents reported participating in. Due to differences in how the survey question was structured in the three surveys, we were not able to use a normalized participation measurement (i.e., percentage of events participated in) across regions. Regional comparisons can nevertheless be made.

The survey asked growers whether they had participated in outreach events within the past 5 years: attended informational field meetings, attended informational classroom-style meetings, read organization newsletters, spoke with organization staff, accessed organization internet resources, completed a sustainable viticulture certification program, completed a sustainable viticulture self-assessment program, attended regional and statewide viticulture industry fairs. The model included several secondary predictor variables as controls, including the number of acres managed (integer), age (six categories), education level (six categories), generations the respondent's family had been involved in agriculture (six categories), gross annual income (eight categories) and years of viticulture experience (integer).

The data included a total of 246 Central Coast, 146 Lodi and 181 Napa Valley cases (predictor variable by outcome variable combinations). The results are summarized in table 5. The unstandardized coefficients (beta) from the regression models are presented, which represent the expected change in the outcome variable for a one-unit change in the predictor variables. Across all three regions, the variable of participation in outreach events was a significant predictor of network centrality variable (while controlling for the six secondary predictors). Table 5 shows the coefficients for participation are positive and statistically different than zero ($p < 0.01$). In other words, the more outreach events survey respondents reported having participated in, the more knowledge-sharing relationships they had.

Interpretation of the coefficients in table 5 must consider the scales of the individual variables. To explain the predictor variable's influence on the outcome variable in meaningful terms, one can calculate the number of outreach events associated with a one-unit increase in a grower's knowledge-sharing relationships (data not shown in table 5). For example, in the Central Coast, participation in 4.78 outreach events over 5 years was associated with an increase of one knowledge-sharing relationship. In Lodi, the number of outreach events was 2.02, and in Napa Valley the number was 4.22. The noticeable difference in Lodi is explained by differences between the variables and not by differences in the outreach program effectiveness. The number of possible outreach events included in the Central Coast and Napa Valley surveys was greater than the number included in the Lodi survey. The range of outreach events participated in was 0 to 24 for the Central Coast, 0 to 27 for Napa Valley and 0 to 10 for Lodi. These differences in the data were reflected in the unstandardized coefficients.

Two regional differences were present. Napa Valley was the only region where gross annual income was a significant predictor of centrality. On average, Napa Valley wine grapes are valued at a much higher price per ton than those farmed in the Central Coast and Lodi (CDFA 2013). Our data shows a positive relationship between centrality and income in the Napa Valley, suggesting that the more successful growers are also among the most connected. In the Central Coast and Lodi, centrality was more evenly distributed across income levels.

Central Coast was the only region where growers' number of generations in agriculture was a significant predictor of centrality. This result is in line with the history of the region. Viticulture at the scale that exists today is relatively new to the Central Coast and the expanding industry has likely attracted many new growers to the region. It is logical that Central Coast growers who are multigenerational are more connected since their families have had more time to establish relationships. Lodi and the Napa Valley have longer histories as established winegrowing regions.

Our results suggest that growers' participation in outreach events may play a role in helping them strengthen their position in the knowledge network. Extensionists frequently acknowledge that the informal discussion among growers before and after outreach meetings is as important as the content delivered during the events. However, we must be cautious about the direction of causality between these two variables because they are likely to have a reciprocal relationship. Growers may attend outreach meetings as a result of learning about them from social connections. Even if all growers are aware of outreach events through official announcements like print mailings or emails, those growers whose peers plan to attend may be more likely to attend themselves. The positive association between network centrality and participation in outreach events is probably synergistic, where both variables catalyze each other. Network-smart extension strategies can

Lodi wine grape growers gather to learn about mechanical pruning equipment and trellising systems from UCCE San Joaquin County farm advisor Paul Verdegaal and fellow growers with experience on the topic. Field meetings cultivate social learning passively. Network-smart extension would integrate facilitation techniques to actively engage growers in knowledge-sharing activities with their peers.

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be designed to capitalize on those mutually reinforcing processes.

Network-smart extension strategies

Cooperative Extension and the many others working in an extension capacity have for a long time understood, albeit anecdotally, that social learning is an important pathway for extending agricultural knowledge. Our results provide scientific verification for that common knowledge. The results also inspire confidence in the networked, partnership model of agricultural extension, and its emphasis on experiential and social learning. The question for extension is how to capitalize on the natural process of social learning and develop network-smart extension strategies.

Network-smart extension means taking advantage of existing network structure or restructuring the network by adding nodes and links, or rewriting existing links, with the goal of more efficiently connecting those with solutions to those with questions (Valente 2012). The goals of network-smart extension are to (1) increase grower awareness of what others know, (2) encourage growers to value what others know, (3) increase access to what others know and (4) decrease costs associated with accessing what others know (Cross and Borgatti 2003). These goals can be achieved through any number of creative extension strategies. Here, we propose four that have relevance to Cooperative Extension and other agricultural support organizations.

Institutionalize knowledge brokerage. In network science, brokerage refers to an individual's ability to bridge disconnected groups within the network. Those who span group boundaries have access to a diversity of knowledge, which is critical for problem solving and innovation (Burt 2004; McPherson et al. 2001). Outreach professionals traditionally work as advisors within a specific domain. The knowledge network may function more effectively if outreach professionals, especially farm advisors and others working for organizations with no profit motive, focus on knowledge brokerage in addition to advising.

Brokers are skilled at playing the role of matchmaker between those with questions and those with solutions (Velasquez et al. 2006). Brokerage requires awareness of others' knowledge deficits and knowledge assets. There is of course overlap between advising and brokerage, but the difference has significant implications for how outreach professionals approach their work and the methods they use to meet growers' needs. Institutionalizing knowledge brokerage has the potential to alleviate the UCCE bottleneck.

Form alliances with knowledge agents. While direct engagement with growers is an essential part of any agricultural extension program, extension goals may be achieved more effectively by allying with outreach professionals such as for-hire vineyard managers, PCAs and consultants, who are optimally positioned in the network to access and spread knowledge throughout the network. Those outreach professionals are highly accessible to growers and are positioned to rapidly respond to grower inquiries. A starting point for developing new strategies with these allies might be train-the-trainer education, which has been implemented with success in various agriculture contexts (Fliert et al. 1995; Moore et al. 2007).

Help build relationships. Agricultural outreach commonly consists of lecture-style meetings, where scientists or outreach professionals communicate knowledge to growers through presentations or demonstrations. This style of outreach misses out on the opportunity to cultivate interpersonal relationships and build reciprocal trust and respect. Drawing on pedagogies that encourage growers to engage with others and share their experiences may help others to value what they know.

Icebreakers, for example, help build such relationships (Prezioso 1989). They are "tools that enable the group leader to foster interaction, stimulate creative thinking, challenge basic assumptions, illustrate new concepts, and introduce specific materials" (Prezioso 1989). Approaches that foster engagement cultivate a culture where individuals take responsibility for and are involved in strengthening their own knowledge network.

Experiment with innovative models. The Community of Practice (CoP) model might be useful for building social learning into agricultural extension. CoPs are formalized groups of practitioners who share a common practice, are confronted with similar challenges and have similar goals, and who strengthen their practical knowledge through continuous knowledge sharing with others in their community (Wenger 1998). In contrast to conventional agricultural extension strategies, which focus on the ultimate outcome of practice adoption, CoPs focus on building knowledge-sharing relationships, learning and innovation. CoPs might be hosted by agricultural support organizations like commissions or voluntary member associations, which would facilitate the process of growers accessing what others know.

CoPs have been used in corporations to increase employee creativity and innovation (Brown and Duguid 2002), and the model served as the framework for UCCE's eExtension program (eXtension 2013) and for the Leopold Center for Sustainable Agriculture's practitioner working groups (Leopold Center 2013). CoPs have been shown to improve networks by establishing new knowledge-sharing relationships and connecting practitioners with others outside of their normal network (Cross et al. 2002; Velasquez et al. 2006). However, there are no studies that have used social network analysis to evaluate the CoP model (Borgatti and Foster 2003). CoP pilot programs, particularly those evaluated using social network analysis, may help assess the model's potential application in California agriculture.

The knowledge network may function more effectively if outreach professionals . . . focus on knowledge brokerage in addition to advising.

Cooperative Extension's role

Cooperative Extension and other agricultural support organizations play an important role in shaping the structure, and therefore function, of knowledge networks. There may be no single or best way to accelerate the natural process of social learning, but extension programs must be adaptive, creative, experimental and flexible in design and execution. Extensionists should be willing to step outside of conventional thinking about how programs can be designed. One challenge of the social learning approach is ensuring that the information being spread through networks is scientifically valid and accurate. Further research is necessary to understand if and how the scientific fidelity of information changes as it spreads through a knowledge network. The results presented in this paper serve as an empirical basis for developing a new generation of extension strategies designed to leverage the knowledge network and accelerate the process of social learning. CA

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Howard walnut trees can be brought into bearing without annual pruning

by Bruce D. Lampinen, John P. Edstrom, Samuel G. Metcalf, William L. Stewart, Claudia M. Negron *and* M. Loreto Contador

In traditionally managed Howard walnut orchards, trees are pruned annually during the orchard development phase, an expensive operation in terms of labor and prunings disposal costs. Our observations and some prior research by others had suggested that pruning may not be necessary in walnut. In a trial of pruned and unpruned hedgerow trees over 8 years, beginning a year after planting, we documented canopy growth, tree height, yield and nut quality characteristics and also the effects of fruit removal. Pruning altered canopy shape but did not lead to increases in canopy development, yield or nut quality. Although fruit removal stimulated more vegetative growth in both the pruned and unpruned treatments, fruit removal did not result in an increase in midday canopy photosynthetically active radiation interception or cumulative yield when fruit removal was stopped after year 4. After 8 years, there were no significant differences in tree height, nut quality or cumulative yield among any of the treatments, which suggests that not pruning young Howard orchards could provide a net benefit to growers.

The recommended training to develop the tree structure of lateral-bearing walnut (*Juglans regia L.*) varieties such as Howard during the first 4 years after planting is to use a combination of heading and thinning cuts (Aldrich 1972; Hasey et al. 1998). After year 4, heading of scaffolds is continued until the tree has reached the desired size, which usually occurs by year 6 to 8. The costs associated with such pruning and disposal of prunings are high — around $1,134 per acre total for years 1 to 6 (UCCE 2012). Some research has indicated that no significant difference in yield results from pruning walnuts (Olson et al. 1990), but that trial was conducted on mature trees. Our observations on breeding program orchards at UC Davis and grower orchards in California have suggested that walnut trees can grow and produce well without pruning even in the early years, so we initiated a trial to gather data over 8 years in a developing Howard walnut orchard.

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.E.v069n02p123&fulltext=yes
doi: 10.3733/ca.E.v069n02p123

In traditional pruning, after the first dormant pruning, relatively few shoots below the terminal bud usually break dormancy and grow, but those that do, grow more vigorously than shoots in unpruned trees. With repeated heading cuts over time, pruned trees develop a dense canopy, which can lead to shading-related dieback of interior limbs by year 5 or 6. In contrast, branches of unpruned trees elongate and produce side shoots, which fill the space around the main branches. The elongation growth on individual branches tends to occur every other year. The result is a more open canopy structure since fewer branching points are generated.

The size of a fruit or nut tree canopy affects the amount of light intercepted, which affects yield. A curvilinear relationship has been documented between intercepted PAR (photosynthetically active radiation) and canopy dry matter accumulation in apple (Wunsche et al. 1996), peach (Grossman and DeJong

Data was gathered over 8 years in a developing Howard orchard to see if trees can grow and produce well without pruning.

1998) and macadamia (McFadyen et al. 2004). A model of potential crop yields by Adam et al. (2011) suggests that the use of light interception is a better estimation of yield sensitivity than an approach that incorporates biomass production. A positive correlation between total canopy light interception and yield has been reported in apple (Barritt et al. 1991; Jackson 1980; Wunsche and Lakso 2000), with an estimated optimal balance between interception, productivity and fruit quality at approximately 70% to 80% interception (Rom 1991).

The objective of our study was to assess the impacts of traditional pruning and no pruning on tree growth and productivity. Fruit removal treatments were incorporated into the trial to assess the impact of crop load on vegetative growth, to see whether trees "stall out" if they are not pruned. The common wisdom is that early cropping can lead to competition with vegetative growth, making final tree size smaller, and that pruning prevents this from happening.

Colusa County orchard

The study began in the spring of 2004 following the second growing season in a Howard walnut orchard planted in 2002 on Paradox seedling hybrid rootstock in Colusa County, California. The soil profile was a mixture of the Arbuckle-Hillgate complex, Hillgate loam and Arbuckle sandy loam series (California Soil Resource Lab 2008). Trees were planted at a spacing of 12 by 25 feet (3.75 by 7.8 meters), with a north-south row orientation.

From 2002 to 2004, irrigation was by single line drip; in 2005 the orchard was converted to microsprinkler irrigation. Irrigation was scheduled using the water budget method, with the goal of supplying orchard evapotranspiration needs with adjustments based on soil moisture monitoring data.

Early training. All trees had received some hedgerow training already. Heading cuts had been made at about 4 to 5 feet (1.25 to 1.5 meters) during the dormant season following the first growing season, and scaffolds had been selected in the dormant season following the second growing season. At the start of the trial, spring 2004, heading cuts were made on the trees in the pruned treatments; the selected scaffolds were left unheaded in the unpruned treatments.

Pruning and fruit removal. Differential pruning and defruiting treatments were initiated in the spring of 2004. Five replications of each of four pruning and defruiting treatments were implemented in a randomized block design: (T1) unpruned with no fruit removed, (T2) unpruned with fruit removed, (T3) pruned with no fruit removed and (T4) pruned with fruit removed. Each replication consisted of three rows with four trees per row. The two trees in the middle of the center row of each 12-tree replication were used for detailed treatment monitoring, but treatments were applied to all 12 trees.

The pruning treatment (in T3 and T4) consisted of removing approximately one-third of the previous year's growth on all shoots that elongated the previous season, thinning shoots that were too close together and removing in-season branching points (sylleptic shoots). No cuts were made on unpruned treatment trees except to remove limbs that were either in the way of tractor traffic through the orchard or impeded the view of the trunk for the mechanical shaker operator. The weight of the removed branches was included in the fresh pruning weights reported by treatment. The pruning treatment was terminated in 2007.

In the spring of 2004, 2005 and 2006, all fruit were removed by hand-thinning from treatments T2 and T4 in mid-April, when fruit were approximately 0.24 inch (0.6 centimeter) in diameter, to assess the impact of crop load on vegetative growth. Fruit were not removed from these treatments after 2006.

Canopy growth in young walnut trees is bimodal: Preformed growth forms in the bud during the previous season, and neoformed growth forms during the current season.

Data collection, 2003 to 2010

Midday stem water potential (MSWP) was measured approximately every other week on 10 trees per treatment from 2005 through 2010. Leaves were bagged at least 15 minutes before measurements were taken with a plant pressure chamber (Soil Moisture Equipment, Goleta, CA) between 1 p.m. and 3 p.m. following methods described by Fulton et al. (2001).

Canopy growth. On young walnut trees, shoot growth is bimodal. The portion of the shoot that is formed during the previous season and overwinters in the dormant bud is known as the preformed portion of the shoot; the portion of the shoot that forms during the current growing season is known as the neoformed portion of the shoot (Sabatier and Barthélémy 2001). Preformed shoot growth is completed by early May, and shoot growth from June through fall is neoformed. The number of shoots

Comparison of yearly tree development in unpruned and pruned Howard walnut trees.

producing neoformed growth was counted on each tree on two dates during summer in 2005 to 2007 and one date in 2008. Terminal shoot growth was measured at the end of the growing season in 2004, 2005, 2006 and 2007. Tree height and trunk circumference were measured at the end of each growing season from 2003 through 2010.

Midday canopy PAR interception was measured in late June to early July from 2005 to 2008 using a Sunfleck Ceptometer (Decagon Devices, Pullman, WA). A grid of 100 measurements was taken in each replication around the same 10 trees per treatment used for MSWP monitoring, using methods described by Grossman and DeJong (1998). In 2009 and 2010, midday canopy light interception was mapped in the same area as the grid using a mobile platform light bar (Lampinen et al. 2012).

There was more shading-related lower canopy dieback in the pruned treatments than in the unpruned treatments.

Nut quality and harvest. The number of sunburned nuts on each tree were counted in early September in 2004 to 2008. The percentage of sunburned nuts was then calculated using the estimated total number of nuts on the tree. In 2004, yield was estimated by counting nuts on the trees and multiplying by average dry weight of nuts. In 2005 and 2006, trees were harvested by hand-shaking, and all nuts were collected, hulled, dried, counted and weighed. Nuts were removed by mechanical shaking in 2007 and 2008. The nuts were run through a small hand-pulled huller-blower with a rotating drum to remove hulls and leaves and weighed in the field. In 2009 and 2010, nuts were mechanically shaken, picked up with a commercial harvester and weighed in the field using load cell–equipped harvest trailers. In all years, subsamples were taken for hulling and drying to allow conversion to dry in-shell weight. Samples were analyzed for quality each year from 2005 to 2010. Statistical analysis ($P \leq 0.05$, Duncan's means test) was conducted using SAS Software (SAS Institute, Cary, NC).

Affects on growth, yield, nut quality

Pruning and fruit removal treatments had only small impacts on MSWP. In 2005, 2006 and 2009, there were no significant treatment differences in seasonal average MSWP (table 1). In 2007, 2008 and 2010, T1 and T4 tended to be slightly more stressed than T2 and T3, but the differences were small (approximately 0.05 MPa) and unlikely to have had significant impacts on tree growth, yield or quality.

Canopy growth. Pruning stimulated more neoformed shoot growth in 2005, 2006 and 2007 (fig. 1). In 2005 and 2006, there were fewer shoots growing in the pruned treatment in late summer than in the unpruned treatment trees (fig. 1). The unpruned trees tended to have a more open canopy structure, while the pruned trees tended to be more dense. The differences were less pronounced by 2010. However, there was more shading-related lower canopy dieback in the pruned treatments than in the unpruned treatments. Fruit removal exacerbated these differences, with the worst shading-related lower canopy dieback occurring in the pruned treatment with fruit removed (T4).

TABLE 1. Seasonal average midday stem water potential (MPa)* by treatment, 2005–2010

Treatment	2005	2006	2007	2008	2009	2010
T1. Unpruned	−0.608a†	−0.625a	−0.664ab	−0.490b	−0.625a	−0.509ab
T2. Unpruned, fruit removed	−0.609a	−0.596a	−0.645a	−0.423a	−0.573a	−0.467a
T3. Pruned	−0.664a	−0.643a	−0.643a	−0.455ab	−0.580a	−0.472a
T4. Pruned, fruit removed	−0.664a	−0.629a	−0.733b	−0.503b	−0.642a	−0.553b

* Measured on 10 trees for each replication approximately every 2 weeks during the growing season.
† Letters indicate statistical significance ($P \leq 0.05$ Duncan's means test) among treatments within a year.

Fruit removal had little effect on overall vegetative growth in the first and second year of the trial, when numbers of fruit per tree were few, but by the third year, shoot growth tended to be more extensive on trees with fruit removed, both in terms of the number and length of shoots; however, this did not result in a significant increase in tree height (fig. 2), midday canopy light interception (fig. 3) or cumulative yield (fig. 4) by 2010.

In 2005, 2006 and 2007, fruit removal tended to result in more fresh pruning weight removed, but the effect was significant for only the pruned treatments (fig. 5). Only a small amount of dormant pruning was applied in 2008. In early June of 2008, the crop load was weighing down branches, making the drive row impassable, and summer pruning was conducted on all treatments to allow passage through the orchard. The problem was most severe in T3 and T4, the pruned treatments, possibly due to heavier

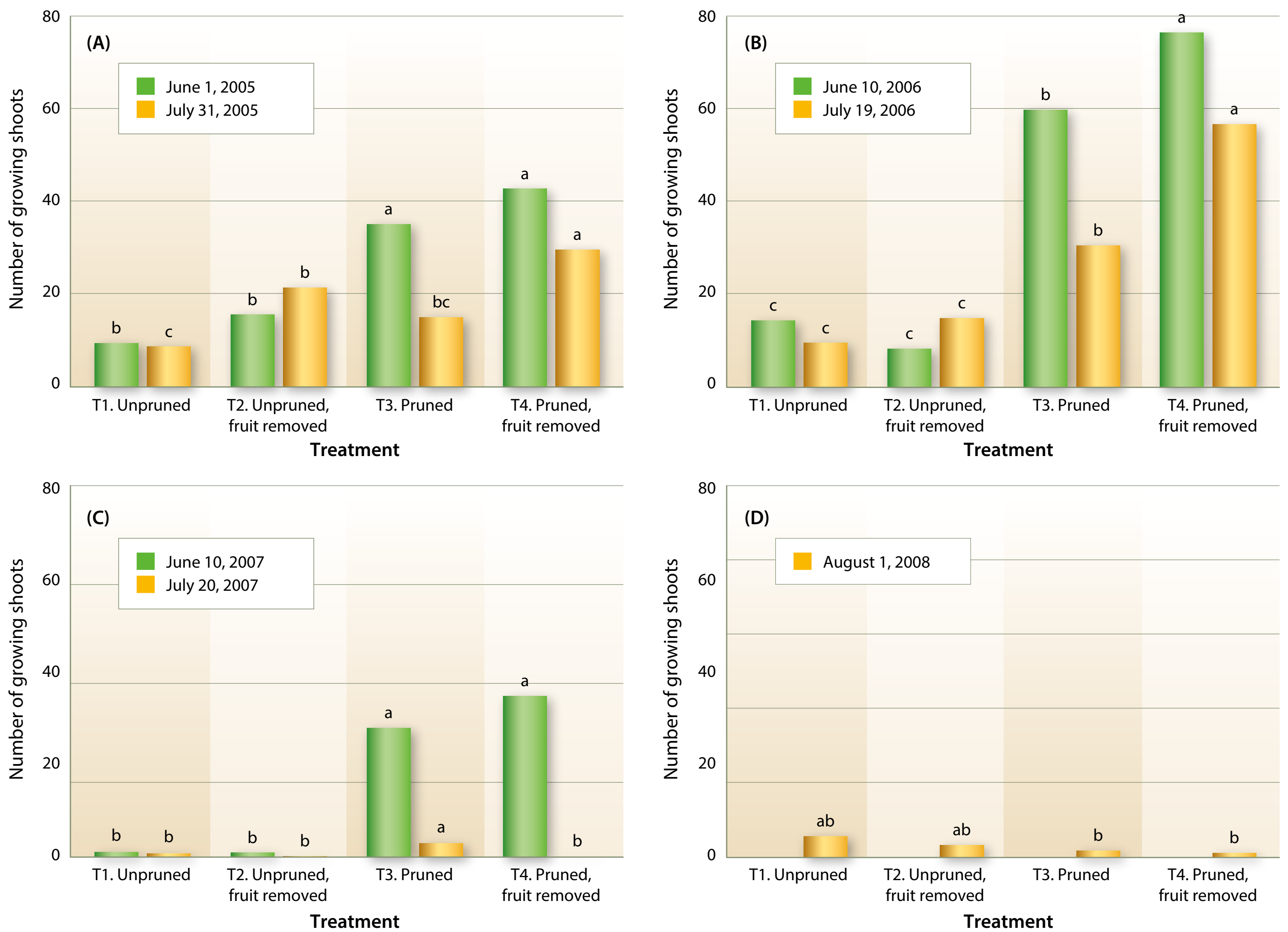

Fig. 1. Average number of neoformed shoots growing per tree on (A) June 1 and July 31, 2005, (B) June 10 and July 19, 2006, (C) June 10 and July 20, 2007, and (D) Aug. 1, 2008, by treatment. Letters indicate a significant difference ($P \leq 0.05$) among treatments on a specific date using Duncan's means test.

cropping as a result of the termination of pruning for the first time the previous winter. The pruning weights in figure 5 do not include the weights from the summer pruning. Severity of summer pruning ranked from most to least severe was T4 > T3 > T2 > T1, with approximately twice as much wood removed from T4 than from T1.

There were no significant differences in trunk cross-sectional area between treatments in any year (data not shown).

Midday canopy PAR interception (reported as a percentage of total available PAR) increased from about 30% in 2005 to 70% by 2010. There were no significant differences in June/July midday canopy PAR interception among treatments in any year (fig. 3). Since midday canopy PAR interception sets an upper limit to potential productivity and no differences were found among treatments, we would not expect major yield differences among treatments once fruit removal ceased; and no significant differences in yield were observed in 2008, 2009 and 2010, after the fruit removal treatment was terminated (fig. 6).

Yield and quality. In 2005, the unpruned treatments had significantly higher yields than the pruned treatments (fig. 6). However, after 2005 these early differences did not persist (fig. 6). In 2007, T2, unpruned and fruit removed in 2003 through 2006 but not in 2007, had a significantly higher yield than any other treatment; T4, pruned and fruit removed, did not have a significantly high yield (fig. 6). In 2008, 2009 and 2010, there were no significant treatment differences in yield (fig. 6).

There were no differences in cumulative yield between T1 (unpruned, no fruit removed) and T3 (pruned, no fruit removed) in any year (fig. 4). Cumulative

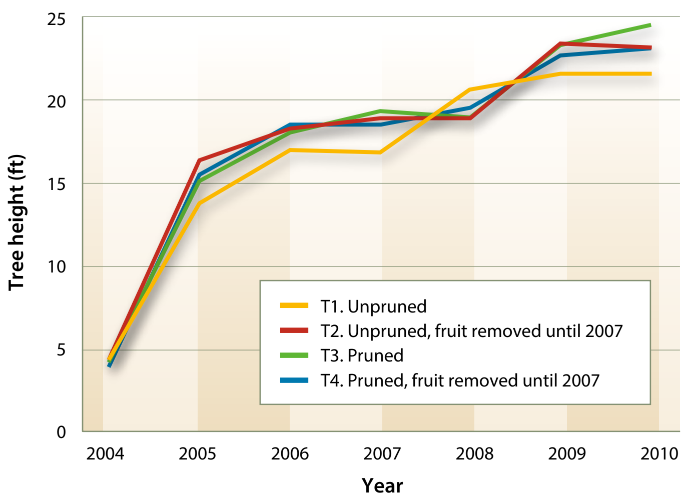

Fig. 2. Tree height, in feet, measured at the end of each growing season. There were no significant treatment differences in height on any date. (1 foot = 0.3048 meter.)

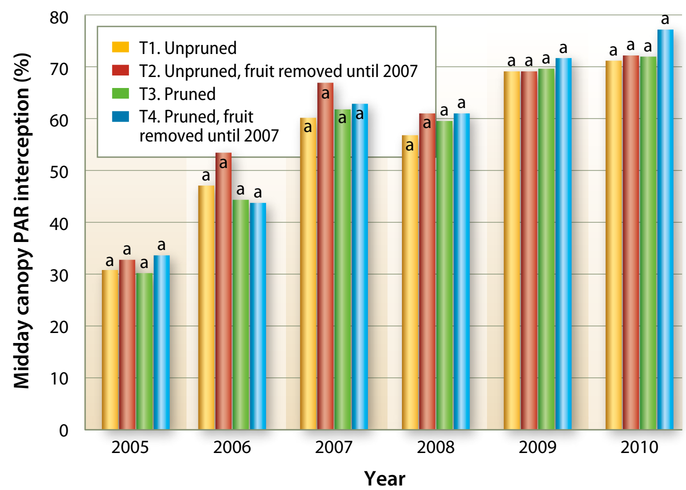

Fig. 3. Midday canopy PAR interception measured on June 22, 2005, June 15, 2006, June 18, 2007, July 3, 2008, June 23, 2009 and July 9, 2010. Letters indicate a significant difference (*P* ≤ 0.05) among treatments within a given year using Duncan's means test.

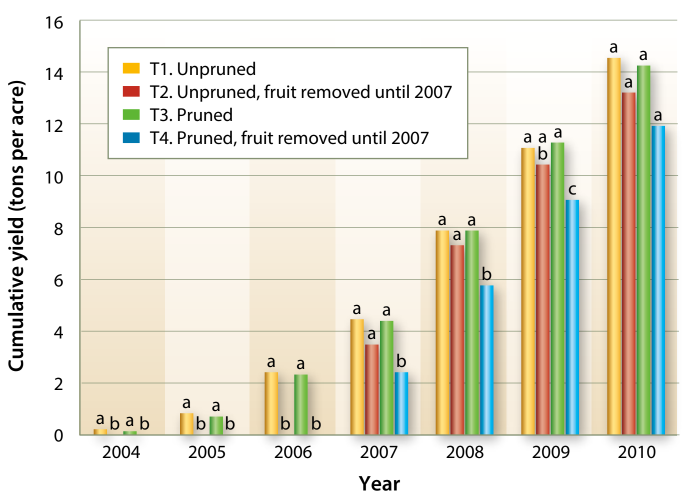

Fig. 4. Cumulative yield (tons per acre) by year and treatment. Letters indicate a significant difference (*P* ≤ 0.05) among treatments within a given year using Duncan's means test. (1 ton per acre = 2,241.7 kilogram per hectare.)

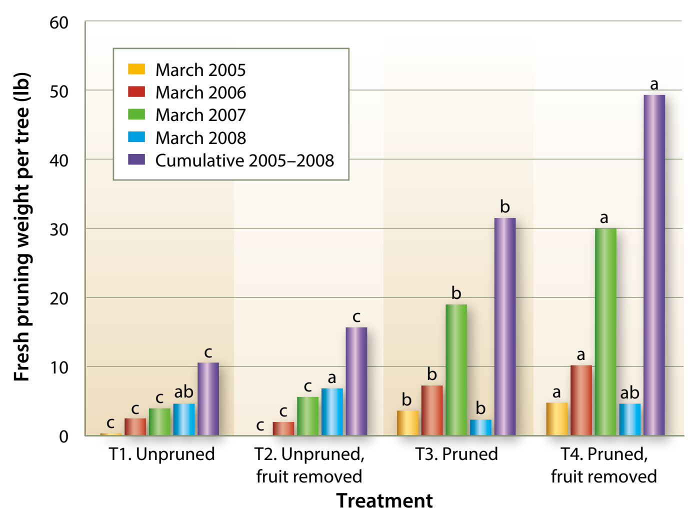

Fig. 5. Fresh pruning weight per tree, in pounds, measured on day of pruning. Pruning weight from unpruned trees is of limbs removed because of wind breakage or because they impeded orchard operations. Letters indicate significant difference among treatments within a given year (or for cumulative total) at *P* ≤ 0.05 with Duncan's means test. (2.20 pounds = 1 kilogram.)

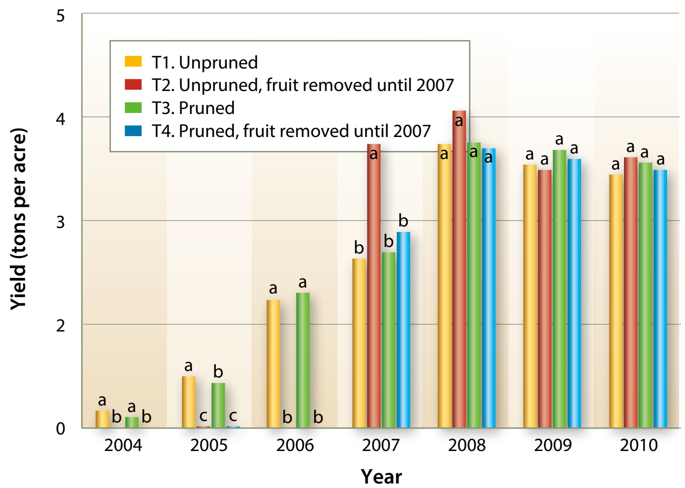

Fig. 6. Yield (tons per acre) by year and treatment. Letters indicate a significant difference ($P \leq 0.05$) among treatments within a given year using Duncan's means test. (1 ton per acre = 2,241.7 kilograms per hectare.)

yield for T2 was not significantly lower than T1 and T3 in any year after fruit removal ceased in 2007, while T4 cumulative yields were similar to T1 and T3 by 2010 (fig. 4).

Quality of nuts from this trial was generally good, both in terms of nut size and color. There were no significant treatment impacts on any quality attributes in any year except in 2008, when the nuts in T1 were slightly larger (with similar crop load) than the nuts in T3 (data not shown). There were no significant treatment impacts on sunburn in any year measured (data not shown). Sunburn was not measured in 2009 or 2010 due to the difficulty of getting an adequate assessment with the large tree size.

No benefits to pruning

After 8 years of pruned and unpruned treatment imposition, there were minor differences in MSWP (table 1) but no significant differences in tree height (fig. 2), nut quality (data not shown) or cumulative yield (fig. 4) among the treatments. The unpruned treatments, which had no pruning except for the removal of branches that were in the way of shakers or tractors, had cumulative yields similar to the treatments that were pruned annually for the first 7 years.

Our results are in agreement with previous pruning studies in walnut that found no significant differences in yield with the exception of one season when unpruned yields were higher (Olson et al. 1990), but that trial was conducted on mature trees. In macadamia, yield decreased directly in proportion to severity of pruning (Olesen et al. 2011), with all pruning treatments resulting in significant reduction in yields except a light pruning treatment.

Decreases in nut size and quality have been documented in unpruned compared to pruned walnut (Olson et al. 1990) and pecan orchards (Worley 1991). However, in both cases the increase in return from improved nut quality was not sufficient to offset the labor costs of pruning. In our trial, there was no significant impact on either major sunburn or nut quality in any year (data not shown).

This study did not show any tree structure-, production- or nut quality–related advantages to pruning under the conditions of this trial. Since costs associated with pruning and disposal of prunings are high, as mentioned above, growers may be able to enhance economic returns by minimizing or eliminating pruning during the development phase of a Howard orchard. The results will not necessarily translate to all varieties and management systems, so caution should be used in implementing a no-pruning practice on a large scale. CA

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