Sustainable Agriculture and Common Assets: Stewardship Success Stories

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For People, Nature, and the Economy

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FOREWORD

California's agricultural sector is economically more productive than ever, generating $26.8 billion in farm receipts in 1997, nearly twice as much as the next closest state. There is growing concern about the future, however, beneath the surface of this apparent success.

Agricultural communities are increasingly endangered. Farmland in California's productive Central Valley has been increasingly urbanized. Clean air, fertile soil, and full aquifers are depleted or overused by the spread of conventional agricultural techniques that ignore the hidden value of these common assets.

There is no easy way to place a price tag on common assets like air, soil, and water. Common assets are ecological and social resources that belong equally to a community of owners and frequently provide benefits beyond what the market system can measure. Their true worth to the community, as a result, often remains undervalued. Yet all of us have a stake in their management.

Common assets are ecological and social resources that belong equally to a community of owners and frequently provide benefits beyond what the market system can measure.

These natural and social common assets are not "owned" by anyone. For this reason, their management often falls to national and local governments. Given the importance of these common assets, there should be a commitment to manage them as an endowment, for which all of us are stewards. This effort should include a commitment to their health and survival in perpetuity for the benefit of current and future generations.

The current condition of our common-asset stewardship is distressing. We use agricultural assets faster than they can regenerate and often allow them to be degraded by pollution or short-sighted practices. We are, in effect, consuming them today and precluding their use by future generations. This is not only ill-advised: it is immoral.

Fortunately, some people are reversing this destructive process. This report, *Sustainable Agriculture and Common Assets: Stewardship Success Stories,* profiles farmers who are finding ways to protect common assets while providing benefits for themselves and their communities now and into the future.

At Redefining Progress, we believe "common assets" is a powerful concept that can provide advocates, consumers, farmers, and policymakers with tools to argue successfully for better stewardship of our agricultural assets. Common assets also provide a policy framework that expands the "bottom line" of agriculture. This report begins the difficult and necessary task of uncovering the too often hidden value of these assets. We hope to better arm those policymakers, and other interested parties, who are advocating policies that would lead to more sustainable agriculture practices.

This report offers examples of three common assets: native pollinators, natural floodplains, and the atmosphere. It also presents the results of a workshop that brought together representatives from government, industry, agriculture, research labs, and nongovernmental organizations.

Inside these pages, you will read about:

- The true value of native bees as pollinators and the dangers of overreliance on honey bee colonies to ensure adequate crop pollination;
- The Cosumnes River Preserve in Sacramento County, where sustainable agriculture is incorporated into the river's floodplains using agricultural methods that are flood-compatible and contribute to waterfowl habitat, water quality, and economic feasibility;
- Allen Garcia, who runs a 1,000-acre organic rice farm on a Nature Conservancy-managed floodplain in a way that creates waterfowl habitat and increases water quality; and
- Ways that California farmers can help combat climate change while restoring the soil's productivity through sustainable farming systems.

At Redefining Progress, we believe "common assets" is a powerful concept that can provide advocates, consumers, farmers, and policymakers with tools to argue successfully for better stewardship of our agricultural assets. Common assets also provide a policy framework that expands the "bottom line" of agriculture. This report begins the difficult and necessary task of uncovering the too often hidden value of these assets. We hope to better arm those policymakers, and other interested parties, who are advocating policies that would lead to more sustainable agriculture practices.

As consumers, we must be willing to provide farmers with financial incentives to use sustainable agriculture practices that are sometimes more expensive but benefit us all. As citizens, we must collectively demand policies that will compensate farmers for the services that sustainable agriculture provides.

As part of this process, Redefining Progress convened a workshop on October 30, 2000, in Modesto, California, bringing together representatives of government, industry, agriculture, research, and nongovernmental organizations. Workshop participants identified an action agenda to help improve the health of community assets and the sustainability of agriculture.

Although not comprehensive, this agenda reflects the collective wisdom, experience, and diverse perspectives of the Modesto Workshop's participants. Policymakers at multiple levels of government, educators, researchers, farmers, and nongovernmental organizations have important roles to play in improving the health of community assets and the economic viability of sustainable agriculture.

1. Research and recognize the value of natural common assets to farmers—as well as urban and rural communities—and compensate management practices that improve the health of these assets.

2. Improve the role of agriculture in the education system at all levels (university, high school, and elementary school) and better incorporate sustainable agriculture into existing agricultural research programs.

3. Reexamine the emphasis on policies that guarantee cheap food, so that food prices may better reflect the positive services farms can provide and help farmers avoid externalizing costs.

4. Experiment and invest in demonstration projects to illustrate the effectiveness of new management regimes, which will increase adoption by farmers.

5. Use a systems approach when dealing with the agricultural sector that encompasses all of the relevant actors and streamlines solutions.

As shown in this report, preserving our common assets can be financially beneficial to both farmers and society as a whole. Equally (if not more) important are the nonmonetary benefits of healthy common assets and sustainable agriculture. These include the aesthetic value of a free-flowing river, the greater variety of ecosystem benefits provided by a diverse habitat as compared to a monoculture, and the health benefits of cleaner air and purer water.

Such benefits are irrefutable—whether they are quantifiable or not. As consumers, we must be willing to provide farmers with financial incentives to use sustainable agriculture practices that are sometimes more expensive but benefit us all. As citizens, we must collectively demand policies that will compensate farmers for the services that sustainable agriculture provides. This report begins to describe a framework that will make political action possible by bringing to light the hidden value of our common assets.

Future generations will judge our stewardship of the planet. Enacting policies that provide incentives to farmers to preserve and enrich common assets through sustainable agriculture is essential.

ACKNOWLEDGMENTS

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This work would not have been possible without the generous support of the Clarence E. Heller and Surdna Foundations. I am particularly thankful to Bruce Hirsh of the Heller Foundation for his critical support and feedback.

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Thanks also are owed to the Redefining Progress staff, especially Michele Gale-Sinex for her invaluable guidance. The report benefited greatly from the comments and suggestions of reviewers, including Joanne Kliejunas, Diana Deumling, Cynthia Pansing, Jane Kelley, Jeanette Howard, Mike Eaton, and Allen Garcia.

INTRODUCTION

California agriculture is more economically productive than ever. It generated $26.8 billion dollars in farm receipts in 1997, nearly double the number-two state, Texas. Yet agricultural communities are more endangered than ever, with farmland in California's productive Central Valley increasingly urbanized.[1] At the same time, the natural, common assets on which agricultural (and all) communities depend—such as clean air, fertile soil, and full aquifers—are being depleted or overused.

Key to the strength of any community is the health of its natural and social common assets. These shared common (or community) assets play different, yet vital, roles in all of our lives. The Earth's atmosphere is one common asset that enables life itself. The ocean's fisheries provide livelihood and sustenance for great numbers of people. Other common assets enhance our quality of life by giving us amenities or defining our communities. The Milwaukee River's downtown River Walk, for example, is a gathering place for residents that reclaimed a degraded resource for the community's use.

This paper focuses on community assets that impact the economic and environmental health of farmers and that are in turn affected by agricultural practices.

To this end, we define and describe three common assets—natural floodplains, native pollinators, and the atmosphere—and their links to agricultural practices that help maintain the health of these assets. By linking common assets and sustainable agriculture, we provide a conceptual and policy framework that expands the farmer's "bottom line" by accounting for social and environmental costs and benefits that are currently ignored.

Redefining Progress sought success stories where farmers practice sustainable agriculture in ways that preserve a common asset, which in turn provided greater benefits to nature, the local community, and the farmers themselves. We sought to quantify how these practices improved or maintained the asset's health. We then held a workshop on October 30, 2000, in Modesto, California, bringing together representatives of government, industry, agriculture, research, and nongovernmental organizations.

Each case study was presented during the workshop. Participants then discussed the connection between sustainable agriculture and the specific common asset, the replicability of the case study, and barriers to the wider adoption of sustainable agriculture practices. In addition, they discussed how these barriers may be overcome without compromising farmers' livelihoods.

LINKAGE BETWEEN SUSTAINABLE AGRICULTURE AND COMMON ASSETS

Farmers often rely on the stream of benefits that natural floodplains, native pollinators, the atmosphere, and other healthy and functioning common assets provide.

This stream of benefits includes flood control generated by fertile soil and ample floodplains that hold water flows; crop yields enhanced by pollination services; and stable weather patterns helped by the soil's ability to sequester carbon, a greenhouse gas that contributes to climate change. Sustainable agricultural practices appear to lead to healthier common assets and more benefits for farmers, people, and nature. Thus, farmers benefit both from healthy assets and, through asset stewardship, society benefits as a whole.

The researchers and Modesto workshop participants analyzed the economic realities and challenges to maintaining healthy common assets through sustainable agriculture, examining current solutions, and what other policies or incentives could be helpful. Much of this study examines the intersection of private land and common assets, where behavior on private lands can degrade or improve the common asset. We explored ways in which sustainable agriculture can benefit the common good while serving the farmer as

The natural, common assets on which agricultural (and all) communities depend, such as clean air, fertile soil, and full aquifers, are being depleted or overused.

1 The American Farmland Trust lists the Central Valley as the U.S.'s most 'threatened' farmland. One study shows that in a single generation more than half of the Central Valley could be converted from farmland to urbanized land. Platzek, Rudy. 2000. *California's Most Important Choice: An Agricultural or an Urban Central Valley?* Valley Vision Project. Ceres, CA.

well. *Table 1* summarizes the potential management practices that allow natural floodplains, native pollinators, and the atmosphere to give greater benefits to both the farmer and the commons.

Workshop participants identified an action agenda to help improve the health of community assets and the sustainability of agriculture. Although not comprehensive, this agenda reflects the collective wisdom, experience, and diverse perspectives of the Modesto Workshop's participants. Policymakers at multiple levels of government, educators, researchers, farmers, and nongovernmental organizations have important roles to play in improving the health of community assets and the economic viability of sustainable agriculture. Many participants at the Modesto Workshop repeatedly raised the following five recommendations *(see Appendix III for Participants List)*.

TABLE 1

OVERVIEW OF SUSTAINABLE AGRICULTURE AND COMMON ASSETS

Common Asset	Sustainable Agricultural Management Practices	Common Benefits	Farmer Benefits
Natural Floodplains (Nonstructural Flood Control Systems)	Reduced pesticide use through organic agriculture or integrated pest management, planting hedgerows, using flood compatible agriculture	Flood control, less expensive flood control, improved wildlife habitat, improved water quality, aquifer recharge	Improved soil productivity
Native Pollinators	Reduced pesticide use through organic agriculture or integrated pest management, provide native pollinator habitat by planting hedgerows, using cover crops	More diverse natural world, maintain the health of natural ecosystems, pollination services for over 100 crops	More productive crops
Atmosphere	Conservation tillage practices, increasing biomass by planting hedgerows or cover crops, improved grazing management	More stable climate, possibly less expensive greenhouse gas reduction options	Improved soil productivity, lower production costs

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5. Use a systems approach when dealing with the agricultural sector that encompasses all of the relevant actors and streamlines solutions.

Recommendations pertaining to specific case studies can be found in the Conclusion and Workshop Discussion sections of individual case study chapters.

POLLINATION SERVICES AS A COMMON ASSET:
THE ROLE OF NATIVE BEES IN CROP POLLINATION

By Claire Kremen, S. W. Adelman[1], Robert Bugg, and Robbin Thorp[2]

In the United States, over 100 crops are insect-pollinated (O'Grady 1987), and 15-30%[3] of the average American diet is comprised of insect-pollinated foods (McGregor 1976, O'Grady 1987, Free 1993, Buchmann and Nabhan 1996, http://www.desertmuseum.org/fp/). Thus insect-pollinated crops make up an important component of dietary stability and diversity. Some of the fruits and vegetables requiring insect-mediated pollination include: almond, apple, apricot, blueberry, cantaloupe, citrus, cucumber, kiwi, peach, plum, squash, sunflower, and watermelon; a far larger set of fruits and vegetables also require insect pollinators for seed production.

Most flowering plants require pollination, the transfer of pollen grains from the male to the female reproductive parts, as a first step for successful seed set and fruit growth. Wind, water, or animals can all contribute to pollination, depending on the floral anatomy and the plant breeding system. While certain plants can only reproduce via animal vectors,[4] others do not require animal-mediated pollination, either because they are self-pollinated, or their pollen is transferred adequately by wind or water. Even self-fertile plants (e.g. tomatoes) or plants that are typically wind-pollinated (e.g. grapes) can benefit from animal vectors, because such vectors ensure pollen transport and help to effect cross-pollination, which can produce larger, better-tasting fruits with more viable seeds, and enhanced genetic diversity in seedlings (McGregor 1976).

It is generally believed that members of the bee superfamily *(Apoidea)* are the most important insect pollinators of most crop plants. This is because female bees are the only insects that visit flowers expressly to collect pollen as food for their larvae. They have morphological adaptations designed for collecting pollen, and they often tend to forage consistently on one species before returning to the nest to deposit their pollen load. This behavioral fidelity enhances the chance that pollen will be transported from flower to flower of the same species.

LINKAGE TO SUSTAINABLE AGRICULTURE

Most flowering plants require pollination, the transfer of pollen grains from the male to the female reproductive parts, as a first step for successful seed set and fruit growth.

Many farmers rely on honey bee (*Apis mellifera*) colonies to ensure adequate pollination of crops that require insect pollination. This is particularly true in California, which makes up 40% of the rental market for honey bees. Rental fees range from $15-50 per colony, depending on the crop. Each year, beekeepers move about 25% of the 2.4 million U.S. colonies throughout the country for rentals from region to region and crop to crop. Transportation of honey bees for long distances entails high costs for beekeepers. Honey production is a more important source of revenue to apiculturists than pollination rentals, making up 67% of revenues (USDA-NASS 2000). Since bees do not usually produce harvestable honey while on a crop, beekeepers may decide to reduce rentals in favor of honey-making when honey prices are high.

Bee colony availability has declined over the past 50 years due to three factors:

1. Pesticide misuse, which is responsible for damages to 15,000 colonies per year[5] (Nabhan and Buchmann 1997, Allen-Wardell et al. 1998);

2. Introduced diseases, including several mites and viruses first detected in the

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[1] Wildlife Conservation Society/Stanford University
[2] University of California at Davis
[3] The higher number is obtained by considering not only direct foodstuffs, but also insect-pollinated crops that contribute to livestock feed, and oilseed crops.
[4] e.g. self infertile plants, plants with heavy or sticky pollen (e.g. cucurbits), plants with highly specialized floral morphology (e.g. alfalfa).
[5] Losses due to pesticide misuse may have been much larger in the 1960s, and were estimated at 500,000 colonies in a single year (Levin 1984) or 10% of all colonies per year (McGregor 1976)

mid-1980s, which have caused the demise of many colonies and annual losses of $160 million to beekeepers for colony upkeep and replacement; and

3. Loss of a 50-year subsidy to the honey industry in 1994, which has caused many beekeepers to quit the industry.

Overall, there are now less than half the number of colonies that operated in the 1950s, and in some regions of the United States, this reduction causes shortages of pollination services at critical times.

Africanized bees pose an imminent threat to the beekeeping industry. Africanized bees, introduced from Africa to Brazil in 1957, have steadily advanced northward and are now present in southern California (Ventura, San Bernardino, and Kern Counties).

Honeybees are vital to American agriculture, yet their contribution in future years remains uncertain.

As they interbreed with European honey bees, they confer an aggressive trait which makes them difficult to manage and potentially dangerous to livestock and humans. Most apiculturists will therefore be reluctant to maintain honey bee colonies if interbreeding occurs, due to the potential liability issues. As many as 80% of beekeepers are expected to abandon beekeeping if Africanization becomes widespread (Buchmann and Nabhan 1996).

Thus the availability of honey bee colonies for pollination rentals varies depending on market and social factors, as well as environmental influences that affect the health and behavior of honey bees. Honey bees are vital to American agriculture, yet their contribution in future years is uncertain.

We also have a valuable natural asset in many species of native bees, which also visit and pollinate selected crops. Native bee pollinators provide a free service to farmers and consumers that is not influenced by market factors. To date, though, the quantitative importance of native bees in crop pollination remains largely undocumented. In a few cases, however, native bees are known to be more effective pollinators than honey bees (e.g. the alkali bee on alfalfa, *Nomia melanderi,* and bumblebee species on watermelons and blueberries, Kevan 1977, Kevan and LaBerge 1979, Kevan et al. 1990, Stanghellini et al. 1997). Thus, in addition to the insurance that native bees provide in the event that managed honey bees fail, they may already be providing a significant and measurable value to agriculture (Kevan et al. 1990).

Native bees may also be at risk from environmental change. Pesticides have taken their toll on native bee populations as they have on honey bees (Parker et al. 1987, Kevan et al. 1990, O'Toole 1993). Habitat loss, fragmentation, and degradation are suspected agents in the decline of native bee populations and diversity (Frankie et al. 1990, Matheson et al. 1996, Allen-Wardell et al. 1998, Frankie et al. 1998). Native bees require natural habitat to provide blooming plants throughout their flight period (Tepedino et al. 1997) and nesting sites for rearing young (O'Toole and Raw 1992). As natural habitats are converted to urban or agricultural uses, the pool of available areas that can support bees is declining. Thus while natural ecosystems may be providing pollinators—and hence pollination services—for free, non-sustainable land use is potentially eroding these benefits.

Finally, global warming constitutes an impending threat to native bee species with unknown consequences. As temperatures climb 2-4°F in the next 50 years, some bee species may find themselves at the limits of their physiological tolerance. Certain species may adapt by moving north or to higher elevations, but some species may not be able to reach suitable habitat patches, particularly if such patches are few and far between due to habitat conversion. These species will go extinct, decreasing both the pool of potential crop pollinators and the insurance policy against crop failure. In California, the biggest impact of global climate change on native flora and fauna is likely to be through the negative synergistic effects of climate and fragmentation (Field et al. 1999).

Native bee pollinators link natural habitats with agricultural areas. Native bee populations may rely on natural habitats to provide forage and nesting resources during part of the year and agricultural areas the rest of the year. Native bee pollinators may provide pollination services in both areas, and may in turn depend on both. Thus problems in one area could affect the other. For example, if natural areas suffer a reduction in pollination services due to declining populations of native bees, some native plants would fail to reproduce, further impoverishing natural areas already declining in species diversity and abundance due to habitat fragmentation and degradation. This in turn will diminish the abundance of forage available for bees in the following year, potentially reducing bee populations available to provide pollination services to crops.

Understanding the contributions of native bees to agriculture, and the dependence of native bees on both natural and agricultural habitat, will help us to develop plans for managing and conserving the pollination services they provide. In our two-year study on various crops in Yolo County, we have documented:

- The role of native bees in crop pollination;
- The role of natural areas in maintaining bee abundance, diversity, and pollination services;
- The economic value of native bees as crop pollinators; and
- The role of land management practices in enhancing pollination services on farms.

The rest of this chapter will discuss what we have learned so far, and indicate what we still need to find out in order to conserve, restore, and maintain these vital services.

THE ROLE OF NATIVE BEES IN CROP POLLINATION

WE SURVEYED THE NATIVE POLLINATORS visiting strawberries, tomatoes, squash, eggplant, watermelon, and muskmelon on several or more organic farms for each crop. Twenty-six or more species[6] of native bees in 19 genera were found to visit these crops (*see Appendix I*). While some crops were visited by only a few species, others were visited by most of them. Interestingly, there seemed to be little specialization by bees on particular crops. A few species visited all of the crops (e.g. *Halictus tripartitus*). A few crop species (watermelon, strawberry) received visits from most of the 19 genera of crop-visiting bees. Thus a complex of native bees in this region appears to be well-adapted to the agro-ecosystem and readily visits a variety of agricultural crops.

We studied pollination services in five crops: tomato, eggplant, strawberry, muskmelon and watermelon. The percentage of visits from native bees, out of all visits by bees (e.g. native plus introduced honey bees), varies from crop to crop, and from farm to farm within crops. *Table 2* shows the percent of native bees out of total bee visits (natives + honey bees) to different crops in farms in Yolo and Solano counties. Since native bees often make up a large proportion of the flower visitors to these crops, they are potentially important pollinators. In addition, they may provide "insurance" in the event that honey bee populations decline due to disease or management problems.[7]

TABLE 2

PERCENT OF NATIVE BEES OUT OF TOTAL BEE VISITS (NATIVES + HONEY BEES)[8]

	Watermelon	Muskmelon	Strawberry	Eggplant	Tomato
Number of farms	14	14	4	5	6
Range	4% - 92%	0% - 42%	87%-100%	33%-100%	97-100%
Average ± S.E.	**34 ± 4**	**8 ± 2**	**96 ± 1**	**74 ± 8**	**99± 0.004**

Although bees may visit crop flowers frequently, visitation alone does not ensure pollination. For this reason, we carried out several different studies to assess how effective different bee species are as pollinators. We restricted these studies to watermelon—a plant that has separate male and female flowers, large, sticky pollen, and requires animal vectors for pollination.

In the first set of studies, we observed the behavior of bees on watermelon flowers to determine whether they are likely to transfer pollen from male to female flowers, and how much pollen they carry. From these

6 Not all bees have yet been identified to species. Here we assume that each genus for which identifications remain to be made contributes only one as yet unidentified species to the pool of crop visitors. Therefore, the figures presented represent a minimum number of species, because some of the genera with unidentified species will contribute more than one species (e.g. *Lasioglossum (Evylaeus)* consists of six morphospecies in our area, R. Thorp, unpublished data).

7 e.g. reduced management due to hybridization with Africanized "killer" bees

8 Data from 1999 study.

studies, we found that all of the bee species we observed (11 out of 18 potential species) visited flowers in a manner consistent with transfer of pollen from male to female flowers. Different bee species carried different amounts of pollen, and individuals within a species also varied greatly. Individual bees may carry from 0-4,000 grains of pollen. For comparison, watermelon flowers require 500-1,000 pollen grains for adequate fertilization and fruit development (Adlerz 1962).

Between honey bees and native bees, all organic farms received more than adequate pollination.

Next, we studied how much pollen is characteristically deposited onto the female stigma of watermelon flowers by the visit of a single bee from different species. As expected from the large variation in pollen loads, these pollen deposition results were also highly variable, both within and between species (10 out of 18 potential species were studied). In general, the minimum and maximum estimates of pollen deposition were consistent with the levels of pollen that bees carry, although they were lower (0-571 grains deposited in a single visit).[9]

Using this information, we next calculated the total contribution of each species to watermelon pollination. While some bees deliver a large number of pollen grains on each visit, their visits are relatively infrequent. Thus it is important to consider both total visitation frequency (estimated over an entire day) and pollen delivery in assessing the total contribution.

Table 3a shows the total estimated amounts of pollen deposited on average by native bees and by honey bees on the organic farms in our study. These estimates were based on two factors: the average visitation frequencies of different bee species over the course of the day, and the average pollen deposited by different bee species per visit. We combined data from separate studies in 1999 and 2000 across 11 farms in each year.[10] Thus these average estimates include the range of both interannual and inter-site variation. *Table 3a* also shows what percent of watermelon pollination native bees or honey bees each potentially contribute, relative to the total amount of pollen necessary to fully pollinate a watermelon (1,000 grains). Finally, the table shows the percent of pollination provided by native bees out of the entire pollination provided by all bees.

Between honey bees and native bees, all organic farms received more than adequate pollination (> 100% of requirement). Our estimates suggest that native bees alone on average could deliver more than enough pollen to pollinate a watermelon fully (111% of requirements). This effect was due to the cumulative service provided by the community of native bees, rather than by a single bee species.

Visitation rates vary across farms, and this depends in part on the environment in which the farm is situated *(see Table 3b on the next page)*. Visitation rates will affect pollen deposition, so we compared farms in three situations: organic farms embedded in a landscape of natural areas, organic farms embedded in an agricultural matrix, and conventional farms.

Since we did not have data over the entire day for each of these situations, but only for the morning period, we used the morning period data (9 a.m.-12:30 p.m.) to estimate the relative amounts of pollen deposited in each situation. From that, we could then estimate the total amounts of pollen deposition in the different farm environments by scaling against the full-day sample, to obtain a figure of 97% *(Table 3b)*. In contrast, on organic farms far from wildlands or on conventional farms, native bees were less abundant, and we estimated that native bees alone would provide on average only 24% and 12% of required

TABLE 3a

POLLEN DEPOSITION ON WATERMELON FLOWERS ON 18 SEPARATE FIELDS

	Average Value
Total native bee pollen contribution (number of pollen grains)	1,116
Honey bee pollen contribution (number of pollen grains)	5,407
Percent of required pollen provided by native bees	111%
Percent of required pollen provided by honey bees[11]	540%
Percent of total pollination effected by native bees out of all bees	17%

[9] It is not surprising that pollen transport would be greater than pollen delivery. Female bees are adapted for collecting pollen to transport to their nests. These adaptations prevent the removal of the entire pollen load that the bee is carrying.

[10] Overlap between the farm fields studied was four fields.

[11] Watermelons require 500-1,000 grains for fruit maturation. We assumed that they required 1000 grains to calculate the percent of required pollen provided by native versus honey bees.

pollination, respectively. Honey bees would be required to make up the difference. Most of the farmers in these situations did indeed rent honey bee colonies.

Honey bees were abundant throughout Yolo County, however, whether farmers rented bees or not. In cases where farmers did not rent honey bees, there may have been colonies nearby, or feral colonies may have established. Only honey bees were sufficiently abundant as a species to provide a complete pollination service on their own. Between the combined contributions of honey bees (managed and feral) and native bees, all farms in Yolo County, regardless of their situation, appear to receive a substantial excess of pollination at this time.

THE ROLE OF NATURAL AREAS IN MAINTAINING BEE ABUNDANCE, DIVERSITY, AND POLLINATION SERVICES

We sampled relative abundance of bees on 20 farm sites, four riparian sites, four chaparral sites, and three native plant hedgerows using pan-traps and PVC traps. We found that most of the species occurring in natural areas also can be found on farms *(Appendix I)*. Chaparral sites had the highest numbers of bees, with on average 3-9 times more bees collected per site.

Table 4 (on page 14) shows the comparison between sites for bee abundance, species richness, and diversity. The data are presented collectively for each habitat type and as averages over habitat types. However, chaparral sites had significantly lower diversity (here defined as species inventoried per specimens collected), whether considered on a site by site basis or collectively. Nineteen species were inventoried in chaparral sites from 3,120 specimens, while the same number of species were inventoried in riparian habitats from only 354 specimens.

Farms and hedgerow sites displayed intermediate abundance and diversity. While the average number of species per specimen showed significant changes with habitat type, the average species richness (number of species) observed at any individual site did not differ significantly with habitat type.

Thus, riparian habitats, while relatively diverse, were low in abundance; whereas chaparral habitats were high in abundance of relatively few bee species. These same species that were numerous in the chaparral habitat also appear to be some of the most important visitors to watermelon on farms in terms of their pollen contribution (e.g, *Halictus, Melissodes*). Thus both natural habitat types have the potential to contribute to maintaining bee diversity, abundance, and pollination services on farms since most of the bee visitors to crops observed in this study have also been found in one or both natural habitat types.[15]

TABLE 3b
INFLUENCE OF FARM ENVIRONMENT ON POLLEN DEPOSITION[12]

Farm Environment	Organic in Natural Area Matrix	Organic in Agricultural Matrix	Conventional
Number of farms	12	9	13
Total native bee contribution (number of pollen grains, 9 – 12:30)	666	169	85
Total honey bee contribution (number of pollen grains, 9 – 12:30)	3,571	2,833	2,726
Total native bee contribution, full day	952	—	—
Percent of required pollen provided by native bees in 9 – 12:30 sample	66%	17%	9%
Percent provided by native bees relative to full day sample	70%	—	—
Estimated percent provided in a full day	97%	24%	12%
Percent of total pollination effected by native bees	16%	6%	3%

[12] Estimates were based on bee visitation between the restricted hours of 9 a.m. and 12:30 p.m. in order to have an equal sample effort between farm types; therefore these values do not represent the entire amount of pollen that would be deposited per flower per day. We then scaled these values to a full day sample by dividing by the proportion of pollination effected in the 9-12:30 period compared to the full day (using the organic farms in the natural area matrix, for which we had sufficient full day data). Organic farms in natural area matrix (N_{1999} = 6, N_{2000}= 6, overlap = 3); organic farms in agricultural matrix (N_{1999} = 5, N_{2000}= 4, overlap = 1); conventional farms (N_{1999} = 3, N_{2000}= 10, overlap = 0).

TABLE 4

COMPARISONS BETWEEN SITES FOR BEE COMMUNITY RELATIVE ABUNDANCE, SPECIES RICHNESS, AND DIVERSITY[13]

	Sites	Overall Abundance	Overall Species Richness (number of species)[14]	Overall Diversity (species/ specimen)	Average Abundance	S.D.	Average Diversity (species/ specimen)	S.D.	Average Species Richness (number of species)	S.D.
Chaparral	4	3,120	19	0.006	780[a]	390	0.016	0.009	10.25	2.06
Farm	20	4,463	32	0.007	223[b]	114	0.054	0.025	9.75	1.91
Hedgerow	3	633	13	0.021	211[bc]	220	0.067	0.058	7.76	2.31
Riparian	4	354	19	0.054	88.5[c]	31.6	0.110	0.035	9	1.82
Significance of statistical test					0.0001		0.003		0.3 n.s.	

Hedgerow samples did not differ from farm samples in abundance or species richness, and bees censused at hedgerows were also found in the farm samples *(Appendix I)*. Thus the hedgerows do not appear to be changing the abundance, richness, or composition of bees on farms, although further work needs to be conducted.

Visitation rates to a given crop varied extensively between farms. Might this be due to the varying environment around each farm and the proportion of natural areas in close proximity to the farm? We tested this in detail using the results from studying visitation to watermelon across 14 farms.[16]

These farms had been selected to vary in the proportion of nearby natural areas. Some, located in the Sacramento Valley, were surrounded by agriculture (chiefly conventional) and were far from natural areas. Others, located along the Cache Creek and Putah Creek drainages, were adjacent to or near extensive natural areas. For watermelon, we found that the proportion of wildlands (chaparral plus woodland plus grassland) in a 1.5 km radius around the farm field did have a significant positive correlation with the visitation rates by native bees, but only in combination with another variable, like average temperature. Together, these two variables explained 44% of the variation between farms, at a significance level of 0.02.

We next tested each type of habitat separately with average temperature as a covariate, and found that the area of grasslands bore no correlation to native bee abundance ($r^2adj = 0.07$, $p = 0.67$), whereas chaparral was marginal ($r^2adj = 0.29$, $p = 0.06$) and woodland bore a strong correlation ($r^2adj = 0.64$, $p = 0.001$). Grasslands in the Yolo County area are used for grazing and largely consist of nonnative grasses and weeds. Thus the presence of natural areas, particularly woodlands but perhaps also chaparral, in the environment around the farm may enhance pollination services. Further work is needed to determine threshold effects:

- How much area is required?
- How close do these habitats need to be to the farm and how may they be dispersed?
- Which habitats are most important for the most important pollinator species,

[13] ANOVA were performed to test for significance on species richness, log abundance, and diversity (the latter using Kruskal-Wallis nonparametric test); the same letter indicates that means do not differ significantly for a given test.

[14] Specimens within selected genera have not yet been identified to species or morphospecies. Thus species richness here actually combines generic and specific richness.

[15] Nine species of crop visitor have not yet been inventoried in wildlands. Of these nine species, six are not likely to be important pollinators of crops or native plants. Some are parasitic and do not collect pollen (*Triepeolus* sp., *Nomada* sp.), some ingest pollen rather than carrying it on their body (*Hylaeus* sp.), and some are introduced species specializing on introduced weeds (*Megachile apicalis* specializing on star thistle). The other three species are bumblebees (*B. sonorus* and *B. vosnesenskii*) and *Halictus farinosus*; while they are known to occur in the wildlands, such larger-bodied insects are less likely to be trapped in the pan traps, and were rare in this pan-trap sample.

[16] Data from 1999.

and what aspects of these habitats (floral resources, nesting resources) are important?

- How do bee species move between habitat areas and farms?

THE ECONOMIC VALUE OF NATIVE BEES AS CROP POLLINATORS

Many farmers rent honey bee colonies to provide pollination services for their crops. If native bees are providing some of these services "for free," what is the value of this service to farmers? Determining the value of "ecosystem services" such as pollination is difficult, since such values fall outside of the normal marketplace, and do not respond to supply and demand. Yet such calculations can be made.

Previous researchers have examined the economic value of honey bees for crop pollination. Estimates have ranged from $8.7-$34.8 billion annually in the United States (in 1999 dollars), depending on the assumptions used (Levin 1984, O'Grady 1987, Southwick Jr. and Southwick 1989, Robinson et al. 1989a, Robinson et al. 1989b, Southwick and Southwick Jr 1992). In general, the more conservative estimates (Robinson et al. 1989a, Robinson et al. 1989b, Southwick 1992), appear more realistic. No formal attempt has been made to value the services provided by native bees.

Here we use our field data on watermelon pollination to estimate the value of native bees to farmers in Yolo County under three different scenarios:

- **Replacement**: How much would it cost farmers to replace native bee services by renting more honey bee colonies?
- **Loss**: How much would farmers lose if native bee services could not be replaced?
- **Insurance**: How much would native bees be worth if honey bees were lost altogether?

Similar valuations could be made for other crop types. Each scenario requires different assumptions that are specified at the beginning of the section.

Replacement

In this calculation, we assume that farmers rent bee colonies because they obtain a marginal value from each bee that is greater than zero. In other words, they only rent as many bees as they need, and at a price that allows each bee visitor, whether a honey bee or a native, to confer added value to the farmer.

We assume that no bees are in excess, and therefore that colony rentals make up the difference between the services provided by freely available bees and what the crop needs. What would the shortfall in pollination be if farmers were suddenly to lose pollination services from native bees?

Under this logic, organic and conventional farms would differ greatly in the value attributed to native bees, and these values would also vary based on farms' proximity to wildlands. This is because native bees made up a higher proportion of the visits to organic farms and an even higher proportion of the visits to organic farms near wildlands.

Determining the value of "ecosystem services" such as pollination is difficult, since such values fall outside of the normal marketplace, and do not respond to supply and demand.

Table 5 shows the replacement value of native bees for watermelon pollination. The value is the cost of replacing the free service provided by native bees with additional honey bee rentals, and the calculation assumes that each visit by a bee, whether native or managed, is of value to the farmers (there are no surplus bees). Thus, their replacement value would be highest on organic farms near wildlands, where they make up a large proportion of flower visitors and contribute between 12% and 97% of the pollination requirements of watermelon,

TABLE 5

REPLACEMENT VALUE OF NATIVE BEES FOR WATERMELON POLLINATION

Management Type	Matrix Surrounding Farm	Average % of native bee visits	Avg. Contribution to watermelon pollination requirements (Table 3b)	Value ($/acre)	Sufficiency of native bees?
ORG	Natural area	37.20%	97.00%	38.8	Yes
ORG	Agricultural	23.10%	24.00%	7.2	No
CNV	Agricultural	17.60%	12.00%	3.6	No

depending on the farm environment.[17] Indeed, few organic farmers in our study rented bees, and thus they relied heavily both on native bees and on honey bees that were freely available (either from nearby rental colonies, or from feral colonies.) In contrast, all conventional farmers in our study rented honey bees.

Loss

How much would farmers lose if native bees were suddenly lost from the system? Given that honey bees appear to be superabundant and provide more than ample pollination for watermelon *(Table 3a)*, one is tempted to say that farmers would lose nothing if native bees were lost from the system.

If we assume, however, that all bees are visiting flowers randomly according to their relative abundances, then prior to saturation with pollen, native bees will be contributing pollen alongside of honey bees in proportion both to their abundance and their pollination efficiency.[18]

Thus we can calculate what would be lost if native bees were no longer there by considering the proportion of total pollination effected that is attributable to native bees out of all bees (*Table 3b*). To calculate the value, we use the following equation, based on Robinson (1989):

$$V_{nb} = D*P*V_n$$

where V_{nb} = the annual value of the crop that is attributable to native bees
D = the dependency of the crop on insect pollinators
P = the proportion of total pollination caused by native bees
V_n = net value of the crop

Watermelons are almost exclusively insect-pollinated (McGregor 1976, Free 1993, Stanghellini et al. 1997, unpublished data), therefore we set D at 99%. Net values of the crop were obtained based on the watermelon seed market because the price variations on the fresh market vary tremendously from farm to farm and season to season. In contrast, prices for the seed market vary less because they are fixed by contract.

Net values were estimated at $200-$500 per acre (Adelman 2000, Rominger 2000). The proportion of total pollination due to native bees depends largely on the frequency of the different bee species in the system. This in turn appears to vary with the management type (organic or conventional) and the farm environment (high or low level of wildlands) in the vicinity of the farm *(Table 3b)*. We therefore calculated the value of native bees for three situations: organic farms with high wildlands, organic farms with low wildlands, and conventional farms with low wildlands, using the appropriate P value *(from Table 3b)* for each situation. These values, presented in *Table 6*, show the value of native bees for watermelon pollination if native bees were lost from these systems. These values are quite similar to the replacement values estimated in *Table 5*. High and low values for each scenario reflect the high and low bounds of net value per acre.

TABLE 6

VALUE OF NATIVE BEES FOR WATERMELON POLLINATION IF NATIVE BEES WERE LOST

Management Type	Land Surrounding Farm	Percent Pollination Effected by Native Bees (P) From Table 2	Net Value of Crop Per Acre (V_n)	Value of Native Bees ($/acre) ($V_{NB}$)
ORG	Natural area	15.70%	200	31.09
		15.70%	500	77.72
ORG	Agricultural	5.60%	200	11.09
		5.60%	500	27.72
CNV	Agricultural	3.02%	200	5.98
		3.02%	500	14.95

Insurance

Next we ask a slightly different question: What would the value of native bees become if

[17] Values were calculated as the percentage of the cost for renting a honey bee colony as a replacement. Typically, watermelon growers require one to two colonies per acre at $15-20 per colony for full pollination. Thus, if native bees made up 12% of the required pollination, as it did on conventional farms, their replacement value would equal 12% x $30 per acre.

[18] Both honey bees and native bees visit flowers between 8 a.m. and 2 p.m., so there is no timing difference that would cause one group or the other to complete all of the pollination before the other group arrived.

honey bees were suddenly lost from the system: for example, due to the spread of the Africanized bee and the loss of the honey bee rental industry? If this were to happen, there would most likely be a large decline in yield. In particular, those farms which rely heavily on honey bee pollination would most likely have to abandon farming crops such as melon that require insect pollination. Consequently the price of honey bee-pollinated commodities would rise, impacting consumer's willingness to pay for these commodities. The loss to consumer surplus resulting from the honey bee decline would equal the value of the service. Native bees could fully replace honey bees on some farms, *(see Table 3a)*. In this case, the value of the service they would provide would equal the value of the consumer surplus that would otherwise have been lost due to honey bee decline (Southwick and Southwick Jr 1992, Adelman 2000).

We calculate this value again using our data on watermelon pollination and considering the impact on the watermelon seed market. This market specifically would affect farmers, because it would determine the price of watermelon seed, an important and expensive input that will determine their net profit.

Southwick and Southwick (1992) estimated a 40% crop loss in the event of complete failure of honey bees. Using data obtained for prices and yields for watermelon seed production in Yolo County, Adelman (2000) calculated that seed prices would increase by $2.55/pound. Societal losses would include the loss to consumers still purchasing watermelon seed ($495 per acre) and the loss to people no longer purchasing watermelon seed ($153 per acre), for a total societal loss of $648 per acre. If native bees could replace honey bee services, they would then be worth this amount to society.

Data presented in *Table 3b* suggest that native bees could replace honey bee services in some farms and situations, but that they would not replace them everywhere. Therefore, there would still be a net loss in consumer surplus, and the current actual value of native bees would be somewhat less than this estimate. This suggests the need for promoting land management practices that would enhance native bee populations across the entire agricultural landscape and maintain their insurance value in the event of a honey bee failure.

EXTRAPOLATING VALUATION OF POLLINATION SERVICES TO OTHER CROPS

WHILE WE LACK DETAILED INFORMATION ON pollen delivery by native bees for other cropping systems, our preliminary results show that the proportion of native bee visitors to selected other crops (e.g. strawberry) can be far higher than for watermelon. Other crops also have different net values per acre than watermelon. We have thus made preliminary estimates of values in other crops, based on the average proportions of native bee visitation *(Table 2)* and estimates of net profits *(Table 7)*.

Values varied between $30 and $344 per acre, depending on the crop. *Table 7* shows these preliminary estimates. These values reflect the amounts per acre that the farmer might lose if native bees were suddenly lost. One caveat is that visitation does not translate directly into pollination, but this estimate assumes that pollination service value is directly proportional to visitation, regardless of the species.

TABLE 7
VALUES OF NATIVE BEE POLLINATION FOR THREE OTHER CROPS

Crop	Net Value (V_n)	Dependency on insects (D)	Average % Visitation by native bees (P) From Table 1	Value of native bees ($/acre) ($V_{nb}$)
Cantaloupe	$413	90%[19]	8%	$30
Eggplant	$180	70%[20]	74%	$93
Strawberry	$551	65%[21]	96%	$344

THE ROLE OF LAND MANAGEMENT PRACTICES IN ENHANCING POLLINATION SERVICES ON FARMS

A VARIETY OF LAND MANAGEMENT PRACTICES appear to enhance bee abundance, diversity, and pollination services on farms.

[19] D value from estimates in O'Grady , 1987
[20] D value from estimate in Robinson et al 1989
[21] D value from estimate in McGregor 1976

Finally, a larger-scale land management practice would protect areas of natural habitat along rivers and in upland areas near farms to provide habitat for source populations of pollinators.

The use of pesticides has been shown to diminish bee abundance and negatively affect pollination services in certain cases (e.g. blueberries, Kevan 1977, Kevan et al. 1979).

We compared visitation rates on 11 organic farms and 11 conventional farms (*results forthcoming*). On conventional farms, reducing the use of pesticides (particularly those most toxic to bees) or careful application of pesticides would assist in maintaining populations of native bees.

For example, use of ground-rig sprayers allows greater control of spray applications than does aerial spraying, and nighttime pesticide applications would reduce harm to female bees since they remain in their nests at night.

Tillage, weeding, and irrigation practices that destroy bee nests or disrupt nesting activities could also be modified to favor bee populations on farms. For example, farmers should avoid flood irrigation since it destroys the nests of ground-nesting bees. Also farmers can promote bee visitation to crops by using irrigation sprinklers only at night, when bees do not fly. Farmers can promote the nesting of ground-nesting bees (which include many of the most important pollinators in our study) by practicing no-till agriculture, scraping areas of fields to provide bare soil for nest sites, and/or plowing shallow so as not to destroy brood cells in nests below the surface.

Providing blooming resources in the off-season of the crop requiring pollination is an important mechanism for ensuring that bee populations are abundant when they are needed for crop pollination. Farmers can provide floral resources by:

- Planting of hedgerows, containing diverse plant species with sequential, overlapping bloom periods (Long et al. 1998);
- Allowing cover crops such as vetch and clover to bloom before plowing them under;
- Leaving weedy borders on field margins and maintaining fallow fields unmowed; and
- Planting rows of bee-attractive plants such as lavender and thyme.

Finally, a larger-scale land management practice would protect areas of natural habitat along rivers and in upland areas near farms in order to provide habitat for source populations of pollinators. Such large-scale conservation efforts could be reinforced through smaller scale restoration activities (e.g. native plantings in hedgerows and tailwater ponds, see Pickett and Bugg 1998) that would provide stepping-stone habitats for pollinators between the larger natural areas.

Further research is required in several areas. With respect to blooming plants, we need to know how to manage other sources of bloom on a farm in order to maintain bee populations without creating too much competition between the blooming plants for the pollination services. It might be possible, for example, to plant an attractive resource such as lavender during an off time and then to harvest the lavender when the crop requiring pollination is flowering. This would oblige the bees to find a new resource.

Further research is also needed to determine the nesting resources that bees require, and how these might be enhanced on farms. We also need to understand how bees use resources in both natural areas and farmlands, how they move between these resources, and which plants should be planted in what spatial distributions to maintain pollination services where they are needed.

WORKSHOP DISCUSSION

FOLLOWING THE PRESENTATIONS (*SEE AGENDA in Appendix II)* workshop participants discussed the potential opportunities and barriers to the wider adoption of pollinator-friendly farming practices.

The goals of pollination discussion were:

1. Discuss the presentation;
2. Identify costs and benefits to farmers of providing bee resources (e.g. hedgerows or lavender);

3. Identify practices that help bees and benefit growers (cover cropping, reduced tillage, irrigation, wind control, farm spin-offs such as tourism);

4. Identify potential negative effects on farms of activities that help bees; and

5. Identify potential values to the broader community of healthy pollinators.

Following the presentations, workshop participants discussed the above questions. The discussion concerning the pollination presentations is summarized below. Participants identified the following barriers and challenges to adopting more pollinator friendly practices.

- Demonstration projects are key.

- Start with a demonstration area showing how pollinator friendly farming can work, then study this site.

- The economics of pollinators is important to communicate widely. This research is very useful, but it will be important to move quickly beyond research to action.

- Positive models, or "show me" projects are important to show that these techniques worked are vital. It is good to start with a demonstration area showing how pollinator friendly farming can work, then study and promote this site.

- Look for additional opportunities to provide pollinator habitat.

- When undertaking habitat projects, such as wetlands restoration, try to build agriculture into these projects (see also the case study on non-structural flood control). Agriculture can also help pollinators.

- Avoid taking productive land out of production, use marginal land instead when planting or using hedgerows or lavender.

- Try policies such as crop insurance and giving price supports to farmers doing activities (helping bees) that help crops.

- Look for other opportunities to provide havens for pollinators, for example roadsides or levees could provide corridors for pollinators.

CONCLUSIONS

THIS WORK IS STILL IN PROGRESS, AND MUCH remains to be discovered both in the analysis of existing data and the collection of new information. Further analysis will examine the impact of farm management type (organic versus conventional) on bee abundance and pollination services. To date we have demonstrated that:

- A diverse assemblage of native bees visits a variety of field crops;

- These native bees also occur in nearby natural areas;

- The environment around the farm (proportion of wildlands in the vicinity of the farm) appears to influence the bee abundance on farms (see also Banaszak 1992); and

- Native bee communities can fully pollinate selected crops when they occur in sufficiently high numbers on farms.

We have also quantified the values provided by native bees through pollination using a variety of scenarios. Native bees provide a measurable service of highest value when they are abundant on a given farm and make up a large proportion of the visitors to crop flowers. No single species of native bee stands out as sufficient by itself, instead it is the entire community of native bees that provides this pollination service.

When valued for their insurance against the risk of failure of honey bees, the value of native bees is evidently much larger. Such a scenario is not altogether unlikely. If honey bees were to fail altogether—through a combination of disease and the introduction of Africanized bees—then native bees would have to take up the slack. This work strongly suggests that native bees could take up the slack, but only on farms where conditions are right. It furthermore suggests that conditions *would not* be right on most farms (e.g conventional farms removed from natural habitats).

Native bees provide a measurable service of highest value when they are abundant on a given farm and make up a large proportion of the visitors to crop flowers.

It therefore seems clear that the majority of farms would be at risk from honey bee failure, and that as a society, we are overly reliant on honey bees as the major source of crop pollination.

Further work is required in order to determine the exact conditions that would favor the restoration and maintenance of native bee pollination services on farms that do not currently enjoy them. In order for farmers to rely entirely on native bees, such services would have to be dependable from season to season, year to year, and farm to farm. It is doubtful that pollination services from a community of native bees could be managed so exactly. Thus, a combination of managed honey bees and restoration for native bees would probably be the best strategy. In addition, selected species of native bees are already managed for crop pollination, and many others have the potential to be managed pollinators (Kevan 1990).

It therefore seems clear that the majority of farms would be at risk from honey bee failure, and that as a society, we are overly reliant on honey bees as the major source of crop pollination.

As described above, restoring and maintaining native bee pollination services could combine conservation of natural areas; restoration of native plants in hedgerows; and maintaining sources of bloom on farm fields along crop borders, in fallow fields, and cover crops. Such activities might also promote the establishment and maintenance of feral colonies of honey bees. Thus natural and restored areas might have pollination service value not only due to native bees, but also due to feral honey bees.

Conservation, restoration, and other practices favoring bees may have added benefits beyond those attributable to pollination services. Conservation of natural areas maintains open spaces for recreation, protects plant and animal biodiversity, prevents erosion, provides local climate control, and maintains watershed integrity. Restoration of hedgerows provides windbreaks, shades drainage ditches, prevents erosion, provides habitat for farmland biodiversity, and is aesthetically appealing. Properly constructed, such hedgerows can also foster populations of beneficial insects—not only pollinating insects, but also predators of pest insects.

Similarly, cover crops can provide a variety of benefits. These include prevention of flooding, reduction of soil erosion and nitrogen fixation, and conservation. Farms can thus help to maintain biodiversity and ecosystem services while themselves benefiting from such services.

NATURAL FLOODPLAINS AS A COMMON ASSET:
OPPORTUNITIES FOR WILDLIFE, FARMS, AND FLOOD CONTROL

By Kate Fitzpatrick with Paige Brown

FLOODPLAINS ARE NATURAL ASSETS THAT provide important services to the ecosystem and downstream human communities. These benefits include storing and holding floodwaters, water filtration, wildlife habitat, and groundwater recharge. The U.S. has historically opted to replace natural flood control systems—floodplains—with an extensive system of dams, dikes, and levees to control, redirect, and streamline the flow of a river. These structures separate the river from its natural floodplain system and thus from the benefits rivers and floodplains provide.

Experience has shown that while structural flood control provides the single benefit of flood control, it does so at great cost to taxpayers, wildlife habitat, water quality, and groundwater recharge. As a result, after years of trying to control the direction, speed, and size of rivers, communities and the government are experimenting with methods of flood control that let a river run its natural course. Natural floodplain management can potentially cost taxpayers less while improving wildlife habitat, water quality, and groundwater recharge.

Nonstructural flood control may cost taxpayers less than structural flood control. The Army Corps of Engineers is unable to keep up with structural needed repairs and maintenance (Army Corps of Engineers 2000). In addition, a combination of increased development in floodplains with increasingly intense flooding episodes has driven the cost of flood damages even higher.

The Federal Emergency Management Agency's (FEMA) expenditures increased from $0.5 billion per year in the 1950s to over $2 billion a year in the 1990s (Miller 2000). Four recent flooding episodes in California's Central Valley totaled $1.6 billion in damages (Army Corps of Engineers 1999). Nonstructural flood control, on the other hand, involves lower implementation and maintenance costs and greatly reduces the potential for flood damages.[22]

In addition to monetary costs, structural flood control has contributed to wide scale loss of wildlife habitat.[23] The Central Valley has lost 99% of its historical riparian forests and about 95% of the Central Valley Wetlands (Noss et. al. 1995). The Central Flyway, a crucial link for migratory birds, has been dangerously fragmented. Flood structures also have threatened anadramous fish like steelhead and salmon by fragmenting river systems and by ruining habitat created by free-flowing rivers. (American Rivers, *The Value of Natural Floodplains*).

Natural floodplain management can potentially cost taxpayers less while improving wildlife habitat, water quality, and groundwater recharge.

Furthermore, an Environmental Protection Agency (EPA) report recently identified hydrological modifications, such as dams, dikes, and levees (which are all structural flood control strategies) as the number two cause of water quality degradation (U.S. EPA 1998). Altering a river's natural flow can change sedimentation patterns, turbidity, water temperature, oxygen content, and the balance of nutrients while disrupting natural pollutant filtration processes.

Separating a river from its natural floodplains also hinders groundwater recharge, a natural and important role of floodplains and a very important issue for California farmers. Much of California, including the Cosumnes river valley, struggles with the depletion of groundwater tables.

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[22] Currently, flooding is the most destructive and costly natural disaster in the United States accounting for 85% of all natural disasters each year (Army Corps of Engineers 2000). In Illinois and Missouri $66 million was spent to relocate 5,100 structures which had previously received $191 million in flood insurance payments (*New Strategies Emerge*, American Rivers Online).

[23] Conversion to agriculture and urban uses has also had huge impacts on habitat and water quality but in the Sacramento delta the widescale conversion could not have happened without the extensive hydromodifications that turned floodplains into usable land.

Restored floodplains significantly aids water table recharge, helping to solve one of the state's more critical problems (Tom Meagher 2000).

These problems have led policymakers to consider nonstructural flood control solutions within a more comprehensive watershed management approach. A recent interagency report declares, "The fiscal and emotional impacts of recent floods, coupled with the changing attitudes and advances in scientific knowledge, have led to the need for a comprehensive study of the existing flood management systems" (U.S. Army Corps of Engineers 1999). There has been a shift in federal policy to put greater emphasis on nonstructural alternatives and improved land use planning.

In addition to a shift in federal policy, regional and local changes in emphasis are also occurring as some communities are realizing that healthy, free-flowing river can be a great asset. In fact, citizens of Napa, California, have opted to try nonstructural flood control so that the Napa river retains its natural beauty and many ecosystem functions *(see Box 1).*

Nonstructural flood control is not a single activity but the use of various strategies that involve instituting floodplain uses that are compatible with periodic flooding, modifying existing structures that are vulnerable to flood damages, and making land-use decisions shaping where and how resources are used in the floodplain. In essence, nonstructural flood control reunites a river

BOX 1

NAPA VALLEY'S LIVING RIVER STRATEGY

Napa valley floods have cost about $540 million over the last 30 years. The existing network of dikes and levees protected some people from flooding but sent so much water downstream so quickly that it flooded property downriver. Because of the severe flood problems and a 30-year-old unused $80 million Congressional allocation for flood control, the Army Corps of Engineers endeavored to present Napa citizens with an acceptable flood control plan. The Corps largely repeated mistakes of the past by proposing to line the Napa River with concrete and dredge the river's channel, all of which would have had severe negative environmental and aesthetic consequences for the river and the community.

Napa County rejected all three variations of Army Corps proposals to expand the concrete-walled flood control system. After two years of research and consensus building the Corps, 27 other government agencies, and 25 nongovernmental organizations created an alternative. Officially called the Napa River Flood Protection Project, this plan is what the Napa Community Coalition refers to as the "Living River Strategy."

The Living River Strategy involves restoring about 500 acres of grazing lands to tidal marsh, reforesting riparian areas, and removing houses, mobile homes, and warehouses from portions of the river's floodplain. These efforts will allow the river's water to go where it naturally does in floods. To implement the Living River Strategy, the county needed $110 million over 20 years in addition to the $80 million in federal funds. The County voted to increase the sales tax to provide the needed revenue.

The success of the Living River Strategy depends in part on agricultural activities taking place in the Napa River tributaries, because of the importance of avoiding increased water flows from these tributaries. However, the profitability of wine grapes creates huge incentives for property owners to replace oak and conifer forests with vineyards in the Napa tributaries. Loss of forest means not only shrinking habitat in the uplands, but also increased erosion, water flows, and pollution from the tributaries draining into the Napa River. All of these would endanger the success of the Living River Strategy.

In fact, slowing erosion and maintaining current levels of water flows in the tributaries was explored as potential Living River strategies. Sustainable agricultural practices that maintain peak flow and reduce sedimentation in tributary areas contribute to the success of the Living Rivers Strategy, thus benefiting farmers and the communities downriver. Recognizing the importance of activities taking place in the tributaries, the Resource Conservation District developed and distributed the *Napa River Owner's Manual*, a guide to good stewardship for landowners in those areas.

Detailed research and intensive coalition building has been undertaken during the development of the Living Rivers proposal, but the role of sustainable agricultural practices in the Napa tributaries could be explored further. The Napa Living River Strategy is likely to serve as a model for other flood control plans that aim to better manage river resources. If Napa proves successful at flood control and maintaining a living river, such approaches are sure to be more widely proposed and perhaps adopted. Thus, illustrating that sustainable agricultural practices enhance the common asset of flood control could encourage wider incorporation of sustainable agriculture practices.

with its historical floodplains, restoring the role of floodplains in storing floodwaters, providing habitat, offering natural water filtration, and aiding in groundwater recharge.

The biggest challenge faced in implementing nonstructural flood control solutions is the cost of forsaking development in the floodplain. Federal governmental policies of disaster relief and flood insurance have promoted development in the floodplain by alleviating local and regional responsibility for flood damages, thus making floodplain development feasible (American Rivers, *In Harm's Way*). In addition, population increase and sprawl adds pressure to develop in floodplains. The cost of keeping development out of floodplains is a stumbling block. However, some land uses in the floodplain (like sustainable agriculture) can be flood-compatible, promote habitat and water quality, and keep the land productive, thus reducing the cost of not developing floodplains.

LINKAGE TO SUSTAINABLE AGRICULTURE

Sustainable agriculture can offer solutions to the challenge of forsaking or limiting development in floodplains. We use "sustainable agriculture," in this case, to mean any kind of agriculture which maximizes, as opposed to degrades, the benefits which natural floodplains can generate. This includes benefits related to ecological processes like habitat and water quality, as well as benefits to the health and economic livelihood of the community.

Some types of agriculture, such as annual row crops, rice, and pasturelands, offer a greater array of benefits than others. Vineyards, for example, can be compatible with periodic flooding but do not provide wildlife habitat, whereas rice and pasturelands do. Also, flooded agricultural land could potentially wash pesticides downstream, harming ecosystems and people. Thus, reducing or eliminating pesticide usage in floodplains may be a better option. Coupling sustainable agriculture with nonstructural flood control can potentially maintain an economically productive use of a floodplain, while also benefitting wildlife habitat, water quality, and groundwater recharge.

We chose to highlight projects in the Cosumnes River Preserve because the project incorporates sustainable agriculture into natural floodplain management with an emphasis on habitat values. The Cosumnes River Preserve is a model of the benefits that can flow from twinning sustainable agriculture with natural floodplain management. The watershed's health is preserved, the community benefits from a healthy watershed and improved water quality, and farmers retain the opportunity to make a livelihood.

THE COSUMNES RIVER PRESERVE

The Nature Conservancy (TNC) and six other non-profits and agencies collaborated to create the Cosumnes River Preserve in Sacramento County on 40,000 acres with goals of preserving and restoring habitat along the Cosumnes River.[24]

Habitat is a particular priority for TNC, and habitat in the Central Valley is in the process of disappearing. Historically, the Central Valley hosted 50 to 60 million wintering waterfowl, due to a rich mosaic of wetlands totaling 4 million acres. By 1985, this acreage had decreased 95% to 292,000 acres. The reduction was caused by wetland conversion to agriculture, flood control, navigation projects, and urban expansion. Despite the amount of habitat lost to date, the Central Valley still hosts 3 to 5 million waterfowl, 60% of the population in California, making it critical to maintain existing habitat (CH2M Hill 1996).

The Cosumnes River Preserve is a model of the benefits that can flow from twinning sustainable agriculture with natural floodplain management. The watershed's health is preserved, the community benefits from a healthy watershed and improved water quality, and farmers retain the opportunity to make a livelihood.

Two trends in Sacramento County, where the Cosumnes River Preserve is located, are leading to habitat loss. First, farmland, which is more wildlife-friendly than urban areas, decreased 19% between 1992 and 1997, with the American Farmland Trust labeling the Central Valley as the nation's most threatened farming land (Kasler 1998). The county saw 32.6% population growth in the 1980s and predicts population will grow by 1.2 million by 2040, increasing demand for new housing, sprawl, and development in floodplains.

Second, wildlife-compatible agriculture is being converted to agriculture not compatible

[24] TNC's partners include Ducks Unlimited, the U.S. Bureau of Land Management, the California Departments of Fish and Game and Water Resources, the County of Sacramento, and the State Lands Commission.

with wildlife. Traditional Sacramento County farmlands, which include pasture for milk production and corn, provided bird habitat.

However, pasture is being converted to vineyards and orchards, which do not provide suitable bird habitat. The rising profitability of wine grapes caused them to surpass milk as the county's top crop in 1997, and the conversions to vineyards continue to rise *(see Table 8).* Sandhill cranes, ducks, and geese that use the Central Valley as a flyway are literally unable to land for much needed rest and feeding stops in vineyards and orchards. The birds can, however, land, rest, and feed in pasture or row crops.

The Cosumnes River Project is attempting to slow or reverse these trends by preserving wildlife-friendly habitat. The Cosumnes River Preserve is one of the remaining fragments of the Central Flyway. The Preserve provides habitat for tens of thousands of migratory waterfowl, the Central Valley's greater Sandhill cranes, migratory songbirds, raptors, rare reptiles, and rare mammals like the endangered giant garter snake and the wild mink.

TNC collaborated with the Army Corps of Engineers (the Corps) to create the first nonstructural flood control initiative in California. Historically, flood control on the Cosumnes included an incomplete system of levees that channeled floodwaters downstream. The levees overtopped or breached fairly regularly, however, with high costs in damages and repairs.

In the January 1997 flood, the damages to structures and property totaled $1.2 million (Flood Damage Assessment). The Corps offered to repair and reinforce the levee system, but a coalition of Preserve partners and local farmers convinced the Corps to spend that money on nonstructural flood control instead. This involved flood-proofing farm structures, breaching levees, and hardening roads so the river could now flood closer to its historical pattern.

TABLE 8

VALUE OF MILK, WINE GRAPES, AND CORN

Crop	1996 Value (millions)	1997 Value (millions)	1998 Value (millions)
Milk	$43.21	$42.24	$50.5
Wine Grapes	$35.95	$41.86	$77.4
Field Corn	$17.81	$19.84	$13.0

Within its efforts to restore the Cosumnes' natural floodplains, TNC has focused heavily on incorporating sustainable agriculture into the floodplains, seeking out agricultural uses that would be flood-compatible and contribute to waterfowl habitat, water quality, and economic feasibility. By combining conservation with sustainable agriculture, TNC hopes to meet its goals of conserving biodiversity by involving the local community and sustaining economic livelihoods.

As a first step, Living Farms, a sustainable agriculture consulting organization, drafted a Sustainable Farm Plan for TNC that recommended a mixture of organic rice, grain, and pasture that would be wildlife friendly, economically sustainable, and that would incorporate the local farm community. In order to conserve biodiversity in a way that helps maintain the local community, TNC uses agricultural easements to maintain wildlife-friendly farms. To do this, TNC partnered with Allen Garcia for an on-site organic rice farm, and is in the beginning stages of a partnership with an organic dairy.

LIVING FARMS: ALLEN GARCIA'S ORGANIC RICE FARM

Living Farms recommended that TNC choose organic rice production as a part of its strategy on the Cosumnes River Preserve. Living Farms argued that rice production best meets Preserve goals of flood-compatibility, waterfowl habitat, water quality, and economic feasibility. As a result, TNC partnered with experienced rice farmers Allen and Sandra Garcia, contracting them to run independently a 1,000-acre organic rice farm on Preserve land.

Pairing rice farming with natural floodplains preserves and expands waterfowl habitat. Flooded rice fields provide seasonal wetland habitat and food for waterfowl. Rice harvesting leaves behind an average of 300-350 pounds of waste grain per acre. Birds as well as water-based invertebrates both eat the rice. The bugs create a new food chain in the flooded fields within a few weeks. These bugs, crayfish, and other invertebrates create an additional 250 pounds per acre of food for the migratory birds (CH2M Hill 1996). Rice fields make excellent habitat because they provide significant fuel for migrating birds that can lose a third of their body weight in migration and thus need ample food sources.

Farmers, in turn, benefit from flooding their fields in the winter. Flooding decomposes the rice stubble, avoiding the practice of burning the fields. This solves the farmers' problem of complying with strict air quality requirements, while the community benefits from cleaner air. The birds also help decompose the stubble by dabbling in the fields and leaving behind nitrogen-rich droppings.

An increasing number of rice farmers have realized these benefits, and the number of rice farmers in the Central Valley who flood their fields in the winter rose from 10% in 1991 to 40% in 1996 (CH2M Hill 1996).

Monthly bird counts at the Cosumnes River Preserve appear to support the idea that rice fields increase the quality of waterfowl habitat. Although the counts represent only a snapshot in time and the numbers are affected by variable conditions, such as temperature and rainfall, the counts denote an upward trend in birds on the preserve following the inception of Garcia's rice farm *(see Figure 1).*

Counts on the preserve peaked at almost 80,000 in 1997 and 1998, and are thought to be attributed at least partially to the rice farm. Records from three years of birds counted specifically in the rice fields denote an increase in waterfowl, and the waterfowl managers expect this to continue.

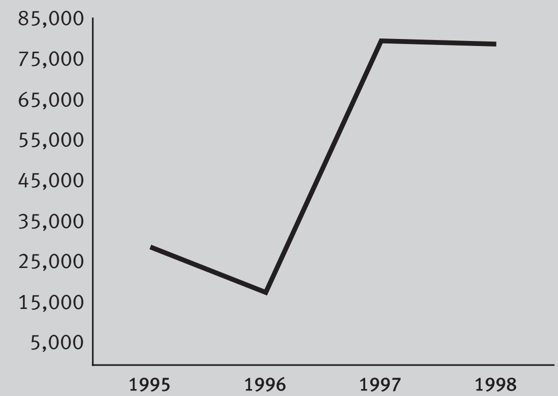
In addition to providing quality habitat and helping air quality, Garcia's organic rice farm helps maintain high water quality in the watershed.[25] A rice farm that used pesticides in a floodplain could pose a threat to the watershed. Although the worst human health dangers are over, pesticide use presents safety issues for farmworkers, people in communities surrounding the floodplain, and wildlife using the rice fields.

For example, the insecticide carbofuran, which is often used in rice production, is one of two pesticides that are responsible for most documented bird kills in California (Kegley et al 1999). Using carbofuran on the Cosumnes Preserve would pose a risk to the birds. Living Farms' organic growing eliminates the issue of chemical presence, and thus is an ideal flood and habitat compatible farm.

In summary, the ecological benefits of rice farming within the floodplain can be high. Compatible within natural floodplains, habitat niches in the river and in the floodplains automatically improve. In addition, rice provides extra forage for migrating waterfowl. Growing organically protects water quality and the safety of the community. The farm also contributes to restoring the traditional groundwater recharge function of natural floodplains. In addition to these ecological benefits, Living Farms has shown that organic rice farming can be profitable. The establishment of sustainable agriculture creates waterfowl habitat while preserving rural farm communities.

FIGURE 1

BIRD COUNTS ON THE COSUMNES PRESERVE



KEEPING WORKING FARMLANDS FOR THE ENVIRONMENT AND THE COMMUNITY: TNC'S USE OF CONSERVATION EASEMENTS

Since the preserve's inception in 1987, its efforts focusing on natural habitat have shown increases in bird use, indicating success at providing better and more habitat. There are limits, however, to how much land can be set aside in refuges. Conservation easements are one tool that allows TNC to provide habitat, yet keep the land in private hands. Much of the land in the Cosumnes Valley is still a patchwork of private farms, consisting mainly of small dairies or annual row crops, meaning that conservation easements can be a good tool in this area.

[25] Water quality stemming from herbicide use in rice fields was a serious issue in the early 1980s, causing fish kills and contamination of downstream water resources. The rice industry collaborated with agencies and researchers to refine techniques to reduce chemical output, such as establishing water holding periods and tailwater recovery recirculation programs.

Conservation easements transfer part of the rights associated with a piece of property while allowing landowners to retain ownership of the land. A conservation easement typically removes the right to engage in some type of intensive development of the land that could damage its ecological, scenic, recreational, or natural resource value.

Conservation easements are one of the most widely used conservation tools for preserving both habitat and farmland. TNC uses easements in the Cosumnes River Preserve to secure agreements with farmers to forgo certain land uses that are incompatible with seasonal flooding or wildlife habitat. TNC currently has purchased easements on 1,000-2,000 acres of land around the Cosumnes Preserve.

Conservation easements transfer part of the rights associated with a piece of property while allowing landowners to retain ownership of the land.

These traditional uses, which are potentially compatible with both seasonal flooding and wildlife, are currently threatened by emerging trends in Sacramento County. These trends include the conversion of traditional farmland to urban uses, vineyards, and orchards. As noted earlier, these three uses do not provide quality wildlife habitat, and orchards and urban uses are incompatible with periodic flooding.

The land value table below makes clear the incentive to convert crops to vineyards. The profitability of wine grapes and orchard fruit makes conversion attractive. Combined with the urban demands of Sacramento, there is pressure to convert agricultural land into commercial uses like subdivided ranchettes. Dairies and row crops are less attractive because of the value in other land uses. Land planted in field crops, rice, or pasture is worth roughly $2,000/acre, while vineyards' value reaches $20,000/acre.

LAND VALUE ESTIMATES

Field crops:	$2,000/acre
Irrigated pasture and rice:	$2,000/acre
Vineyard potential:	$3,100-$4,400/acre
Planted vineyards:	$10,000-$20,000/acre

Conservation easements offer a means to shift the economics by paying farmers to agree to avoid converting some uses such as pasture to vineyards. The landowner creates the easement by donating or selling the easement (development or use rights) to a second party.

Easements give farmers needed capital, offer TNC a cost-effective means to provide bird habitat, and keep a working farm in the economy and on the tax rolls. The farmer receives an upfront sum for agreeing not to plant vineyards or orchards—or to develop the land commercially. The easement lasts in perpetuity, and its value is typically based on the difference in land values when the potential for conversion to vineyards is removed.

How does this work? Let's examine a hypothetical situation where a cash-strapped farmer is growing rice on land worth $2,000 per acre. This rice farm also provides great wintering habitat for ducks. But the area all around her is being converted to vineyards, wiping out habitat and creating a tempting offer to sell as land with vineyard potential could go for $3,100 per acre.

TNC can buy the land outright at that price and preserve the land, taking it out of production. Or, TNC could pay the farmer $1,100 per acre for the promise of keeping the land in rice production. An added bonus is that once a farmer agrees to avoid certain land uses, the land valuation may decrease, which often decreases property taxes.

From TNC's perspective, buying easements can be preferable to buying land because TNC does not need to manage or maintain the land, yet the asset is preserved and the land remains productive. Maintaining rural farms can also maintain the quality of life in a community. The use of easements has allowed TNC to expand conservation of habitat and the restoration of floodplains into a broader arena. Using conservation easements helps protect wildlife habitat in a cost-effective manner and keeps farmland in production to help maintain a vibrant community.

A SPECIFIC CASE STUDY: HORIZON ORGANIC'S DAIRY

ANNUAL ROW CROPS AND IRRIGATED PASTURE, traditional uses within the Cosumnes floodplains, can be flood-compatible and also provide quality habitat. This is true generally for dairies in the lower Cosumnes floodplain. While there are water-quality problems associated with many existing dairies, the row crops and irrigated pastures associated with dairies provide critical habitat for foraging sandhill cranes, raptors, and geese. And most dairies, built with historic flooding patterns in mind, have their feed lots and milking facilities located above flood levels.

Because of these benefits associated with dairies, TNC staff began targeting the dairy sector several years ago. The idea was that strengthening the financial health of existing dairies would help them resist conversion to perennial crops such as vineyards or orchards. These efforts have resulted in the purchase of easements on one existing dairy (the Machado dairy) and the purchase, jointly with Horizon Organic Dairy, of a 600-acre property adjacent to the Preserve which until recently housed a dairy.

When it purchased this property, Horizon Dairy planned to construct a new organic dairy farm, combining irrigated pastureland and row crops. The new dairy would have been a source of milk for Horizon's west coast customers (now supplied from Idaho and Nevada) and a buyer of organically produced grains and other feed crops. TNC in turn would be assured that the land would be protected from urban development and preserved as a working farm where sustainable, wildlife friendly agricultural practices are employed for crop and dairy production.

Horizon purchased the property for its organic farming and dairying purposes. Simultaneously, TNC purchased an easement that limits Horizon's use of the property to maintain the land's open space and agricultural production for conservation purposes. TNC has a right to require that the property remain in sustainable agricultural use in perpetuity. Additionally, Horizon agreed to permanently set aside a 110-acre freshwater marsh that provides critical habitat for the giant garter snake and other endangered species.

The California Farmland Conservancy Program of the California State Department of Conservation and the U.S. Bureau of Reclamation's Conservation Program funded the easement acquisition. By purchasing the property and simultaneously selling the easement, Horizon was able to reduce the net cost of the acquisition by about 40 percent, thus offsetting some of the opportunity costs of keeping the land in pasture rather than converting to vineyards (Horizon Press Release 2000).

As of this writing, Horizon is reviewing its plans for a new dairy at the Cosumnes site. The company has recently been approached by a number of California dairy producers interested in making the organic conversion and becoming cooperative producers for Horizon. Since this strategy offers Horizon a business alternative that avoids major new capital investment, it is inherently more attractive than construction of a new dairy.

Horizon and TNC are evaluating options for the Horizon-owned site on the Preserve in the event that Horizon opts not to build a new dairy. Among the options would be to sell the site, which is fully permitted for a dairy, to a third party that would produce for Horizon. Alternatively, the property—which is certifiable as organic—could produce inputs for an off-site organic dairy.

Using conservation easements helps protect wildlife habitat in a cost effective manner and keep farmland in production to help maintain a vibrant community.

WORKSHOP DISCUSSION

FOLLOWING THE PRESENTATIONS *(SEE AGENDA IN Appendix II)* workshop participants discussed the potential connections between sustainable agriculture and nonstructural flood control.

DISCUSSION QUESTIONS:

The objectives of the discussion were to:

- Reflect on and discuss the presentations;
- Identify benefits and issues associated with other opportunities for habitat and flood friendly farming, e.g. hunting or bird watching fees for use. Allen Garcia's farm was designed not only to be flood compatible, but also habitat rich; some crops (vineyards) may be flood-compatible and/or habitat-compatible, but not both;
- Discuss easements: what are some of the barriers to their broader use (e.g. funding, need for more tax incentives, feels too restrictive to landowner, NGO's can't afford them); and
- Develop recommendations for policies or incentives to overcome these barriers.

Opportunities for the Twinning of Natural Floodplain Management and Sustainable Agriculture

- Twinning sustainable agriculture with nonstructural flood control or floodplain management could present a great opportunity to sustainable agriculture, particularly if floodplain management becomes more commonly employed. Floodplain management could improve the economics that farmers face by offering capital for conservation easements, a potentially low-cost source of land to lease, or payments for flood or wildlife friendly farming practices.

- Need to value services: for example, one participant noted a study that estimated that wetlands are worth $10,000 for improved water quality. Farmers need to accrue financial compensation for the benefits they provide.

Obstacles to the Widespread Use of Natural Floodplain Management in Conjunction with Sustainable Agriculture

Through the behavior of individual farmers, the health of an asset and its associated benefits can be improved.

- On the Cosumnes River Preserve, it is the organic price premium that makes rice farming economic, so it is uncertain if floodplain management presents significant economic opportunities for farmers in the absence of a price premium;

- Where nonstructural flood control impacts existing farms in the floodplain, take only marginal land out of production, not high quality farmland;

- More research is needed to determine the importance of agricultural practices in the tributaries of Napa River; and

- More research is needed to uncover what crops are most compatible with floodplain management. For example, grazing land can withstand flooding and provides good bird habitat, but manure run-off may be an issue during floods. Similarly, if agriculture in floodplains does use pesticides, what dangers might that present for downstream communities?

CONCLUSION

Living Farms is an excellent model for maximizing the benefits available in natural floodplains. Through organic rice growing, the farm contributes to increased habitat, high water quality, groundwater recharge, and community livelihood. In making sustainability a broader effort in the valley, the Cosumnes River Project has brought in other compatible agriculture, like Horizon Dairy, and has worked with local farmers through the use of easements. This project shows creative solutions on multiple levels, ones that will necessarily be a part of a watershed-wide, nonstructural flood control effort.

Through the behavior of individual farmers, the health of an asset and its associated benefits can be improved. Living Farms presents a model that shows how farmers can benefit from the behavior, while highlighting the challenges and barriers facing those who wish to implement of these strategies.

AGRICULTURE AND CLIMATE CHANGE:
HOW CALIFORNIA FARMERS CAN BE A PART OF THE SOLUTION TO CLIMATE CHANGE BY PROTECTING THE EARTH'S ATMOSPHERE

By Paige Brown

WHAT DOES DIRT HAVE TO DO WITH THE Earth's atmosphere? A great deal, as we now know. The atmosphere is a critical common asset, shared by all and necessary for life on Earth. Increasing the amount of soil organic matter can help protect the atmosphere's health and restore soil's productivity. Historically, conventional agricultural and grazing practices have led to the loss of soil organic matter, which reduces soil productivity and releases carbon dioxide, the most prevalent greenhouse gas that causes global warming.

Conversely, when soil fertility is restored by using more sustainable agricultural practices, soil organic matter, which is comprised of carbon, is returned to the soil, thus improving soil quality and keeping carbon out of the atmosphere.

Over the last several hundred years the conversion of forests and grasslands to other uses and the combustion of fossil fuels have resulted in the atmospheric buildup of greenhouse gases that are responsible for climate change. Agriculture is a piece of this puzzle. Some agricultural practices (such as conventional tillage practices, crop residue removal, and increased erosion) have released an estimated 55 gigatons of soil carbon globally, which is about a third of the global total loss from soils and vegetation of 150 gigatons of carbon (IPCC 1995, Houghton, 1995).[26]

LINKAGE WITH SUSTAINABLE AGRICULTURE

FARMERS, LIKE EVERYONE ELSE, DEPEND ON THE critical services provided by the atmosphere. The consequences of global warming cannot be predicted perfectly, but California farmers may experience less productivity or even crop failure due to increased heat stress, pests, disease infestations, and reduced water storage from the winter snow pack (Field et al. 1999).

While these risks alone may not be enough to change farming practices due to agriculture's relatively small role in current emissions, more sustainable agricultural practices can be a part of the solution. More sustainable agricultural practices that store carbon could offer farmers improved yields and an additional income source if policies are adopted to provide payment from the U.S. government or greenhouse gas emitters for the carbon sequestered by farmers.

The amount of carbon in the soil is determined by organic matter inputs or decreasing decomposition, such as by adding other organic matter like manure or composts. Conventional agricultural practices typically result in a gradual reduction in carbon held in the soil as it is released into the atmosphere. By modifying land management practices, (e.g. practicing conservation tillage or using cover crops) more carbon can be stored in the soil and plants.

The practices listed in *Box 2 (on page 34)* are consistent with farmers' needs and goals in most situations because they prevent soil erosion, conserve water, enhance soil biodiversity, reduce energy use, improve water quality, decrease siltation of reservoirs and water ways, and allow for the possibility of double cropping. Therefore, projects or activities that increase the organic matter yield a double dividend by improving the productivity of the land and slowing the buildup of greenhouse gas emissions in the atmosphere.

NEW OPPORTUNITIES FOR FARMERS

THIS SECTION OUTLINES TWO CASE STUDIES that illustrate sustainable agricultural

The atmosphere is a critical common asset, shared by all and necessary for life on Earth.

More sustainable agricultural practices that store carbon could offer farmers improved yields and an additional income source if policies are adopted to provide payment from the U.S. government or greenhouse gas emitters for the carbon sequestered by farmers.

[26] Carbon emissions from land-use changes (deforestation in particular) have contributed about 30 percent of the buildup of carbon in the atmosphere.

Converting from conventional tillage to conservation tillage can sequester an estimated 0.5 tons of carbon per hectare per year while increasing filtration and soil fertility, minimizing compaction, reducing erosion, and lowering labor and fossil fuel costs.

practices that store carbon in the soil, may improve agricultural productivity, and possibly create a new source of income for farmers. Potentially, greenhouse gas emitters, such as utility companies or the U.S. government, could pay farmers to undertake activities that either avoid carbon emissions or remove carbon from the atmosphere. Recent policy developments may allow carbon sequestration activities to pay double dividends—improving soil health and creating a new "crop" for farmers to sell, presenting a huge opportunity for California farmers.

Politicians and the public increasingly support reducing greenhouse gas emissions. Some utility companies such as Enron, Wisconsin Electric Power Company, and American Electric Power have invested in projects that avoid emissions by stopping deforestation, instituting conservation tillage, or installing wind power.[27]

Fortunately, policymakers in the U.S. are also exploring compensating farmers for helping protect the atmosphere. Senator Pat Roberts (R-Kansas) introduced The Carbon Cycle and Agricultural Best Practices Act (S. 1066) that was passed by the U.S. Senate in October 2000. (The bill was not voted upon in the U.S. House of Representatives before the end of the 106th Congress.)

The Bill appropriates $15 million in funding for climate change research by a consortium of universities that includes Kansas State University and the University of Kansas. "Through voluntary practices like conservation tillage, crop rotation, the Conservation Reserve Program, buffer strips, and new technologies, America's farmers and ranchers are contributing to clean air and water, healthy soil, sustainable forestry, and improved wildlife habitat," Senator Roberts said. "Some of these practices help to store carbon dioxide in the soil, making the soil more fertile and less vulnerable to erosion while reducing climate change" (Roberts 2000).

In California, Governor Gray Davis (D) recently signed the Greenhouse Gas and Emissions Inventory and Registry Act. The bill in part will establish a voluntary system where companies, cities, or groups can register their greenhouse gas emission reductions. The bill rightfully stresses reductions from energy use, but it could provide a vehicle to show the role that farmers can play in climate mitigation. California farmers could potentially register the carbon sequestered in their soil and gain credit for reductions.

Carbon Sequestration Opportunities in California

Several recent studies tested and quantified the potential for carbon sequestration in California, under conservation tillage and organic farming, thus helping shed light on the potential benefits to the atmosphere and the farm.

Opportunities for Conservation Tillage in California

Conservation tillage was originally developed to improve water quality and agricultural sustainability, and it also leads to higher soil carbon.[28] Some of the potential benefits of minimizing tillage include reduced fuel and labor costs and increased soil moisture and organic matter. These practices minimize plowing, leave crop residues on the soil surface, and reduce soil erosion (CTIC 1998). Converting from conventional tillage to conservation tillage can sequester an estimated 0.5 tons of carbon per hectare per year while increasing filtration and soil fertility, minimizing compaction, reducing erosion, and lowering labor and fossil fuel costs (Lal et al. 1998).

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[27] For example, the Prairie Soil Carbon Balance Project (PSCB) in Canada is a consortium of government, private sector, agricultural research centers, and nongovernmental organizations investigating the use of agricultural soils as a climate change mitigation option. An association of Canadian energy and utility companies is providing part of the funding for the PSCB project because they are interested in obtaining carbon credits from such activities in the future. The PSCB project is investigating the effects of cropping and tillage systems on soil carbon storage and carbon balances in managed pastures and native rangelands with perennial cropping. The project is estimated to abate about 3 to 10 million tons of carbon. John Bennett, a conservation farmer from Biggar, Saskatchewan, notes the potential for Canadian farmers: "the Prairie Soil Carbon Project, with its most cautious figures, estimates that prairie farms can sequester 1.3 metric tons of carbon, per hectare, per year." (http://www.wcwga.ca/profarm/story_41.html).

[28] Conservation tillage can involve no-till, minimum tillage, reduced tillage, surface tillage, ridge tillage, ridge-furrow tillage, or terrace fields depending on what's appropriate for the agricultural system and terrain.

Hopefully California farmers will be able to take advantage of the opportunities conservation tillage presents. During the last decade, conservation tillage increased 300% in the Midwest (Mitchell 1999). While conservation tillage is being adopted widely in the Midwest, California farmers have not widely adopted the practice. California has been called the last conservation tillage frontier in the U.S.

Being the last frontier can pose both challenges and opportunities. The fact that conservation tillage has not yet been adopted widely yet could mean that increasing sustainable tillage practices faces hurdles, but it also means that the room for improvement is great.

Jeff Mitchell of UC-Davis has been leading a team of researchers investigating the suitability of using conservation tillage on row crops including tomatoes, melons, and organic vegetables. The team has identified two hurdles to the greater adoption of conservation tillage in California: lack of suitable equipment and uncertainties related to managing surface irrigation. Mitchell's team has experimented with combinations of cover cropping, organic mulches, reduced tillage, and herbicide applications to determine the possibility of suppressing weeds, improving production efficiencies, and conserving soil moisture.

The studies are ongoing, and more research will be needed. However, preliminary results show that no-till tomato production, when combined with a cover crop, sequesters carbon. *Figure 3* summarizes soil carbon after two years of no-till under two different cover crop mixtures (triticale/vetch 14.8 tons per hectare and rye/vetch 13.8 tons per hectare) compared to conventional tillage (fallow 12.8 tons per hectare) (Herrero et. al. 2000).

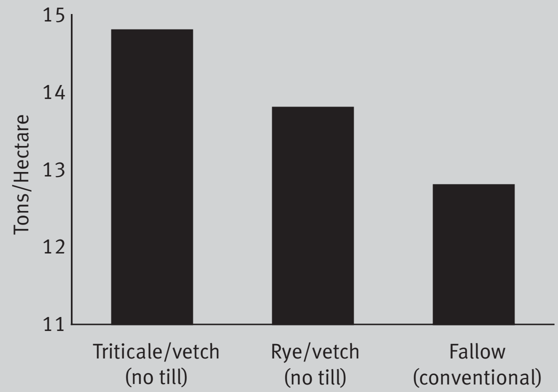
Enrique Herrero, a researcher at UC-Davis, also found that soil water content appears to increase under no-till relative to conventionally tilled plots and no-till lowers soil compaction. Soil carbon increases can be realized under conservation tillage. No-till with triticale and vetch as winter cover crop sequestered two tons of carbon more per hectare than conventional tillage, while no-till with rye and vetch as winter cover crop sequestered one more ton.

But barriers remain in California. The main question is: can conservation tillage prove more profitable than conventional tilling?

In other states, conservation tillage combined with cover cropping has proven more profitable than their conventional counterparts.[29] For example, one Iowa farmer reported a $138 per acre increase in returns over conventional management systems (Burnham 2000). If appropriate tillage management systems can be found, California farmers could improve productivity, reduce costs, and possibly get paid for doing so.

FIGURE 3

SOIL CARBON UNDER NO TILL AND CONVENTIONAL TILLAGE



Conservative estimates put the value of a ton of carbon at a minimum of $25 per ton, yet $50 per ton is also reasonable. Farmers, therefore, could gain an extra $25-100 per hectare per year for their carbon storage (until the storage capacity of the soil is reached).

The Potential for Sustainable Farming Systems to Sequester Carbon

The Sustainable Agriculture Farming Systems (SAFS) project is a study comparing conventional and alternative farming systems in Sacramento Valley (Clark 1998). The SAFS project was undertaken in 1988 by a group of farmers and UC researchers. It has three main objectives:

1. Compare conventional, low-input, and organic farming systems;

2. Evaluate known and novel farming practices that show potential to reduce dependence on nonrenewable resources; and

[29] T.J. Burnham, "New Tillage," *California Farmer*. May 2000. Farmers from Iowa, Tennessee, Oregon, and Pennsylvania reported cost savings ranging from $14-675 per acre.

3. Distribute information generated by the project in an effort to facilitate a dialog about the adoption of more sustainable farming practices.

The study, which began in 1988, compares four farming systems that differ in crop rotation and use of different inputs. The four systems are:

- *Conventional Four*: Four-year crop rotation under conventional agriculture using practices typical of the area.
- *Conventional Two*: Two-year rotation under conventional agriculture using a tomato and wheat rotation.
- *Low-Input*: Four-year crop rotation using synthetic fertilizer and pesticide inputs that were reduced 40-60% using legume cover crops for fertility and mechanical cultivation for weed control.
- *Organic Management*: Four-year crop rotation following regulations of California Certified Organic Farmers using legume and grass cover crops, animal manure, and cultivation.

In general, the SAFS project found that low-input and organic farming methods improved soil quality (including increased storage of plant nutrients and soil carbon), biological activity, and water infiltration.

The SAFS project investigated the different abundance and types of weeds, diseases, arthropod and nematode populations; differences in soil biology, physical and chemical properties, and water relations; crop growth, yield, and quality; and the economic viability of different systems.

In general, the SAFS project found that low-input and organic farming methods improved soil quality (including increased storage of plant nutrients and soil carbon), biological activity, and water infiltration.

However, the researchers noted some challenges with these farming systems. For example, nitrogen mineralization becomes slower or more unpredictable in management systems depending on cover crops and/or organic amendments for nitrogen fertility.

Research at the SAFS project and other studies show the potential benefits of organic and low-input farming systems. However these systems must be profitable to be adopted by farmers. The SAFS study found that premium prices for organic produce make organic farming profitable. More research is needed to find cost-effective and reliable fertility and weed management practices for organic and low-input systems.

Farmers Should Receive Compensation for Carbon Storage Services

Low-input and organic farms store more carbon than conventional agricultural systems. If carbon storage payments come to pass, then these systems will increase in relative profitability to conventional systems. *Table 9* compares carbon sequestration and profitability of the different cropping systems.

The conventional system on a two-year rotation is the most profitable and common Sacramento Valley cropping system. If organic farms retain their price premium and secure payments for carbon, organic management may be more widely adopted as the profit differential between organic and conventional farming will decrease.[30]

The study found that soils in the organic and low-input systems sequestered more carbon due to the increase in soil organic matter. While carbon payments would not reorder the profitability of various farming systems, they could narrow the gap between conventional and organic farming. Also, carbon payments could help cushion a loss of the price premium for organic farms.

WORKSHOP DISCUSSION

Following the presentations (*see the Agenda in Appendix II)* workshop participants discussed potential connections between sustainable agriculture and carbon stored in soil.

Discussion Questions for Workshop

- What are barriers to the greater adoption of conservation tillage in California?
- If barriers are financial, what are possible policy responses to create greater incentives?
- If barriers are informational, what are research needs or how can we get existing information out?

[30] SAFS 1997

- Would more information on domestic policy, such as congressional legislation or the California Registry for Climate Change be helpful?

ADDITIONAL OPPORTUNITIES TO PROMOTE CARBON SEQUESTRATION

- In promoting carbon sequestration, stress the benefits to farmers (which include improved soil productivity, decreased erosion, and improved water retention) over climate benefits.

- Also investigate carbon stored in above-ground biomass, rather than focus only on soil carbon. Above-ground biomass may provide more benefits in some cases. Hedgerows can provide a windbreak and offer refuge to beneficial insects such as pollinators and predators of crop pests. For example, Operation Green Stripe, a Monsanto education and conservation program, provides Future Farmers of America (FFA) with grass seeds and educational grants. FFA then recruits farmers to establish vegetative buffers between their fields and surface water supplies. The Green Stripes program may reduce erosion and very likely sequesters carbon.

- One barrier identified by farmers at the workshop was the need for specialized equipment to practice conservation tillage. One way to encourage greater conservation tillage would be to establish an equipment sharing service or system for farmers' use.

OBSTACLES TO THE BROADER ADOPTION OF CARBON SEQUESTRATION

- Since organic farmers cannot use herbicides, and weeding is labor intensive, weeds are a problem. As a response organic farmers must often plow under weeds, while non-organic farmers need not plow, due to their use of herbicides. Plowing also emits carbon.

- For nut crops, cover crops may increase risk of freezing and present harvest challenges. However, other farmers found that certain types of cover crops can avoid frost damage to nut crops.

- Change is hard, and cultural and social biases need to change. For example, a current bias in favor of clean fields is one impediment to the greater adoption of conservation tillage.

- More crop specific research is needed to determine the viability of conservation tillage techniques in California.

- Carbon sequestration should not overrule natural ecosystem processes or dominate land use decisions. For example, wildfires are an integral part of many ecosystems, yet lead to carbon emissions. Similarly, wetlands emit methane, a greenhouse gas that is more damaging to the atmosphere than carbon. Restoring wetlands increases methane, yet this fact should not stop wetland restoration projects.

CONCLUSION

GOOD LAND STEWARDSHIP IMPROVES productivity, provides wildlife habitat, and keeps carbon out of the atmosphere. Even when global warming impacts are not considered, sustainable agriculture provides many other benefits.

Farmers can profit by providing low-cost greenhouse gas reduction opportunities. By modifying management practices and using those techniques described in the previous section (such as conservation tillage, reduced erosion, or protecting grasslands), more carbon can be stored in the soil and plants. Farmers potentially would receive a "credit" for each extra ton of carbon they keep out of the atmosphere. These credits could then be sold to utility companies or other carbon emitters, allowing them to mitigate their greenhouse gas

Good land stewardship improves productivity, provides wildlife habitat, and keeps carbon out of the atmosphere. Even when global warming impacts are not considered, sustainable agriculture provides many other benefits.

TABLE 9

CARBON SEQUESTERED AND PROFITABILITY OF FARMING SYSTEMS

Farming Systems	Tons of Carbon/Acre (millions)	Current Profitability ($/acre)	Profitability with Carbon Storage ($/acre)
Conventional Four	.012	$238	$239
Conventional Two	No Change	$340	$340
Organic Management	.546	$300	$327
Low-Input	.314	$145	$150

emissions less expensively than they otherwise could.

Everybody wins: farmers get much-needed capital to improve practices and emitters get an inexpensive emission reduction. Eventually, of course, the agricultural sector will have sequestered as much carbon as it can, as the soil can only hold so much, but everyone will have some extra time to find new ways to protect the atmosphere.

BOX 2

SEQUESTRATION OR EMISSION REDUCTION ACTIVITIES

Specific activities on agricultural and grazing lands that enhance soil productivity and sequester carbon include the following:

Restoring productivity in degraded croplands. Restoring degraded farmlands is one of the clearest "win-win" opportunities because it slows the increase of carbon in the atmosphere while helping improve the livelihoods of farmers.

Instituting agroforestry on croplands or pastoral lands. Agroforestry could include growing trees with crops or cattle or the use of hedgerows (see also pollination chapter). Combining perennials with crops has the potential to both improve agricultural productivity and increase carbon sequestered in above-ground biomass and in the soil.

Reducing erosion. Activities and practices that increase soil organic matter content also reduce wind and water erosion. Erosion removes carbon and carries away plant nutrients, depletes soil productivity, and reduces future crop growth and carbon sequestration. Reducing erosion in the United States could reduce carbon emissions by about 12-23 million tons per year (Lal et al. 1998).

Practicing conservation tillage. These practices minimize plowing, leave crop residues on the soil surface, and reduce erosion. Conservation tillage was originally developed to improve water quality and agricultural sustainability, but it also leads to higher soil carbon. Conservation tillage may involve no-till, minimum tillage, reduced tillage, surface tillage, ridge tillage, camber bed system, ridge-furrow tillage, or terrace fields, depending on the type of agricultural system and terrain involved.

Improving plant productivity. Improving productivity almost always means increased plant growth and more soil organic matter. Irrigation, agroforestry, fertilization, improved crop rotations, green manure crops, reduction of bare fallow, improved plant varieties and pest control are some of the practices can increase crop productivity.

Improving water management. Improved irrigation and drainage are important aspects of water management. Since most irrigation is located in arid and semi-arid regions, many irrigable soils are inherently low in organic matter in their native state. Converting these dryland soils to irrigated agriculture may increase soil organic carbon (Lal et al., 1998).

Improving grazing practices. Much of the world's grasslands are degraded due to overgrazing, salinity, alkalization, and acidification (Oldeman et al. 1991). Degradation typically results in loss of perennial cover, increased erosion risk, and loss of productive potential. Restoring vegetation and productivity results in increases in biomass, litter, and soil carbon. Soil conservation practices maintain nutrients which, in combination with improved water retention, usually increases plant growth and productivity. Because overgrazing is the most significant cause of degradation in the world's grasslands, improving grazing practices can improve soil carbon levels.

Protecting grasslands. Intense grazing or conversion of grassland substantially reduces biomass and soil carbon levels. Protecting grasslands increases soil carbon and is likely to provide significant biodiversity benefits.

APPENDIX 1 BEE VISITORS TO CROPS AND THEIR OCCURRENCE IN DIFFERENT HABITATS

Bee visitors to crops and their occurrence in different habitats. Parasitic bees (e.g. bees that do not collect pollen themselves but that lay their eggs in other bees nests) are indicated by an asterisk.

Habitat or Crop type			Pan and PVC trap specimens				Vouchered observations								No. ov
			Riparian	Chap-arral	Farm	Hedge-row	Water-melon	Musk-melon	Squash	Cuc-umber	Egg-plant	Tomato	Straw-berry	Sun-flower	visited crops
(Number of sites)			4	4	20	3	34	14	1	2	8	10	6	1	
Family	Genus	(Subgenus) species			x										0
Andrenidae*	Calliopsis	sp.	x												0
Anthophoridae	Anthophora	urbana					x					x			2
Anthophoridae	Apis	mellifera	x	x	x	x	x	x	x	x	x	x	x	x	8
Anthophoridae	Bombus	californicus	x		x	x	x	x		x	x	x	x		6
Anthophoridae	Bombus	sonorus			x			x			x				2
Anthophoridae	Bombus	sp.			x										0
Anthophoridae	Bombus	vosnesenskii			x		x	x				x		x	4
Anthophoridae	Ceratina	sp.	x	x	x		x								1
Anthophoridae	Diadasia	sp.	x	x	x	x	x							x (*ana-vada*)	2
Anthophoridae*	Epeolus	sp.			x										0
Anthophoridae	Melissodes	sp.	x	x	x	x	x	x					x	x	4
Anthophoridae*	Nomada	sp.			x		x								1
Anthophoridae	Peponapis	pruinosa	x		x		x	x	x	x					4
Anthophoridae	Svastra	obliqua	x		x									x	1
Anthophoridae	Svastra	sp.	x												0
Anthophoridae*	Triepeolus	sp.		x	x		x						x		2
Anthophoridae	Xylocopa	sp.		x	x										0
Colletidae	Colletes	sp.													0
Colletidae	Hylaeus	sp.	x		x		x								1
Halictidae	Agapostemon	texanus	x	x	x	x	x	x		x	x	x	x		6
Halictidae	Halictus	sp.			x										0

Habitat or Crop type			Pan and PVC trap specimens: Riparian	Chap-arral	Farm	Hedge-row	Vouchered observations: Water-melon	Musk-melon	Squash	Cuc-umber	Egg-plant	Tomato	Straw-berry	Sun-flower	No. of visited crops
Halictidae	Halictus	farinosus		x	x								x		1
Halictidae	Halictus	ligatus	x		x	x	x	x					x	x	4
Halictidae	Halictus	tripartitus	x	x	x	x	x	x	x	x	x	x	x		7
Halictidae	Lasioglossum	(Dialictus) sp.	x	x	x	x	x	x		x	x	x	x		6
Halictidae	Lasioglossum	(Evylaeus) sp.	x	x	x	x	x	x		x	x	x	x		6
Halictidae	Lasioglossum	sp.		x	x		x								1
Halictidae	Lasioglossum	titusi			x		x	x					x		3
Halictidae*	Sphecodes	sp.	x		x		x						x		2
Megachilidae	Ashmeadiella	sp.	x	x	x	x	x						x		2
Megachilidae*	Coelioxys	sp.													0
Megachilidae	Dianthidium	sp.		x											0
Megachilidae	Hoplitis	sp.		x											0
Megachilidae	Megachile	sp.			x										0
Megachilidae	Megachile	apicalis		x	x								x		1
Megachilidae	Megachile	sp.	x	x	x	x	x	x							2
Megachilidae	Megachile	fidelis			x										0
Megachilidae	Osmia	sp.	x	x	x	x	x								1
Megachilidae*	Stelis	sp.				x									0
Melittidae	Hesperapis	sp.		x											0
Minimum number of species			19	19	32	13	22	13	3	7	7	8	14	6	41
Minimum number of genera															29
Minimum number of non-parasitic species at crops															23
Minimum number of non-parasitic genera at crops															15

APPENDIX 2 WORKSHOP AGENDA

8:30-9:00 **Sign in and Continental Breakfast**

9:00-9:15 **Introduction: What are Common Assets?**

9:15-9:45 **Pollination Services**: How much might bees be worth to your farm or your grocery budget?

Bob Bugg, UC Davis: *Encouraging Beneficial Insects on Farms*
Robbin Thorp, UC Davis: *The Advantages of Native Bees For Agriculture*
Claire Kremen, Stanford University: *How Landscape Around Farms Effects Pollination Services*

9:45-10:30 Pollination Services: Moderated group discussion.

10:30-10:45 Break

10:45-11:30 **Natural Floodplain Management**: What are farm-friendly alternatives to structural flood control?

Mike Eaton, The Nature Conservancy: *Natural Floodplains in the Cosumnes River Preserve*
Allen Garcia, Living Farms: *Rice Farming in Natural Foodplains: Prospects and Challenges*
Mike McElhiney, USDA NRCS: *Floodplain Easements in Stanislaus County*

11:30-12:30 Natural Floodplain Management: Moderated group discussion

12:30-1:15 Lunch will be provided.

1:15-1:45 **Carbon Sequestration**: What might healthy topsoil be worth in dollars?

Paige Brown, Redefining Progress: *Agriculture and Climate Change: Opportunities for Farmers*
Dr. William R. Horwáth, UC Davis: Carbon Sequestration and Soil Fertility
Martin Lemon, Monsanto: *Conservation Tillage*

1:45-2:30 Carbon Sequestration: Moderated group discussion.

2:30-2:45 Break

2:45-3:45 **Linkages Among the Assets & the Common Assets Concept**: Moderated group discussion.
What policies and activities would benefit more than one common asset, in other words what are the best opportunities? What are other important common assets with linkages to sustainable agriculture? What does the concept of common assets evoke? Is it a helpful description of public, shared assets?

3:45-4:00 Next Steps/Wrap up

4:00-5:00 Reception

APPENDIX 3 WORKSHOP PARTICIPANTS

Ron Alves, Almond grower, Modesto Jr. College

John Bayer, Farmer

Kelly Briggs, Central Valley Water Quality Control Board

Bob Bugg, University of California, Davis

Steve Burke, Protect Our Water (POW), San Joaquin Valley Conservancy

Allen Cover, Walnut grower, Modesto Jr. College

Kevin Dolan, University of California, Davis

David Dyer, USDA-Natural Resources Conservation Service

Mike Eaton, The Nature Conservancy

Barbara Eniti, Modesto Garden Project

Jennifer Foster, USDA-Natural Resources Conservation Service

Mike Fuller, Community Alliance with Family Farmers, Eco Farm

Michele Gail-Sinex, Communication Consultant

Allen Garcia, Rice farmer, Director of Living Farms

Charles Gibson, Modesto Jr. College

Russ Hill, Community Alliance with Family Farmers

William Horwath, University of California, Davis

Claire Kremen, Stanford University researcher

David Kupfer, Farmer, Ecological Farming Association

Cindy Lashbrook, Living Farm Systems

Brian Leahy, Executive Director, California Certified Organic Farmers

Martin Lemon, Monsanto

Mike McElhiney, USDA-Natural Resources Conservation Service

Tom Meagher, Army Corps of Engineers

Jeff Mitchell, University of California, Davis

Neal Nelson, Neal's Marsh

Jenna Olsen, Tuolumne River Preservation Trust

Rudy Platzek, Farmer and Valley Vision Project

Marcie Rosenzweig, Full Circle Organic Farm

Robbin Thorp, University of California, Davis

Cully Thomas, University of California, Davis

Bill Thompson, Four Seasons Ag Consulting, Inc.

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