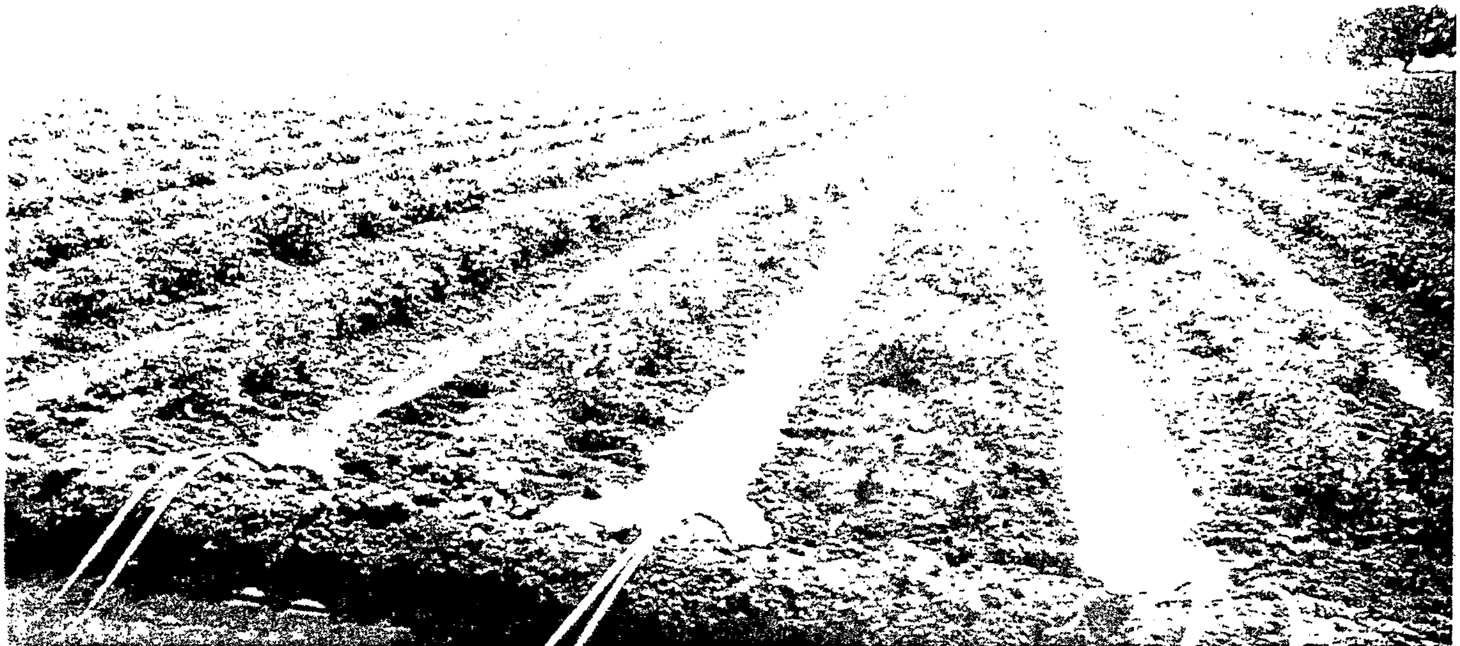
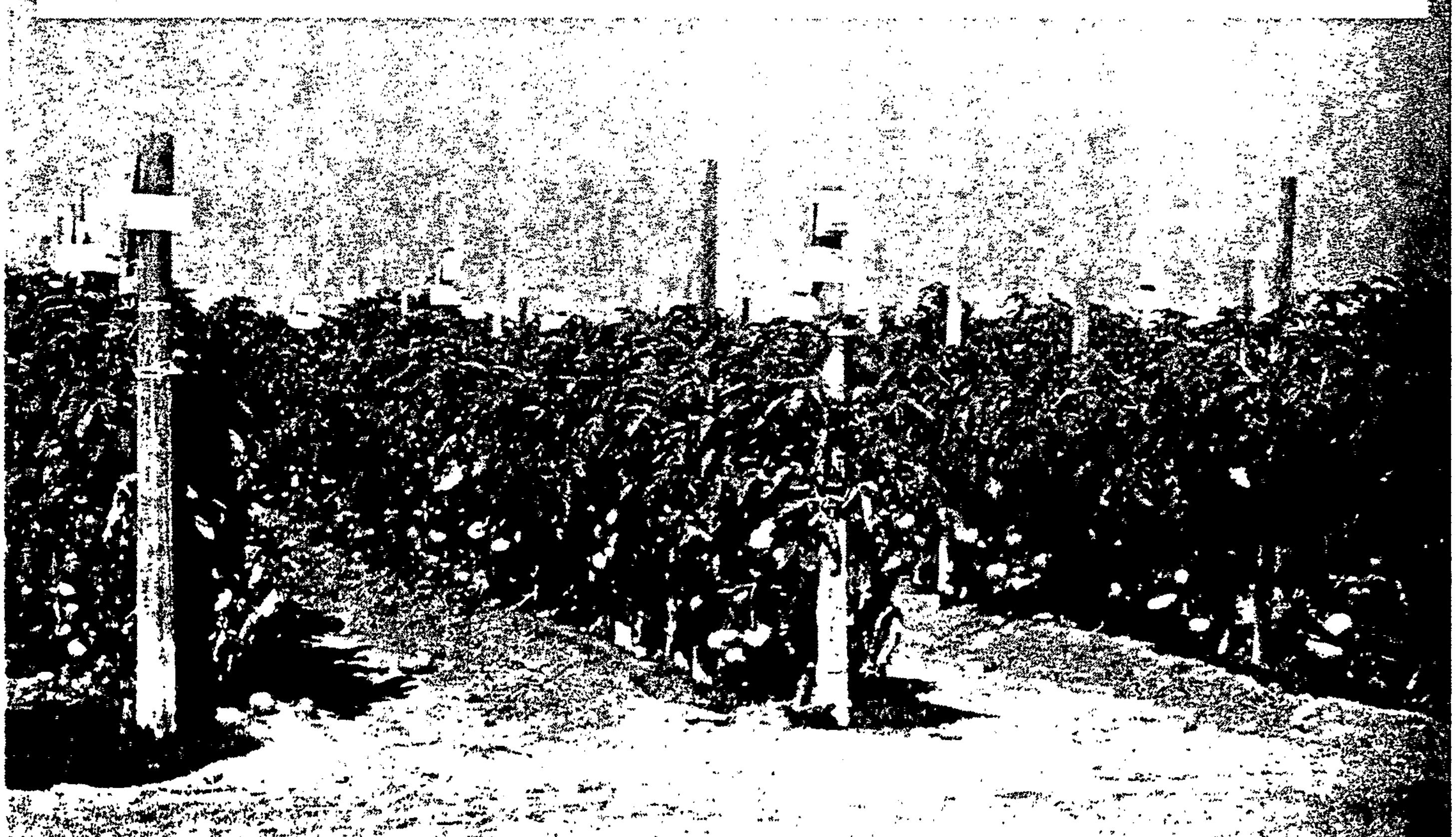


AGRICULTURAL SOLUTIONS

IMPROVING WATER QUALITY IN CALIFORNIA THROUGH WATER CONSERVATION AND PESTICIDE REDUCTION



Natural Resources Defense Council / March 1998

Agricultural Solutions: Improving Water Quality in California Through Water Conservation and Pesticide Reduction

Ronnie Ann Cohen
Jennifer Curtis

Natural Resources Defense Council / March 1998

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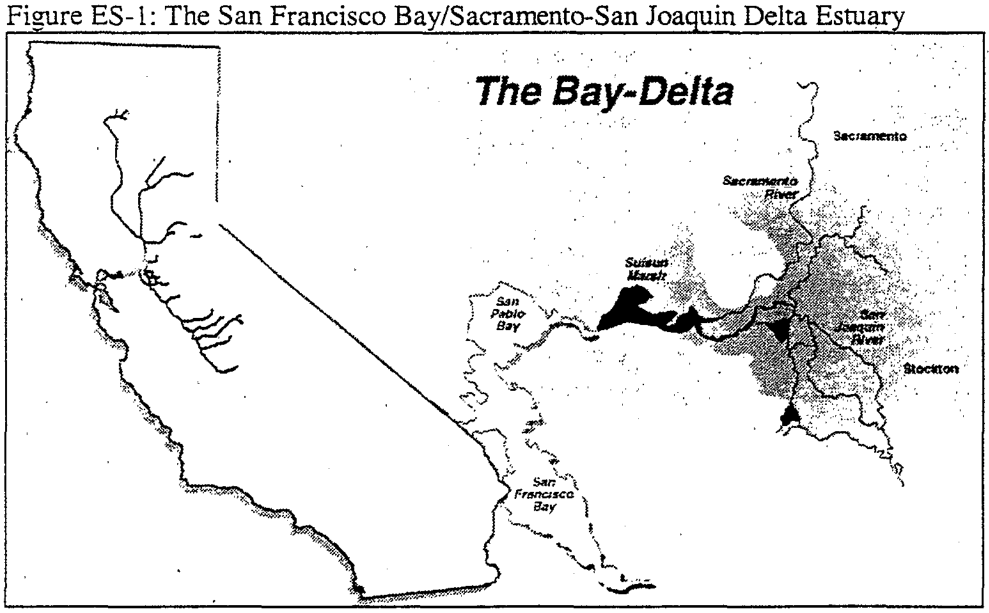
EXECUTIVE SUMMARY

Agriculture contributes more than half of the pollution entering the nation's rivers and lakes; recent studies have identified it as the greatest source of water pollution in the United States. California's San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) is one of many water bodies in the country suffering from impaired water quality due, in part, to agricultural activities in its watershed. The Bay-Delta, which is the largest estuary on the west coast and the hub of the state's water delivery system, is critical to California's environmental and economic health. Evidence of pollutant effects in the Bay-Delta is sufficient to designate much of the Estuary as threatened or impaired due to combinations of different toxic pollutants found in its waters.

Figure ES-1: The San Francisco Bay/Sacramento-San Joaquin Delta Estuary



Source: CALFED Bay-Delta Program

This report examines water conservation and pesticide use reduction techniques that can improve water quality in the Bay-Delta ecosystem, and presents case studies of farms and projects that have put these techniques to use. While this report focuses on selenium and pesticides, many of the techniques discussed can reduce loads of other pollutants as well.

The centerpiece of this report is a series of case studies describing farmers who have successfully applied water conservation and/or pesticide use reduction

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techniques. However, farmers using these techniques are still in the minority. Thus, this report offers a series of recommendations for promoting sustainable agriculture, focusing research and development for such techniques, and providing the technical and financial assistance to support these changes.

AGRICULTURAL WATER POLLUTION

When water from rainfall or irrigation reaches agricultural fields it mobilizes salts, trace elements such as selenium, and other contaminants, including pesticides, that may be present in the soil. Before the federal and state water projects were built in California, the low rainfall received by most farming regions in the state mobilized naturally occurring salts and trace elements very slowly. With irrigation water now catalyzing the process, these elements, along with fertilizer and pesticide residues, can mobilize more rapidly and concentrate in harmful amounts in water draining from fields into the Bay-Delta and its tributaries. Selenium and pesticides are among the most problematic constituents of these flows.

Selenium

Selenium is a trace element found naturally in crude oil and in most soils, especially those that developed from Cretaceous shales, such as soils on the west side of California's San Joaquin Valley. While small amounts of selenium are necessary to life, higher concentrations are toxic. Toxic effects of selenium on fish and wildlife include adult mortality, reduced growth, immune system dysfunction, reproductive abnormalities such as reduced reproductive success, and deformity and death in hatchlings. Selenium can also be toxic to humans. While there have been no reported human deaths due to environmental selenium, there have been cases of acute selenium poisoning and fatalities from accidental or over-ingestion of products containing selenium.

The issue of selenium in agricultural drainage water first received widespread public attention in the 1980s, when selenium-laden drainage from the Westlands Water District in California's San Joaquin Valley caused deaths and deformities in thousands of waterbirds at Kesterson Reservoir. While selenium is only one of many pollutants in agricultural drainage, it is of primary concern in California both because of its wide natural distribution in the soils on the west side of the San Joaquin Valley, and because of its proven toxicity, as illustrated by the Kesterson tragedy and elsewhere.

Pesticides

Pesticides are chemicals used to control insects, weeds and plant diseases. They are inherently toxic compounds; risks to human health and the environment primarily depend on the relative toxicity of individual compounds. Experimental and epidemiological studies demonstrate that humans exposed to pesticides are subject to a variety of health risks including cancer, neurotoxicity, reproductive harm, birth defects and damage to the immune and endocrine systems. Pesticides also have caused cases of acute poisoning in farm workers. Environmental risks such as toxicity to beneficial insects, aquatic organisms, and birds also are well documented.

Organochlorine pesticides such as DDT are routinely detected in the Bay-Delta watershed. A highly persistent class of chemicals, organochlorines are only slightly soluble in water, but their residues persist in soil and aquatic sediments and can concentrate in the tissues of aquatic organisms for years after they are applied. While DDT has been banned, other organochlorine pesticides such as dicofol and endosulfan remain in use throughout California's Sacramento and San Joaquin Valleys.

Organophosphate pesticides are also found in the Bay-Delta watershed. While less persistent than the organochlorines, at high enough concentrations organophosphates can be acutely toxic to aquatic organisms.

FARMING PRACTICES THAT PROTECT WATER QUALITY

Water conservation and pesticide use reduction can help improve Bay-Delta water quality. Water conservation can improve water quality by reducing the volume of surface runoff and subsurface drainage, by potentially reducing the pollutant loads of the remaining subsurface drainage, by allowing more efficient application of agricultural chemicals, and by limiting irrigation-induced erosion and sediment loads.

In addition to improving water quality, water conservation can leave more water in rivers, streams, and wetlands for fish and wildlife, as well as reduce the number of fish killed directly by water diversions. Conservation can also help farmers increase crop yields and quality, and reduce production costs as a result of water and energy savings, and reduced pesticide and fertilizer applications.

Alternative pest management techniques can minimize pesticide contamination of the Bay-Delta ecosystem. Many of these techniques, including cover crops, soil building, and crop rotation, are designed to prevent conditions that encourage pest problems, thereby eliminating the need for chemical intervention. Other alternative techniques control pest populations by enhancing populations of natural predators, or by relying on natural or less toxic substances to reduce or eliminate pests.

CASE STUDIES

This report illustrates on-the-ground situations where water conservation and pesticide reduction techniques are being used successfully, and where farmers have found that these techniques maintain or increase the economic viability of their farming operation. Farmers and programs profiled for this report include:

West Stanislaus Hydrologic Unit Area (HUA) Program, Stanislaus County. The HUA program was developed to reduce runoff of pesticide-laden sediment into the San Joaquin River. Using a mix of information and education, cost-sharing, technical assistance, and monitoring and evaluation, the program has reduced water use by 18 percent, saving over 12,000 acre feet of water per year. Cumulatively the program has prevented over 718,950 tons of sediment from entering the impaired San Joaquin River.

John Texiera of Trecho Farms in Los Banos. Through his extensive soil building program and use of drip irrigation John has reduced herbicide use by 30 percent, synthetic fertilizer use by 25 percent, and water use by 50 percent.

Jim and Deborah Durst in Esparto. Using crop rotations, building soil fertility, and using other integrated pest management techniques, the Dursts have completely eliminated use of synthetic pesticides and fertilizers.

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Lundberg Family Farms in Richvale. Using creative irrigation and integrated pest management (IPM) techniques, the Lundbergs have reduced synthetic pesticide use 100 percent on organic fields and 50 percent on Nutra-farmed fields, and have also reduced water use by 25 percent.

Panoche Drainage District in Fresno County. Panoche has been directly confronted with the necessity of reducing selenium loads into the San Joaquin River, and as a result has adopted a variety of policies that are geared towards encouraging farmers to reduce or eliminate their drainage. Many farmers in the district, including two who are included in this report, have changed their irrigation practices as a result of these policies.

Sherman Boone in Denair. Releasing beneficial insects into his orchards and growing a cover crop both to improve soil fertility and provide habitat for beneficial insects, Sherman has eliminated synthetic insecticide use and reduced synthetic herbicide by 33 percent and synthetic nitrogen fertilizer by 50 percent.

Claude and Linda Sheppard in Chowchilla. Using beneficial insects, and other IPM techniques, the Sheppards have completely eliminated use of synthetic pesticides. They have also adopted irrigation water management techniques that have kept their water use 25 percent below the regional average for cotton.

Craig McNamara in Winters. Growing cover crops for weed and insect control and for soil building, and using insect mating disruption techniques for codling moth, on half of his acreage Craig has reduced synthetic herbicide by 35 percent and reduced synthetic nitrogen fertilizer use by 50 percent.

Doug Hemley in Courtland. Using insect mating disruption techniques to address codling moth problems, Doug has reduced insecticide use by 50 percent.

Steve Nishita in San Juan Bautista. Using a linear move irrigation system, Steve has reduced water use, improved irrigation efficiency, reduced labor costs and improved yields on his farm.

Mark Gibson in Hollister. Relying on beneficial insects and a cover crop Mark has completely eliminated use of synthetic pesticides and fertilizers in his walnut orchards, and eliminated use of synthetic insecticide, herbicide, and fertilizer use in his apricot orchards.

RECOMMENDATIONS

The farmers profiled in this report illustrate with their practices the changes that are possible in resource management. These case studies clearly demonstrate that farmers *can* significantly reduce their water use, as well as their reliance on synthetic pesticides and fertilizers. At this time, however, the farmers who are choosing to use these techniques are in the minority. While there are many factors that affect the choice of farming techniques, there is much that can be done on a policy level, using a mix of incentive-based and regulatory programs, to encourage increased use of sustainable farming techniques.

Sustainable agriculture does not compete on a level playing field: farmers are often faced with water rates that do not reward conservation, tax policies that encourage the use of pesticides, processing and marketing infrastructure that penalizes organic growers, and other disincentives to sustainable agriculture. We recommend the following enforcement, monitoring, research and development, technical assistance, and economic incentive programs to promote sustainable agriculture.

Enforcement

⇒ Congress should maintain and strengthen key environmental laws. In particular, Congress should amend the Clean Water Act to provide tougher controls on polluted runoff and more aggressively promote pollution prevention. The Administration should vigorously implement and enforce these laws.

⇒ The Bureau of Reclamation should implement the water conservation planning requirements of the Reclamation Reform Act and the Central Valley Project Improvement Act. The case studies in this report illustrate that there are a wide range of cost-effective techniques available to farmers that would help achieve the conservation goals embodied in these laws. The government must use its authorities to provide meaningful leadership.

⇒ States have an affirmative responsibility under the Clean Water Act to identify impaired waters and to establish Total Maximum Daily Loads (TMDLs) for stressors of concern for those waters. In cases such as California where the state has failed to meet its responsibilities, the law requires EPA to act. Therefore, EPA must establish TMDLs for all impaired waters in California, including implementation plans to achieve the limits set forth in each TMDL. The State has long failed to meet its responsibilities under the Clean Water Act to develop TMDLs, and EPA intervention is warranted and overdue.

⇒ EPA should enforce the new Food Quality Protection Act which protects infants and children from exposure to particularly hazardous pesticides.

⇒ The CALFED program, a joint federal/state planning effort for the Bay-Delta, should make conservation and pollution prevention programs the central approach to achieving water quality and water supply reliability goals. These programs should include performance targets and enforcement mechanisms to assure compliance.

Monitoring

⇒ The state should develop and maintain a comprehensive water quality monitoring program, with uniform testing protocols, to develop better baseline information regarding the source and level of pollutants throughout the state's waters, and over time to evaluate the impacts of targeted pollution prevention programs.

⇒ Water quality monitoring should include tracing pollutants back to their source, to facilitate development of targeted source reduction programs. Current testing frequently focuses on evaluating the toxicity of a water source to various indicator species, but usually fails to isolate the cause of the toxicity, and to trace it back to its source.

⇒ The state should assure stable, long-term funding for water quality monitoring programs in order to develop meaningful data on pollutant trends. Interruptions of data collection due to inadequate funding or other reasons can make it difficult or impossible to perform meaningful analysis of water quality trends.

Technical Assistance

⇒ Site specific information is of great value for selecting appropriate water conservation or pesticide use reduction measures. The state and federal governments should fully fund a Mobile Irrigation Lab Program to do site specific evaluations and follow up. Funding for these labs has been extremely limited in recent years.

⇒ The state should fund on-farm demonstration projects incorporating water conservation and chemical use reduction strategies.

⇒ Farmer to farmer networking programs such as the Biologically Integrated Orchard Systems (BIOS) program coordinated by the Community Alliance with Family Farmers (CAFF) have played a pivotal role in providing farmers with the information and technical assistance they need to adopt alternative pest management systems. Programs such as these should be supported and expanded.

⇒ Resource Conservation Districts (RCDs) are a valuable, underutilized resource. RCDs were formed as an independent local government liaison between the federal government and private landowners. When motivated and given the necessary resources, RCDs can play a valuable role in offering technical assistance and promoting sustainable farming practices. However, many RCDs do not have any source of income and are thus severely limited in the conservation assistance that they can offer. The state and federal governments should consider providing a permanent source of funding for RCD pollution prevention and resource conservation programs.

⇒ USDA should increase its efforts to identify and disseminate alternatives to particularly hazardous pesticides.

Research and Development

⇒ Research should be conducted on alternative pest management strategies that are designed to prevent pest problems from developing and reduce reliance on pesticides. Research priorities include the use of cover crops, crop rotations, biologically-based materials such as pheromones and enhancement of natural predator populations.

⇒ Research should be done to determine the relationship between cover crops and water-use, and to develop low water use varieties.

⇒ Additional research is needed on the relationship between soil fertility, pest management and water use. Farmers in these case studies found that soil fertility was key to reducing chemical inputs. Some also found that an extensive soil building program could reduce water use.

⇒ Additional research dollars should be directed towards improving efficient irrigation technologies. Dramatic improvements in technology, especially in drip and subsurface drip irrigation, have been made in recent years. Continued advances in technology are possible and should be aggressively pursued.

⇒ Further research should be done to develop early varieties of rice and other water-intensive crops that benefit from winter and early spring rains and that can be harvested after a shorter growing season and less applied irrigation.

Economic Incentives

⇒ The federal government should phase out irrigation subsidies, which encourage wasteful use of water as well as cultivation of marginal quality lands where irrigation especially contributes to water quality problems.

⇒ Water deliveries should be measured to each farm, and farmers should be charged only for water they use. Although some farmers interviewed for this report adopted water conservation technologies despite water rate structures that discouraged conservation, many spoke disparagingly of rate structures that charged farmers on a per-acre basis regardless of water use. These rate structures promote waste, not conservation.

⇒ The state should renew and expand its system of revolving fund loans for irrigation system upgrades. Such assistance can help overcome the obstacle of high up-front capital costs, which may otherwise dissuade farmers from adopting cost-effective technologies.

⇒ Financial incentive programs should be tied to a whole farm approach that addresses water use, water quality, soil health and erosion, and chemical use reduction. This will avoid shifting environmental problems from one medium to another, and will also help focus resources on measures and techniques that have multiple benefits. The USDA program described in the West Stanislaus case study demonstrates that such an approach can be extremely effective in achieving water conservation and water quality benefits.

⇒ The CALFED Bay-Delta Program should condition the receipt of any program benefits by agricultural water users on implementation of conservation measures, including water measurement and volumetric pricing to promote conservation.

⇒ Pesticides should be taxed according to their toxicity. Higher taxes should be placed on the more toxic chemicals, including those that are scheduled to be phased out, to give extra incentives for early replacement with less toxic alternatives.

⇒ Congress should appropriate full funding for the President's Clean Water Action Plan. The fiscal year 1999 funding initiative calls for a total increase of more than $568 million for improved polluted runoff controls, watershed restoration, and public health protections.

⇒ Federal resources for polluted runoff, in particular new money under the USDA's Environmental Quality Incentives Program (EQIP) and the EPA's Clean Water Act funds (both slated for increases in the President's Clean Water Action Plan), should be targeted to high priority watersheds for which watershed restoration programs have been developed.

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AGRICULTURE-INDUCED WATER QUALITY PROBLEMS IN THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ECOSYSTEM

Conventional agricultural practices frequently create water quality problems. However, there are numerous farming techniques that can reduce agriculture-induced water quality problems. This report identifies farming techniques that can improve water quality by reducing water use and limiting reliance on synthetic pesticides and fertilizers, and presents a series of case studies where these techniques have been used successfully.

The San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) is one of many water bodies in the country suffering from impaired water quality due, in part, to agricultural activities in its watershed. California's Central Valley, which is part of the Bay-Delta watershed, is the most intensively farmed region in the country. It is not surprising that farming in the Central Valley has caused water quality problems in the Bay-Delta ecosystem. Because of the critical importance of the Bay-Delta to California's environment and economy, there is a particular need to explore techniques that could reduce the negative impacts of farming practices throughout the Bay-Delta ecosystem.

There are numerous farming techniques that can reduce agriculture-induced water quality problems.

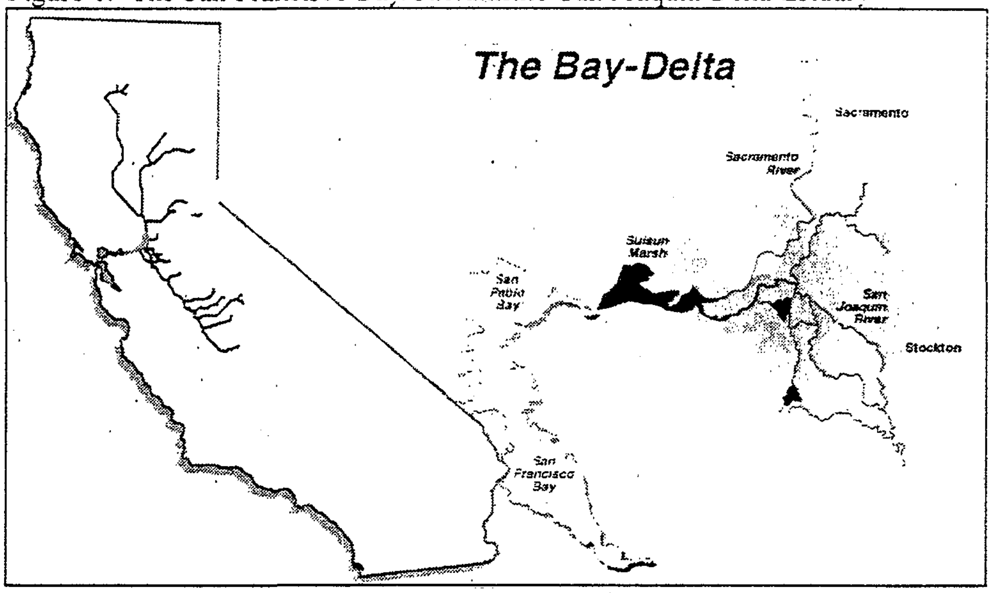
CALIFORNIA'S CENTRAL VALLEY AND THE BAY-DELTA ECOSYSTEM

California's Central Valley and the San Francisco Bay/San Joaquin-Sacramento Delta (Bay-Delta) encompass a complex and interdependent set of ecosystems. The Central Valley drains the Sacramento and San Joaquin Rivers, as well as numerous smaller rivers which originate high in the Sierra Nevada and Cascade Ranges. The massive flow of freshwater from these rivers converge in the Delta, carrying enormous quantities of sediment and nutrients into the Bay and for miles out into the Pacific Ocean.

The meeting of freshwater from the rivers with salt water from the ocean forms a highly productive ecosystem known as an estuary. The Bay-Delta is the largest estuary on the West Coast, encompassing roughly 1,600 square miles. It sustains an abundance of plants, invertebrates, amphibians, fish, shellfish, birds and other wildlife. The estuary provides critical habitat for several endangered species such as the California Clapper Rail, the Delta smelt and the Sacramento River winter-run Chinook salmon. Two-thirds of California's salmon pass through the Bay-Delta, as do nearly half the waterfowl and shorebirds migrating along the Pacific Flyway.[1]

The Delta lies at the eastern end of the Estuary, at the confluence of the Sacramento and San Joaquin Rivers. The Delta is considered the hub of the state's water system, and provides almost 55 percent of the state's managed fresh water supply. Water taken from the Delta provides drinking water for 22 million Californians, and irrigates 4.5 million acres of farmland.[2]

Figure 1: The San Francisco Bay/Sacramento-San Joaquin Delta Estuary



Source: CALFED Bay-Delta Program

The Central Valley and Bay-Delta were historically havens for hundreds of species of fish, birds, and other animals. In particular, the topography and climate allowed for the evolution of an unusually wide variety of anadromous fish species (fish that rear in freshwater, migrate to the sea and return to their natal streams to spawn). Thus, Central Valley rivers historically supported very large numbers of salmon, and had salmon runs in virtually every month of the year.

In addition to salmon, Central Valley rivers and the Bay-Delta supported dozens of other anadromous, resident and marine fish species, including, but not limited to steelhead trout, longfin and Delta smelt, green and white sturgeon, Sacramento splittail, blackfish, squawfish, and other varieties of bass, chub and perch. The Central Valley and the Bay-Delta also were used historically by hundreds of species of birds; millions of these animals relied on these upland, marsh, wetland and open water habitats every year.

The health of the Bay-Delta ecosystem has declined precipitously, largely as a result of human activities such as farming that deplete freshwater flows, impair water quality, and otherwise destroy habitat. Evidence of this decline is abundant and well-documented. According to a recent report on the health of the Bay-Delta:[3]

- Populations of Central Valley chinook salmon continue to exhibit long-term declines. The most severely threatened, the Sacramento River winter-run

Chinook, which is listed as both a federal and a state endangered species, had an all time low of 189 fish returning to spawn in 1994.

- The Striped Bass Index, which measures the relative abundance of that fish and is considered an important measure of the Estuary's health, has been in decline since 1977 and was at an all time low of 2.1 in 1996. This can be compared to a record high of 117.2 in 1965.
- The Delta smelt, once-abundant in the Delta and Suisun Bay, has declined to such low levels that in 1993 it was listed as a federal and state endangered species.
- The endangered Clapper Rail, a native bird, has declined from tens of thousands at the turn of the century to fewer than 6,000 in the 1970s, fewer than 1500 in the 1980s, and as low as 500 in 1991. The number of waterfowl in the Estuary also has decreased during the past decade.
- Thirty percent of all water samples collected during a 1992 study of multiple rivers draining into the Bay-Delta were found to be toxic, and the pesticide diazinon appeared in 90 percent of the toxic samples.

Water is the key to the abundance and diversity of the natural resources of the Central Valley and the Bay-Delta. The quantity and quality of river water flowing through the Estuary are critical factors determining the abundance, distribution and reproductive success for many species of fish dependent upon the Bay-Delta. Protecting and restoring the Estuary is critical to California's environment and economy, and addressing water quality problems, including the provision of adequate freshwater flows, is central to these restoration efforts.

AGRICULTURAL WATER POLLUTION IN THE BAY-DELTA ECOSYSTEM

According to recent federal, state, and local studies, agriculture is the greatest source of water pollution in the United States, contributing more than half of the pollution entering the nation's rivers and lakes. When water from rain or irrigation reaches farming fields, it mobilizes salts, trace elements such as selenium, and other contaminants, including pesticides that are present in the soil. These pollutants may enter natural water bodies in two ways:

- surface runoff/tailwater -- applied irrigation water or rainwater may run off fields directly into water bodies, or into ditches that eventually drain into natural water bodies; or
- subsurface drainage -- water may percolate through the soil, leaching trace elements, salts, and other pollutants. This drainage may seep into groundwater basins, eventually move through the soil directly into natural water bodies, or collect in perforated drainage pipes for ultimate disposal elsewhere, generally into a natural water body.

Pesticide and nutrient loads are carried primarily in surface runoff, while salts and trace elements are principally carried in subsurface drainage.

Before the federal and state water projects were built in California, the naturally low rainfall levels received by many farming regions in the state mobilized naturally occurring salts and trace elements very slowly. With irrigation water now catalyzing the drainage and runoff process, these elements, along with fertilizer and pesticide residues, are transported into the Bay-Delta estuary and its tributaries – often in harmful amounts – in the water draining from fields.

At certain times of the year, these agricultural return flows into the Delta can be voluminous, and freshwater flows quite limited. During the summer months the lower San Joaquin River consists almost entirely of agricultural return flows, as does up to thirty percent of the Sacramento River in certain stretches during rice growing season.[4] Over 100 river miles of the San Joaquin River have been designated as water-quality impaired by the United States Environmental Protection Agency (EPA).

High pollutant levels have produced toxic effects in the Estuary's fish, shellfish, and bird species.

High pollutant levels have produced toxic effects in the Estuary's fish, shellfish, and bird species.[5] There are four categories of pollutants in the Estuary: inorganic chemicals, including trace elements; organic chemicals, including pesticides and fertilizers; biological pollutants; and suspended sediments and other particles. Pollutants that pose water quality concerns in the Bay-Delta region that are attributable to agriculture include:[6]

- Arsenic
- Boron
- Carbofuran
- Chlordane
- Chlorpyrifos
- Copper
- DDT
- Diazinon
- Methidathion
- Molybdenum
- Salts
- Selenium
- Sodium
- Toxaphene
- Total dissolved solids (TDS)
- Total Organic Compounds (TOCs)

Many of these pollutants cause cancer, birth defects, or genetic mutations in some types of organisms.[7] Tissue analyses indicate that concentrations of ten trace elements, DDT, and PCBs sampled in the Estuary's mussels, clams, fish, and birds are either significantly higher than concentrations in samples collected elsewhere in the state, or exceed State Maximum Allowable Residue Level or the Median International Standard.[8] According to the San Francisco Estuary Project, an organization established by the federal government and jointly sponsored by the U.S. EPA and the State of California, the evidence of pollutant effects is sufficient to designate much of the Estuary as "threatened or impaired" by combinations of different toxic pollutants.[9]

The magnitude of water quality problems in the Estuary has been extensively documented elsewhere[10] and is not presented here in detail. Rather, this report looks at what on-farm techniques are available to improve water quality in the Bay-Delta ecosystem, and presents case studies of where those techniques have been used. While this report focuses on selenium and pesticides, many of the techniques discussed can reduce loads of other pollutants as well.

Selenium

Selenium is a trace element found naturally in crude oil and in most soils, especially those that developed from Cretaceous shales, such as soils on the west side of California's San Joaquin Valley. While small amounts of selenium are necessary to life, higher concentrations are toxic. According to the National Research Council, there is only a small margin of safety between levels considered essential and levels associated with toxicity.[11] The California State Water Resources Control Board and

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the Central Valley Regional Water Quality Control Board have recommended that water used for wetlands management in the Grasslands area of California's San Joaquin Valley should contain average selenium concentrations of 2 parts per billion (ppb) or less. University of California scientists have identified 1 to 1.5 ppb of waterborne selenium as the range that causes no adverse effects[12] – anything higher constitutes a risk to the ecosystem. Levels in agricultural drainage frequently exceed 50 ppb, and may be as high as 10,000 ppb.

Toxic effects of selenium on fish and wildlife include adult mortality, reduced growth, immune system dysfunction, reproductive abnormalities such as reduced reproductive success, and deformity and death in hatchlings.[13] Selenium can also be toxic to humans. While no human deaths due to environmental selenium have been reported, there have been cases of acute selenium poisoning and fatalities from accidental or over ingestion of products containing selenium.[14]

The potential problems that selenium can cause were graphically illustrated by the tragedy at Kesterson Reservoir in the San Joaquin Valley, when selenium from agricultural drainage water delivered to a portion of a wildlife refuge led to death and deformity in thousands of waterbirds and the eventual closure of the refuge in 1986. A December 1996 monitoring report confirmed that dangerously high and even toxic levels of selenium persist at Kesterson, in some places as high as 1000 times the level considered safe.[15]

In 1987, the EPA reduced its ambient freshwater aquatic life water quality criterion for selenium from 35 to 5 ppb. However, EPA has acknowledged that this criterion has substantial limitations in that: 1) the standard does not completely account for selenium bioaccumulation;* and 2) the criteria have not been derived to protect wildlife that are using selenium contaminated habitats.[16] Recent studies indicate that based on real-world data from nature, EPA's current 5 ppb threshold is set too high, and at a level that has been associated with short-term catastrophic impacts on sensitive fish and wildlife populations.[17]

Selenium in the Bay-Delta Ecosystem

Selenium poses one of the biggest water quality problems in the Bay-Delta watershed. Bay shellfish, fish, birds, and harbor seals have been shown to be contaminated by elevated selenium levels.[18] The State of California has issued health advisories warning pregnant women and children under 16 not to eat certain duck species because of elevated selenium levels, and advising everyone else to limit their consumption as well.[19]

While selenium is only one of many pollutants in agricultural drainage, it is of primary concern in California both because of the high levels found in portions of the San Joaquin Valley, and because of its proven toxicity, as illustrated by the Kesterson tragedy and elsewhere.[20]

Bay shellfish, fish, birds, and harbor seals have been shown to be contaminated by elevated selenium levels.

* Through bioaccumulation (uptake and retention of a chemical by an organism, regardless of exposure pathway) and possibly biomagnification (ingestion of contaminated food resulting in progressively higher concentrations at higher trophic levels), aquatic plants and animals can accumulate tissue concentrations of some drainage contaminants 100 to 10,000 times greater than those in the water. In the case of selenium, bioaccumulation and biomagnification can increase selenium levels more than 1,000 times from water levels to levels found in fish and wildlife. M.K. Saiki and T. P. Lowe, 1987. "Selenium in Aquatic Organisms from Subsurface Drainage," *Archives of Environmental Contamination and Toxicology* 16:657-670.

When irrigation water is applied to soils naturally high in selenium, selenium leaches out into the irrigation water, along with salts that are found in the soils. In portions of the San Joaquin Valley, layers of subsurface clay trap this salty irrigation water in crop root zones, which results in reduced crop yields, and, potentially, the death of entire crops. Some water districts in areas with such problems have constructed extensive systems to collect this salt and potentially selenium-laden subsurface drainage. Once collected, much of this drainage is dumped either directly or indirectly into the San Joaquin River, which flows into the Bay-Delta. While saving some crops, this form of disposal poses a threat to the aquatic ecosystem.

There are numerous sources of selenium in the Bay-Delta ecosystem, including agricultural return flows to the San Joaquin River, discharges from municipal sewage treatment facilities, industrial wastewater treatment facilities, hazardous waste sites, and oil refineries. The sources of the selenium vary by area in the Estuary, time of year, and water year type. Riverine sources -- particularly that of the San Joaquin River -- appear to be primary contributors during winter months when flows are high, while in-Bay sources such as oil refineries and sewage treatment plants are the major contributors when river discharges are low, because during these times the San Joaquin River flows are diverted for urban and agricultural uses before they reach San Francisco Bay.[21] Selenium loads increase dramatically when San Joaquin River flows do reach the Bay. Recent studies estimate that riverine sources and in-Bay sources each contribute 2500 kilos of selenium annually to the Estuary, although July through December, riverine sources contribute 70 percent of the loading.[22] The in-Bay sources are in a more toxic form, which is estimated to bioaccumulate 10 times more rapidly than the form found in riverine sources.[23]

Increasing freshwater flows may help limit the negative impacts of selenium in the ecosystem.

The toxicity of selenium may also be influenced by the amount of freshwater flowing through the system. A recent study of clams in the North Bay indicates that river inflow appears to influence bioavailable selenium concentrations, presumably by affecting residence times and dilution of local selenium inputs.[24] High inflows in May 1995, for example, coincided with the lowest concentrations of selenium in resident clams, while subsiding flows in October 1995 correlated to increased selenium concentrations. Thus, increasing freshwater flows may help limit the negative impacts of selenium in the ecosystem.

Based on concentrations of selenium observed in North Bay clams -- concentrations which "substantially exceeded values that convincingly reduce growth or cause reproductive damage when ingested by birds and fish" -- the authors of the study predict that selenium exposures of birds and fish dependent on the clams for food have probably dramatically increased since the late 1980s to levels likely to be of concern.[25] However, they note that no direct studies of selenium concentrations in these species have been conducted since 1990. The authors of the study hypothesize that one possible cause for the increase could be an increase in selenium discharges from refineries and in inputs from the San Joaquin River and western Central Valley.

Although selenium receives more attention than other water pollutants from agriculture, other pollutants are also of concern in the Bay-Delta ecosystem. The National Research Council formed a committee to design and evaluate a comprehensive research program on irrigation-induced water quality problems in the San Joaquin Valley. The committee found that:

Selenium is just one example of a trace element being concentrated as a consequence of irrigation practices. The toxic effects caused by selenium are only symptoms of the range of effects that can be caused by elevated salt concentrations. The underlying issue is clear: irrigation, like many other uses of water, degrades water quality for later users. The contaminants of concern and the severity of the impacts may vary, but the phenomenon of irrigation-induced water quality contamination can no longer be ignored.[26]

Pesticides

Pesticides are chemicals used to control insects (insecticides), weeds (herbicides) and diseases (fungicides). The vast majority of pesticides in use today are applied in agriculture to manage pests that threaten crop productivity and quality. Most pesticides are synthetically manufactured and do not occur in nature, though some are naturally-occurring, derived from plants or made from inorganic compounds such as copper salts and sulfur.

Eight-hundred and sixty pesticide active ingredients (the chemical registered to kill or control the pest) and 21,500 formulated pesticide products are registered for use by the EPA.[27] Pesticides are inherently toxic compounds -- risks to humans and the environment primarily depend on the relative toxicity of individual compounds. Most drinking water treatment facilities are not designed to remove pesticides from tap water.

Experimental and epidemiological studies demonstrate that pesticide exposure may pose a variety of health threats to humans including cancer, neurotoxicity, reproductive harm, birth defects and damage to the immune and endocrine systems.[28] These chemicals have been shown to cause cases of acute poisoning in farm workers.[29] Infants and children may be at special risk, and a recent study indicates that every day 1 million American children age 5 and under consume unsafe levels of a class of pesticides that can harm the developing brain and nervous system.[30] Environmental risks such as toxicity to beneficial insects, aquatic organisms, and birds are also well documented.[31]

Pesticide Contamination of the Bay-Delta Ecosystem

In 1995, over 198 million pounds of pesticides were used in California agriculture, representing roughly 94 percent of the total volume of pesticides used in the state.[32] Agricultural pesticide use in California increased approximately 31 percent between 1991 and 1995, while acreage in production remained constant.[33] Approximately 60 percent of reported pesticide use in California occurs in the San Joaquin Valley, where agricultural production is particularly intensive.[34]

In 1995, over 198 million pounds of pesticides were used in California agriculture.

Pesticide contamination throughout the Bay-Delta ecosystem is well documented.[35] A highly visible and dramatic repercussion of pesticide use in the Bay-Delta watershed occurred in July of 1991 when a train loaded with the pesticide metam-sodium derailed near the town of Dunsmuir. The accident spilled almost 20,000 gallons of the pesticide into the Sacramento River, killing one million fish and all aquatic life along a 40 mile stretch of the river.[36] This spill demonstrated the potential for pesticide contamination of surface water to cause serious damage to aquatic ecosystems. It is important to note that the quantity of pesticides released into the environment through routine use of agricultural pesticides is far greater than those dumped during the spill. Doses of pesticide residues resulting from routine use are generally smaller than those experienced after a large accident and thus the possible effects are more subtle and difficult to observe. This by no means decreases the dangers posed by everyday usage.

In 1995, over 22 million pounds of pesticides were applied within the Sacramento River watershed, and 119 million pounds in the San Joaquin River watershed.[37] Much of the Sacramento Valley is dedicated to rice production, and agricultural discharges from rice fields and other crops transport pesticides such as molinate, thiobencarb, carbofuran, and methyl parathion. Between 1980 and 1983, 7,000 to 30,000 common carp died per year in the Sacramento River as a result of molinate discharges to the river.[38] Since 1984, California regulatory agencies have developed management plans that require holding times for irrigation water. These have substantially reduced rice herbicide discharges and eliminated fish deaths due to such discharges.[39] However, follow-up tests and monitoring for rice herbicides in agricultural drains of the Sacramento River have found that residues of herbicides remain at levels of concern for aquatic organisms including larval striped bass and mysid shrimp despite these holding times.[40] Concentrations of molinate, thiobencarb, and carbofuran are still detectable in the Sacramento River, the Delta, and Suisun Bay.[41]

Organochlorine pesticides such as DDT are routinely detected in the Sacramento and San Joaquin rivers. Some organochlorine pesticides, including dicofol and endosulfan, remain in use throughout California's Sacramento and San Joaquin Valleys, while DDT and a number of other organochlorines have been banned for many years. A highly persistent class of chemicals, organochlorines are only slightly soluble in water, but their residues persist in soil and aquatic sediments and can concentrate in the tissues of aquatic organisms for years after they are applied. Some of the highest bed-sediment concentrations in the country of DDT, and its breakdown products DDD and DDE, have been found in the San Joaquin River.[42] Every fish sample collected by California's Toxics Substances Monitoring Program (TSMP) at the Vernalis Station on the San Joaquin River between 1978 and 1987 contained high levels of organochlorine pesticides, particularly DDT and toxaphene.[43] In 1994, edible fish species were sampled from thirteen locations throughout the Bay, and in a number of samples the concentrations of the organochlorine pesticides dieldrin, total chlordane, and total DDT exceeded EPA screening values for safe human consumption.[44] Organochlorine pesticide residues have also been found in Bay birds and marine mammals.[45]

Some of the highest bed-sediment concentrations in the country of DDT, and its breakdown products DDD and DDE, have been found in the San Joaquin River.

Organophosphate insecticides are also found in the Bay-Delta. While less persistent than the organochlorines, at high enough concentrations organophosphates can be acutely toxic to aquatic organisms. Testing by the Central Valley Water Quality Control Board along a 45-mile stretch of the San Joaquin River between 1991 and 1992 found that the organophosphate insecticides diazinon and parathion were the cause of high invertebrate mortality. Residues of these chemicals have been traced back to use in alfalfa fields and fruit and nut orchards.[46]

FARMING PRACTICES THAT PROTECT WATER QUALITY

Once water pollution has occurred it is difficult and expensive to clean up – thus, the most effective solution is to prevent this pollution before it occurs. The National Research Council has noted that, "preventing pollution by changing farming practices, rather than treating problems after they have occurred, should be the primary approach to solving water pollution problems caused by farming practices."[47] Water conservation and pesticide reduction are valuable tools for pollution prevention.

AGRICULTURAL WATER CONSERVATION

Water conservation can improve water quality by reducing the volume of surface runoff and subsurface drainage, by potentially reducing the pollutant loads of the remaining subsurface drainage, by allowing more efficient use of agricultural chemicals, and by limiting irrigation-induced erosion and sediment loads.

Water conservation, at the level of each farm, can be effective in reducing selenium contamination and other water quality problems in the San Joaquin River and in the Bay-Delta. According to a report by the Environmental Defense Fund, "There is no doubt that drainage discharges have caused and continue to cause significant damage to one of California's major river ecosystems, as well as to extensive portions of the Central Valley wetlands that are the backbone of the Pacific Flyway. There is also broad consensus that a principal part of the solution to this problem lies at the individual farm level."[48]

A study funded by the California Department of Water Resources and the State Water Resources Control Board was designed to evaluate whether the discharge of selenium and other toxic trace elements in drainage water could be reduced by improving on-farm irrigation practices and drainage management.[49] That study found that:

- Capturing and re-using tailwater and implementing better irrigation management practices such as precise irrigation scheduling reduces the volume of drainage.
- The total load of selenium and boron in drainage water is proportional to drainage flow. Reductions in drainage flow result in proportionate reductions in selenium and boron loads.
- Source control by improved irrigation management significantly reduces drainage flows that result from deep percolation.

Water conservation techniques can also reduce pesticide and fertilizer pollution.

Water conservation techniques can also reduce pesticide and fertilizer pollution by enabling more efficient application of agricultural chemicals, by reducing the volume of runoff and drainage, and by reducing irrigation-induced erosion, which may carry pesticides into adjacent water bodies. For example, the West Stanislaus Sediment Reduction Plan focuses largely on water conservation techniques, noting that irrigation-induced erosion is the main cause of nonpoint source sediment problems in the San Joaquin River, and that organochlorine pesticides, such as DDT, are adsorbed to the sediment carried by tailwater and transported into the San Joaquin River. The Sediment Reduction Plan notes that "on-farm conservation practices, singly and in combination, can be effective in reducing sediment loadings into the San Joaquin River and, from there, into the Delta."[50]

A precursor to the West Stanislaus Sediment Reduction Plan was a study done by the USDA Soil Conservation Service (now the Natural Resources Conservation Service) and the U.S. Navy to determine what amount of sediment is carried off of leased agricultural lands at the Crows Landing Naval Auxiliary Landing Field in Western Stanislaus County. This study sought also to determine the effectiveness of various best management practices in controlling off-site sediment and chemical movement. The study found that

> *The key practice in reaching the goal of decreased chemical and sediment movement is irrigation water management -- correctly managing the flow rate, total volume, and amount of time the irrigation water is applied. In other words, to effectively use the available water to meet the crops' water and nutritional needs while minimizing tailwater and runoff erosion. Positive results from this practice may include increased water distribution uniformity, better infiltration, decreased water and power use, greater chemical effectiveness, and the potential for an increase in crop yields.*[51]

Water conservation can have many other benefits in addition to improving water quality. For the environment, water conservation can leave more water in rivers, streams, and wetlands for fish and wildlife, and can reduce the number of fish killed directly by water diversions. The potential on-farm benefits of water conservation include increased crop yields and quality, and reduced production costs associated with water and energy use, as well as reduced pesticide and fertilizer applications.

Despite the numerous benefits of water conservation, such methods have not been universally embraced. While some innovative farmers have adopted these techniques, as illustrated in the next chapter, many have not.[52] In part this may be due to imperfect information and to perceived risks associated with adopting new technologies. Another major barrier is the price of water – it often is so heavily subsidized that it distorts the financial benefits of water conservation. The National Research Council has noted that "the most pervasive economic issue contributing to irrigation-related water quality problems and affecting the choice and success of solutions is the cost of water. The subsidized low cost of water results in more water being used, encourages farmers to cultivate less desirable lands, and leads to increased agricultural runoff."[53] Thus reducing water subsidies would encourage water conservation and improve water quality.

Some critics argue that increasing water prices will destroy the economic viability of western agriculture. There is ample evidence that this is not the case. As noted in a recent report by the Council for Agricultural Science and Technology, "Many strategies are available to growers attempting to adapt to the future. These strategies include altering the crop mix to emphasize high value fruits and vegetables; employing sophisticated technology and management schemes in managing water at the field level; and investing in research to develop improved crops, cultivation methods, and irrigation water management techniques."[54]

The report noted that "the energy crisis of the 1970s sharply increased the costs of pumped irrigation water in some regions. Growers responded by employing water conserving technologies and strategies and by substituting capital and labor for energy."[55] A similar response can be seen to shortages and corresponding price increases for water. For example, during California's 1987-1992 drought, there was a 12 percent decrease in irrigated acreage, but the value of California produced food and fiber increased by over 34 percent over the same period, "as growers abandoned marginal land, employed the most modern irrigation technologies, and switched to higher-value crops."[56]

There is widespread agreement that growing demands on scarce water resources are likely to lead to rising water prices in the future. The techniques described in this report can help agriculture adapt to those higher costs.

Water Conservation Techniques

Techniques available to improve irrigation efficiency are numerous, and new techniques are constantly emerging and improving. Some of these techniques apply to the delivery system through which a district delivers water to its customers, while others are techniques that individual farmers can apply. Some of the technologies that have been found to be effective in reducing water use include the following:[57]

- Soil moisture monitoring involves using any of a variety of technologies, including a basic hand probe/feel method to monitor soil moisture and to use that information to determine more accurately when crops need to be irrigated. Soil moisture monitoring technologies include:
  - ⇒ tensiometers – a device made of a porous ceramic tip which is inserted into the soil and capped at the ground surface with a vacuum gauge which registers soil water tension;
  - ⇒ neutron probes – a moisture monitoring tool that uses atomic particles to register soil moisture;
  - ⇒ gypsum blocks – a tool made from electrodes embedded in plaster of paris. Blocks are buried in the ground, allowing electrical resistance to be read at the surface and related to soil moisture content; and
  - ⇒ infrared thermometry.
- California Irrigation Management Information System (CIMIS) is an integrated network of more than 85 computerized weather stations located throughout California. Weather data including temperature, humidity, and wind strength and direction are collected from each station and transmitted via satellite to a central computer in Sacramento. The computer then uses this data to estimate

evapotranspiration (ET) for a reference crop, which can be used by farmers to calculate their crop's ET and determine how much water to apply.

- Canal automation allows water deliveries to start and stop on demand, reducing operational spills and losses, and facilitating implementation of precise irrigation scheduling.
- Tailwater recovery/reuse captures field runoff in pits dug in low-lying areas of the farm and recirculates the water to the top of the field.
- Micro-irrigation allows the farmer to deliver just the right amount of water needed by the plant with a very low flow of water. Micro-irrigation techniques include drip, subsurface drip, bubbler, and micro-spray technologies, which all operate on the same concept of providing water directly where it is needed.
- Surge flow delivers water to irrigation furrows in timed releases. After a surge the soil forms a water seal permitting the next surge of water to travel further down the furrow. This technique reduces the time needed for irrigation water to be distributed the full length of the field, reducing deep percolation and resulting in higher water use efficiency.
- Laser leveling adjusts earth-moving machinery in the field to remove high spots and fill low spots so there is little variation in the field contour. As a result, larger fields of a uniformly low grade can be irrigated with less water.
- Low Energy Precision Application (LEPA) is an adaptation of the traditional center pivot sprinkler system. In a center-pivot system, a pipeline is suspended above the field on a row of mobile towers. LEPA systems, however, use tubes extending down from the pipeline to deliver water at a low pressure to locations where the plant can use it most efficiently. Unlike a center-pivot system, in which water is delivered from a solid-set sprinkler placed above the machinery frame, the LEPA system includes a series of "spinners" – sprinklers that throw water out in a spinning motion – fed from pipes dropped from an overhead line and emitting water close to the ground, which cuts water loss from evaporation and wind and increases application uniformity.
- Limited irrigation/dryland farming irrigates only the upper end of the field leaving the lower end of the field solely dependent on rainfall. This technique minimizes or eliminates field runoff and reduces deep percolation and evaporative losses.
- Gated pipes supply water through a series of openings in a supply pipe. This system has been improved to allow irrigators more control over timing and quantity of water flows.
- Canal lining can reduce water seepage, particularly if soils are sandy or porous.

PESTICIDE USE REDUCTION

Alternative pest management practices can minimize pesticide contamination of the Bay-Delta ecosystem. Reductions in pesticide use can be achieved by decreasing the rate of application (volume of active ingredient applied per acre), the frequency of applications and the percent of acres treated. Volume, on its own, however is an inadequate measure of pollution prevention because it does not account for pesticide toxicity. It is quite possible, for example, to reduce the volume of a relatively harmless compound and replace it with a more toxic pesticide applied at a much lower rate. Such a change would serve no purpose.

D-039802

An over-reliance on pesticides, contrary to what might be expected, may be counterproductive and may make crops *more* susceptible to pest damage. Pesticide resistance is a growing problem that often requires farmers to utilize increasingly toxic substances. As recent article in *California Farmer* noted: "A system that relies too heavily on broad spectrum pesticides may have contributed to last season's insect problems in San Joaquin Valley cotton farms."[58]

An over-reliance on pesticides, contrary to what might be expected, may be counterproductive and may make crops more susceptible to pest damage.

Many alternative pest management techniques are designed to prevent conditions that encourage pest problems – stopping the problem before it arises – thereby eliminating the need for chemical intervention. The farmers profiled in this report have accomplished reductions in volume without switching to more toxic compounds and, moreover, have adopted practices that reduce their reliance on pesticides.

Alternative farming practices have the potential both to reduce pesticide use and sustain profitability.[59] Based on our observations, farmers who have successfully reduced their reliance on pesticides follow a number of important principles: first, they take advantage of and enhance biological relationships and natural processes that exist on their farms, including the ability of naturally occurring predators and parasites to control unwanted pests. Second, they utilize management skills and information to reduce costs, improve efficiency and maintain production. Third, they emphasize crop diversity, which provides them with greater flexibility and stability in coping with environmental and economic hardships.

Alternative farming practices can improve water quality in the Bay-Delta by reducing the need for pesticides and the volume of pesticides used. Widespread adoption of alternative practices is currently hindered, however, by a variety of barriers. These include inadequate funding of alternative agricultural research and extension efforts, farm policies that penalize crop rotations and other beneficial practices, and marketing standards that specify cosmetic criteria for fruits and vegetables that can only be attained with the use of pesticides.

Pesticide Reduction Techniques

Techniques for reducing synthetic pesticide use and reliance in agriculture include the following:

- Integrated Pest Management (IPM) is an ecologically-based approach to pest management developed in response to pesticide resistance and secondary pest outbreaks. IPM integrates all available pest control tactics and relies on the use of economic thresholds designed to keep pest populations below a given level at which damage is expected to cause losses in yields or profits. Combined with the use of monitoring for pests and natural enemies, economic thresholds help farmers decide if and when treatment of a pest problem is necessary.
- Crop rotation is accomplished by successively growing different crops in the same field. In addition to breaking the reproductive cycle of numerous pests, crop rotations can increase organic matter and water-holding capacity of soil.
- Cover cropping involves planting legumes and/or grasses planted between annual crop plantings or as part of a perennial orchard or vineyard. Such crops provide a source of nitrogen, attract and harbor beneficial insects, and increase soil tilth, water retention, and organic matter.
- Biological control introduces and enhances natural enemy populations to control pests.

D-039803

- Biopesticides are pesticides of natural origin or that are nature-identical, including bacteria, viruses, fungi, nematodes, microbially-produced toxins (e.g., "B.t."), behavior-modifying chemicals (e.g., pheromones), and botanical insecticides.

CASE STUDIES

This chapter presents case studies of California farmers and their on-the-ground methods of reducing water and pesticide use. The case studies include a wide spectrum of farms: farm size ranges from 150 to 11,000 acres; crops include both annual and perennial crops. A number of the farmers grow some or all of their acreage organically. Not every farmer both reduces pesticide use and conserves water, and not all of their farming practices are environmentally benign, but many have found that water conservation and pesticide use reduction are very compatible goals, and that these goals are consistent with a profitable farming operation.

Many have found that water conservation and pesticide use reduction are very compatible goals, and that these goals are consistent with a profitable farming operation.

While improving water quality and other environmental benefits is a motivating factor for many of the farmers, for others it is just an added benefit of trying to reduce costs, improve yields, or stretch reduced water supplies.

These case studies are not exhaustive, nor is every technique presented here appropriate for all farms. Before adopting any new practice a farmer must adapt it to local conditions, including soil type, water quality, pest pressures, and cropping sequences. The key to success is in implementing the right techniques for the particular crop and location. These case studies serve to show a range of techniques available to farmers for reducing water and pesticide use, while retaining or improving economic viability.

Reported reductions in pesticide and water use were provided by farmers. NRDC did not calculate these reductions, but instead relied upon growers' calculations of reductions in the volume of water and pesticide use.

A WHOLE FARM APPROACH TO WATER QUALITY

WEST STANISLAUS HYDROLOGIC UNIT AREA PROGRAM STANISLAUS COUNTY

The West Stanislaus Hydrologic Unit Area (HUA), a special study area set up by the U.S. Department of Agriculture, includes 200 square miles of irrigated fields and orchards in western Stanislaus County. Until recently, the area lost as much as a million tons of sediment to the San Joaquin River each year, much of that sediment laced with organochlorine pesticide residues, including DDT. Facing the possibility of regulatory intervention by the State Water Resources Control Board if this problem was not addressed, the West Stanislaus Resource Conservation District (RCD) began a voluntary sediment reduction program, and has achieved significant water savings in the process.

Cumulatively, the program has saved over 32,000 acre-feet of water and has prevented over 718,950 tons of sediment from entering the impaired San Joaquin River.

In 1991, the West Stanislaus area was selected to receive special USDA funds for accelerated assistance for water quality improvements. The West Stanislaus RCD and the USDA's Natural Resource Conservation Service (NRCS) (formerly the Soil Conservation Service) developed a sediment reduction plan as part of the authority granted to the USDA by the Watershed Protection and Flood Prevention Act to provide planning assistance to federal, state, or local agencies. As a first step, the USDA brought in a sociologist to identify cultural barriers to changing farm management practices. According to District Conservationist, Mike McElhiney, despite his initial skepticism about the need for a sociologist, input from this investigation, such as the necessity of better alerting farmers to the severity of the sediment problem and of adopting a coordinated resource approach, was instrumental in developing the program.

The HUA program includes: 1) information and education; 2) cost-sharing assistance; 3) technical assistance; and 4) monitoring and evaluation. Growers who wish to qualify for cost-sharing develop a contract in cooperation with the RCD, and agree to implement a comprehensive set of measures specified in the contract. The technical assistance has included an active Mobile Irrigation Lab program which has been funded by the local irrigation districts and irrigation system manufacturers since the state reduced funding for its mobile irrigation lab program.

The program has received a high level of interest, thanks in part to strong support by community leaders, including an active RCD Board of Directors. The University of California Cooperative Extension has also played a key role in conducting applied research and outreach. According to Mike McElhiney, program participation was also catalyzed by water price increases during the 1987-92 drought.

As a direct result of the program, irrigation efficiency improvements have reduced water use by 18 percent, saving over 12,000 acre-feet per year and improved average irrigation efficiency from 56 percent to 80 percent. Cumulatively, the program has saved over 32,000 acre-feet of water and has prevented over 718,950 tons of sediment from entering the impaired San Joaquin River.

The program has recently undergone some changes as a result of the 1996 Farm Bill. In 1997, the USDA allocated over $354,000 for on-farm water conservation and water quality projects in the West Stanislaus HUA, which now includes portions of Merced and San Joaquin Counties. The funds will be used for incentive payments and for cost-sharing of up to 75 percent of the cost of approved measures, up to $10,000 per year, and up to $50,000 during the life of the 5 to 10 year contract between the farmer and the USDA. The Funds were authorized as a result of the 1996 Farm Bill's Environmental Quality Incentives Program (EQIP). Some of the conservation practices eligible for cost-share assistance include:

- critical area planting
- sediment basins
- tailwater return systems
- vegetative filter strips
- field borders
- cover crops
- irrigation systems
- pumping plant for water control
- concrete ditch lining
- waste storage facilities
- waste storage ponds
- windbreak establishment
- fencing off riparian areas
- wetlands development
- wetlands restoration
- nutrient management
- pest management

According to Mike McElhiney, the program adopts a "whole farm" approach, and looks at all the resource issues in an integrated fashion. All conservation plans developed under the program include both irrigation water management and pest management elements. This year, Mike hopes the program will include conversion of floodplain land from cropland to wetlands in order to form a buffer strip to filter sediment and pesticides before they enter the San Joaquin River as seepage or tailwater.

The program adopts a "whole farm" approach, and looks at all the resource issues in an integrated fashion.

The following are examples of farmers that have been involved in the HUA program.

ART FILICE, JR.
FILICE FARMS
PATTERSON, CALIFORNIA
STANISLAUS COUNTY

⇒ *150 acres of apricots, apples, and beans*
⇒ *Water use reduced 40-50 percent*
⇒ *Synthetic fertilizer reduced 25 percent*

Art Filice, Jr. owns six acres, and farms approximately 150 acres. He farms mostly apricots, along with apples and beans. Art has been farming for 20 years, and his family has been farming for close to 40 years.

Filice Farms receives water from the Patterson Water District (PWD), a contractor with the federal Central Valley Project (CVP). Water is delivered through cement canals pumped onto the field. PWD charges $30 per acre-foot, and requires customers to pay for at least two acre-feet per acre regardless of use. Water is measured through weirs in the canal laterals, although Art admits the measuring devices are in need of repair. Art also has access to groundwater, which costs approximately $27-$30 per acre-foot to pump.

As one of the HUA program participants, Art has converted 48 acres of orchards from furrow irrigation to sprinkler irrigation. He knew that he was using too much water with furrow irrigation, and in fact previously had to plant different root stocks at the ends of his fields because he knew those trees would sit in water. The sprinklers allow for more uniform irrigation and reduced Art's water use by almost 50 percent, from 4-5 acre-feet per acre to 2½ -3 acre-feet per acre. Art also noted that he has achieved significant savings in labor costs with the sprinkler system. Finally, Art believes that his new system is better for the trees and will keep them healthier, most likely extending their productive life. Specifically, with a furrow system farmers must cease irrigation 10 days prior to harvest in order to allow the ground sufficient time to dry and harden so that harvesting machinery can be brought into the fields. Sprinklers enable farmers to keep watering right up to harvest, which is better for the trees and produces a better quality crop.

Art installed the sprinkler system himself in approximately four weeks, and estimates that the system will pay for itself in six to eight years. He received $10,500 in financial assistance from the HUA program to help pay for the system, and also received technical support.

Art also installed drip irrigation on six acres of land that were not level. He runs the drip system on a 5 horsepower submersible pump, which he can run during off-peak hours to save on energy costs. He found that installing a drip system was a less expensive alternative then contouring the land, and is also able to apply fertilizer directly through the drip system, which reduces the amount he needs to apply, and provides a uniform application.

In addition to financial assistance from the HUA, Art took advantage of the Mobile Irrigation Lab system that HUA makes available free of charge to farmers in the area. The Mobile Irrigation Lab provides an irrigation evaluation, testing irrigation and pumping systems, determining irrigation efficiency and offering recommendations for improvements. Surveys can determine water use and efficiency, distribution uniformity, analysis of tailwater sediments, and equipment performance checks. Art highly recommends the Mobile Lab service to all farmers, noting " its always good to know how well you're doing, and with the lab you find that out in numbers, and with scientific analysis."

GEORGE KLOPPING
DEL PUERTO FARM
PATTERSON, CALIFORNIA
STANISLAUS COUNTY

⇒ *1800 acres of walnuts, apples, apricots, mixed row crops*

⇒ *Pre-irrigation water use reduced 50 percent; main irrigation season water use reduced 30 percent*

⇒ *Pesticide use reduced 60 percent on apricots, apples, and some walnut orchards*

George Klopping farms 1800 acres of land, all owned by Patterson Frozen Foods. He grows 300 acres of walnuts, 120 acres of apricots and apples. In the winter he also grows spinach, wheat and peas, and in the summer dry beans, lima beans, tomatoes, and alfalfa.

George gets his surface water from the West Stanislaus Irrigation District, and also has five wells. To supplement surface water supplies he also reuses water from Patterson Frozen Foods. This water is pumped from the cannery to ponds several miles out side of town. In the ponds the water is aerated to remove odors and reduce biological oxygen demand (BOD), and it is held there for delivery to cropland. The cost of his surface water is approximately $41 per acre-foot, with groundwater costs at about $30 per acre-foot. The district charges farmers for a minimum of two acre-feet per acre, even if the land is fallowed, a rate structure which can discourage conservation.

George now pre-irrigates some crops with sprinklers, which saves 50 percent of the water he used when pre-irrigating with furrow irrigation. Switching to sprinklers and microsprinklers from furrow irrigation produced a better crop, and was easier to do, once he learned the system. He admits that when he first saw other farmers using sprinklers 35 years ago he thought it would never work, but that he has been proven wrong.

When he first saw other farmers using sprinklers 35 years ago he thought it would never work.

George has also added a polymer, polyacylamide (PAM), to his irrigation water to help the water infiltrate rather than runoff the field. A mobile lab found that prior to his use of the polymer, runoff could be as high as 50-60 percent because water would form a seal over the soil pores. By using PAM, infiltration has increased by 15-40 percent, significantly reducing water use and tailwater runoff.

As another sediment reduction measure, George has constructed several sediment basins to catch tailwater coming off the end of his fields. The water is held until the sediment settles out, and then recirculated onto the field or sent to the river free of silts. Every two to four years the sediment in the basin is sent back to the field. According to NRCS staff, the tailwater return system has reduced water diversions by approximately 30 percent.

George believes that the key to the success of the HUA program is the cost-sharing assistance, as well as the active involvement of the RCD in getting word out to farmers. He pointed out that farmers learn from each other, and that if a few farmers are successful at a practice, others will soon be trying it too. He noted that if he were to move to a new area, "I'd watch the best farmer in the area, and would do whatever he did."

George has also reduced his pesticide use by experimenting with the use of pheromones, naturally-occurring chemicals emitted by female insects to attract male insects. George places dispensers treated with pheromones throughout the orchard. This has the effect of confusing male moths such that they cannot find female moths. On his apricots he uses pheromones for protection against the peach twig bore, and on his apples and walnuts he uses pheromones for protection against the codling moth. George now uses one winter spray of the insecticide asana, and pheromones during the spring and summer to disrupt the mating patterns of the pests, thus eliminating a summer spray of diazinon or asana. Similarly, where he used to spray guthion every 27 days on his walnuts and apples to protect against the codling moth, he now uses pheromones, and only sprays with guthion once during the season. He finds that pheromones are more expensive, but that it is easier to send people back into the fields after using pheromones because there is no re-entry wait, thus a more timely thinning, irrigation, and harvest is possible. He also noted that using pheromones is preferable if you have close neighbors, so that they are not exposed to the toxicity of the sprays.

JOE RUBINO
VERNALIS FARMS
VERNALIS, CALIFORNIA
STANISLAUS COUNTY

⇒ *130 acres of apricots*
⇒ *Synthetic fertilizer use reduced 100 percent*
⇒ *Synthetic pesticide use reduced 75 percent*
⇒ *Water use reduced 50 percent*

The Rubino family has operated Vernalis Farms since the mid-1960s. They receive water from Del Puerto Water District, through a metered delivery pipeline from the CVP Canal. The Rubinos also have access to groundwater supplies which, at $40 per acre-foot, cost the same as surface supplies.

Joe Rubino was one of the first participants in the HUA cost-share program. In 1993, Joe worked with the HUA to develop a total resource management plan for his farm. The main goal of the plan was to eliminate pesticides and sediment from his drain water by eliminating runoff. In 1993 and 1994, Joe installed a subsurface mainline and a solid set sprinkler system on 130 acres of apricots, funded in part by a $10,500 grant from the HUA cost-sharing program. Prior to the HUA program, Joe had considered installing a sprinkler systems but had been put off by the cost. "Now," he says, "I'm not sure why, because the economic gains have been tremendous." [60]

"My experience is that a system pays for itself within two to three years, and that's a good investment."

Regarding the cost of the system, Joe said, "I had read all of the papers from the University on projected paybacks, and I would have to say that their figures were very conservative. My experience is that a system pays for itself within two to three years, and that's a good investment. Plus, there are just so many benefits."[61]

Joe has also improved his irrigation scheduling with use of gypsum blocks to measure soil moisture content, and with use of data from the California Irrigation Management Information System (CIMIS). The new system has successfully eliminated *all* runoff from Joe's orchards, and has resulted in savings of one acre-foot per acre in 1993, and two acre-feet per acre in 1994 through 1996. Total water savings since 1993 are 615 acre feet. At $40 per acre-foot this has produced a cumulative savings on water costs of almost $25,000.

Also, as part of the Total Resource Management plan, Joe planted a permanent cover crop on the orchard floor to improve permeability of the soil and reduce runoff and sedimentation. Joe planted a mix of legumes and other nitrogen fixing plants, and as a result no longer uses commercial fertilizer. Soil analysis has documented that his plants are receiving sufficient nutrients via the cover crop method. The cover crop has also increased habitat for beneficial insects, greatly decreasing his volume of pesticide application. Since 1995, Joe has used only one dormant spray of *Bacillus thuriengensis* (B.t.), a naturally-occurring bacteria that contain a toxin in their spores which poisons moth larvae, but is harmless to humans, beneficial insects, and wildlife. Joe also applied fungicides in 1995 and 1997 because of excessive rains at blossom time.

The sprinkler system and the cover crops, Joe says, have dramatically improved the soil condition, infiltration and irrigation efficiency, decreased labor cost and associated mechanical costs, and essentially eliminated sediment runoff. He estimates that his irrigation efficiency has improved by 50 percent. Joe also finds the system simple to run and less labor intensive than furrow irrigation. Instead of the three people Joe needed when he furrow irrigated, the sprinkler system can be operated by one person.

NORMAN CROW
J&N CROW FARMS
CROWS LANDING, CALIFORNIA
STANISLAUS COUNTY

⇒ *242 acres of row crops and walnuts*
⇒ *Water use reduced by 30 percent*

Norman Crow's great-great grandfather came west from Missouri to start farming in the San Joaquin Valley. A fourth generation farmer and current Chairman of the West Stanislaus Resource Conservation District, Norman is committed to doing whatever it takes to reduce the loss of topsoil from his farm, and has been a community leader on this issue.

The Central California Irrigation District delivers water to J&N Crow Farms through a pipeline. The Crow Farms also have access to groundwater supplies.

In 1993, Norman developed a total resource management plan in cooperation with the USDA and the NRCS field office staff since which time he has made continual improvements in irrigation water management and sediment reduction. His initial actions under this plan were to laser-level 77.5 acres of his land in order to reduce slope and regrade drainage, and to construct two large sediment basins in order to contain sediment leaving his farm. In 1994, he established a minimum till system in his orchards, planting cover crops to reduce runoff during the rainy season and improve soil permeability during irrigation season. In 1995, he installed 3900 linear feet of subsurface mainline to eliminate open earthen ditches, reducing seepage and evaporation losses. In 1996, he added 1520 linear feet to this system.

As a result of these actions, he has reduced the load of sediment shed by his land by 7048 tons, virtually eliminating nonpoint source pollution from his farm into the impaired San Joaquin River. The technique of laser leveling reduced his water use by 14 inches per acre on those lands, while the subsurface mainline reduced water use an additional four inches per acre.

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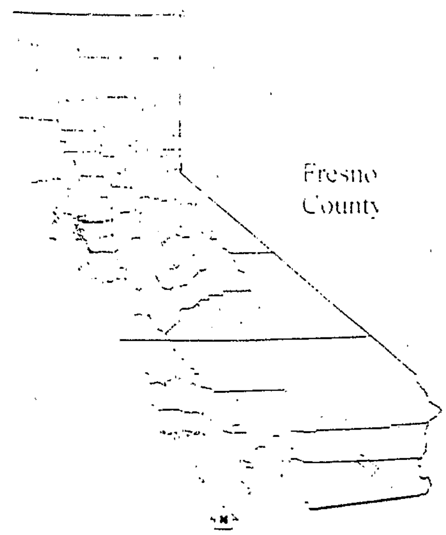


USING COMPOST TO REVITALIZE THE SOIL

JOHN TEXIERA
TRECHO FARMS
LOS BANOS, CALIFORNIA
FRESNO COUNTY

⇒ *450 acres of fresh market tomatoes, processing tomatoes, melons, and cotton*
⇒ *Herbicide use reduced 30 percent*
⇒ *Synthetic fertilizer use reduced 25 percent*
⇒ *Water use reduced 50 percent*

John Texiera farms on the west side of California's Central Valley -- an arid, barren part of the state that is best described as a desert. Soil in this region is high in salts and low in organic matter, inducing most of its farmers to use elevated levels of synthetic fertilizers and pesticides. John, a third generation farmer, emanates enthusiasm for his business. He has a vision and a plan for rebuilding soil fertility and reducing use of chemicals and water.

Most of John's acreage is devoted to growing tomatoes to be sold on the fresh market or for processing. Twelve percent of his fresh market tomatoes are grown organically and 20 percent of his processing tomatoes are grown organically. After two years of tomatoes, he rotates with either melons or cotton in order to break the reproductive cycle of crop-specific pests.

Irrigation

John's operation is distinguished from his neighbors in that for the past eight years he has utilized subsurface drip irrigation equipment. Although it took him at least a year to get the drip system working efficiently, the system has reduced water use by as much as 50 percent (from 32 inches per acre when using a more traditional furrow system to 16 inches per acre under the new drip system). John also adds his synthetic nitrogen fertilizer directly to the irrigation water in a process called "fertigation." Because the fertilizer is applied directly beneath plant roots, he has been able to reduce its use 25 percent. This system's drip tubing has the added advantage of keeping water away from weeds that grow between the tomato beds, reducing the need for herbicides.

Soil Fertility

Another distinguishing feature of John's approach to farming is his extensive soil-building program. On just 14 acres of land he manufactures 7,500 tons of compost. The compost is derived from cotton gin trash, woody parts of the cotton plant leftover from harvest that would otherwise be considered waste. The trash is donated by a local gin and laid out in fields in long piles about three feet high. The key to creating compost is the right mixture of water and oxygen: each pile is periodically sprayed with water and stirred with a specialized machine for 90 to 120 days before it is ready to be applied to the field. John claims that residues of pesticides and other contaminants remaining in the cotton gin trash are removed by the intense heat (up to 140° F) created by microorganisms inside a compost pile. Thus, John's compost takes trash from a cotton plant and turns it into fertile soil.

"Most fo. . s think, the soil out here is dead but I've seen it come alive."

Compost provides a number of benefits to soil including the addition of organic matter and humus which increase the soil's water-holding capacity. A typical amount of organic matter for California soils is between 1 and 1.5 percent. Such soils hold approximately 35 to 20 pounds of water. When the organic matter content is raised to 4 or 5 percent, soils can retain as much as 165 to 195 pounds of water. John has seen the addition of compost increase his organic matter from 0.9 to 1.2 percent in just 10 months. For John, getting into the business of using compost has made farming fun again. As he says, "Most folks think the soil out here is dead but I've seen it come alive."

That is why John has rarely ever used a pre-plant fumigant and has now completely eliminated the use of pre-emergent herbicides. These broad-spectrum chemicals destroy both harmful and beneficial microorganisms in the soil and thus are incompatible with compost applications which are designed to enhance production of beneficial microorganisms in the soil. Although John still uses on-the-spot "contact" herbicides like Roundup on an as-needed basis, using compost and sub-surface drip tubing has enabled him to reduce total herbicide application by 30 percent or more.

In his organic acreage, John relies heavily on the nutrients provided by compost, manure, and other soil-building measures. For insect control he uses organically-approved soaps and pyrethrum-based insecticides. He manages spring time diseases such as blight with copper-based fungicides and incorporates hand-hoeing for weed control. This year John hopes to reduce synthetic insecticide use even further by trying a new insecticidal product made from garlic on his conventional acreage.

Economic Issues

John's production costs for his organic tomatoes are higher than those of his low-chemical-input operation. For example, hand-hoeing is more expensive than herbicide use. But John receives a premium price for his organic tomatoes: his processing tomatoes receive roughly 20 percent more than other tomatoes. Although his fresh market tomatoes also receive a premium price, John is concerned that this will not last as more and more growers get into the organic business. Over time he expects competition to drive the price down.

Although John uses compost at Trecho Farms, these lands are his only under lease, and thus he so he is not inclined to invest as heavily in building soils that he may lose. He is, however, using extensive compost applications on a farming operation that he owns with his brothers. Located in Merced county, Texiera and Sons grow fresh market tomatoes, cotton, alfalfa and grains.

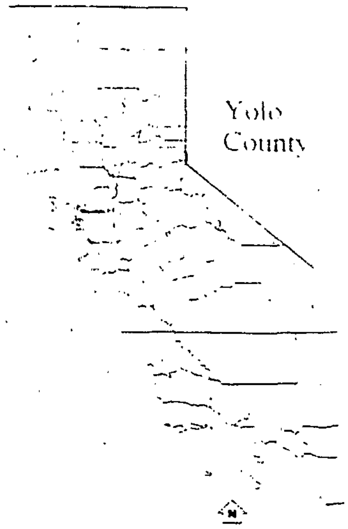
Challenges and Recommendations

"Reducing chemical inputs and water use in my part of the state requires investing in soil health and expensive irrigation equipment. That's not an easy thing to do if you've got a short term lease," says John. Farmers experience the benefits of building balanced soils only in the long term: the addition of compost builds organic matter content over a number of years; installation of sub-surface irrigation equipment requires an initial capital investment that is paid back over time. As John sees it, the issue of land ownership is a major barrier for farmers. As noted above, John has had to limit his use of compost at Trecho Farms because he rents the land on a short term lease. Like many farmers in the area, he is never sure how long he will be able to keep the land in production before he loses the lease. Thus John uses far more compost at a neighboring 3,500 acre ranch which he and his brothers partially own and have on a long term lease.

His advice to other farmers who want to reduce their use of chemicals is to start slowly and cautiously and learn from other farmers. He notes however, that this requires, "getting out from behind the windshield and into the fields."

Table 1: Comparison of Texiera's Conventional, Low Input, and Organic Pest Management Practices for Tomatoes

	Conventional	Low-Input	Organic
Weeds	Preemergent herbicide application such as Treflan; contact herbicides used on an as-needed basis.	Sub-surface drip irrigation; plastic mulch around plants; hand-weeding later in the season on an as-needed basis.	Plastic mulch, hand-weeding, sub-surface drip irrigation.
Insects	Two sprays of an organophosphate for aphids (fresh market tomato) and 1-2 sprays for stinkbugs (processing tomatoes).	Two sprays of an organophosphate for aphid control in fresh market tomatoes and 1 spray for stink bug control in processing tomatoes; trying garlic-based insecticide.	Several applications of Safer's soap and pyrethrum.
Diseases	Copper (Cocide) for blight, fungicides such chlorothalonil on late season tomatoes.	Several fungicide sprays for late season diseases.	Sulfur and copper-based fungicides used for blight and molds.
Soil Management	Synthetic nitrogen fertilizer.	Composted gin trash applied -- between 2-10 tons an acre; additional soil amendments including chilean nitrate, guano; synthetic nitrogen fertilizer applied through drip tubing; weekly monitoring of petioles to determine plant nutrient needs.	Compost, manure, other soil amendments.



BUILDING BIODIVERSITY ON THE FARM

JIM AND DEBORAH DURST
ESPARTO, CALIFORNIA
YOLO COUNTY

⇒ *625 acres of organic vegetables*
⇒ *Synthetic pesticide use reduced 100 percent*
⇒ *Synthetic fertilizer use reduced 100 percent*

Jim and Deborah Durst are very successful organic vegetable growers who have mastered the art of creating biological diversity on their farm. Their production system has evolved through years of experimentation and thus provides valuable information on how to reduce pesticide use in row crop production.

The Dursts started farming in 1980, growing grains and beans with conventional methods including the use of synthetic pesticides and fertilizers. After eight years of barely making a profit, the Dursts decided to try their hand at growing and marketing organic vegetables. Within two years they were offered a contract to produce 60 acres of organic processing tomatoes with Muir Glen, a tomato canning company specializing in organic processing and marketing.

Today the Dursts farm 120-150 acres of organic processing tomatoes in addition to numerous fresh market vegetables including cucumbers, melons, winter squash and more than 15 varieties of specialty fresh market tomatoes.

Crop Rotation

"Your best trump card as an organic grower is biodiversity."

The Dursts have built their organic production system around the guiding principle of creating biological diversity. Not only does this assist them in managing pests and building soil quality but a diversity of crops enhances their economic stability by spreading the risks of production over a greater number of crops. As Jim says, "Your best trump card as an organic grower is biodiversity."

The Dursts create biological diversity by planting and rotating a wide variety of cash crops and by planting cover crops. Crop rotations recycle nutrients in the soil, break the reproductive cycle of pests and help balance the accumulation and decomposition of soil organic matter. An aerial picture of the Durst's farm would capture a colorful patchwork of crop varieties. The Dursts rotation strategy is to plant any given vegetable once every three years. In alternate years, they grow a legume crop such as alfalfa or dry beans.

Cover crops return organic matter to soils, promote soil structure and stimulate microbial activity which makes nutrients available to succeeding crops. Depending on the condition of particular fields and the cropping system planned, the Dursts like to plant either a cover crop of Sudangrass in the summer and disc it into the soil in the fall, or a winter legume cover crop such as vetch in the fall to disc into the soil in the spring. Using a three year rotation and planting cover crops can have numerous benefits for pest management and soil health.

Pest Management

In the Sacramento Valley, a number of pests can present problems for tomato production, including stink bugs and tomato fruitworms. The Dursts prefer to scout their own fields for potential pest problems and do not contract with a private pest management consultant. "We often participate in studies being conducted by the Bio-Integral Resource Center and the University of California and this gives us quite a lot of contact with researchers who are knowledgeable about pest problems," says Jim.

Relatively few materials are approved for use in organic production that effectively treat pest problems once they have manifested. Thus the Dursts pay close attention to conditions in fields that have a history of pest problems, and have developed methods for preventing most pest outbreaks. The most important preventive technique is to rotate crops and break the reproductive cycle of pests that thrive in monoculture. The Dursts have also found that by growing a variety of crops at the same time, they can provide a more diverse habitat to attract populations of natural enemies. "If you're going to grow vegetables organically, you've got to stay away from monocropping and make sure always to have something growing that flowers and provides nectar for beneficial insects," says Jim.

The Dursts deal with the worst pest of tomatoes, the tomato fruitworm, by transplanting or direct seeding plants early in the season to avoid higher population levels later in the season. When necessary, they treat with insecticides approved for use in organic production, including B.t., insecticidal soaps and the botanical insecticide pyrethrum. "Pests such as the cucumber beetle are extremely persistent in annual vegetable crops and often appear in cycles. We always plant a few extra melons and squash as an insurance measure against potential losses," says Jim.

Disease and Weed Management

Synthetic herbicides cannot be used in organic production, so the Dursts integrate a number of non-chemical weed control techniques. Pre-irrigation is used where possible to germinate surface weed seeds. Before planting, crop beds are mechanically cultivated. After planting, weeds are largely managed by mechanical cultivations combined with hand hoeing. The Dursts usually cultivate three to seven times per season depending on the crop, and use hand-hoeing approximately three times throughout the growing season. During the winter, when cultivation is not possible, the Dursts use a propane-based flame weeder that assists in weed control. The high temperatures generated by the flame weeder desiccate rather than burn weeds.

Planting crops in rotation and using cover crops also helps reduce weed seed populations in the soil. Jim has also found that using alfalfa in rotation helps reduce perennial weeds.

Diseases that affect the crops of processing tomato growers in the Sacramento Valley include phytophthora root rot, vascular wilts caused by the fungi Fusarium and Verticillium, powdery mildew and bacterial speck. The Dursts plant resistant tomato cultivars and make sure to minimize conditions in the field such as poor drainage that may create a favorable environment for plant diseases. If necessary, such as during a cool, wet spring, the Dursts apply sulfur dust to control powdery mildew and copper hydroxide to control bacterial speck.

Soil Fertility

Soil fertility is an important but often overlooked aspect of pest control.

Soil fertility is an important but often overlooked aspect of pest control. The Dursts strongly believe that plants grown in balanced fertile soils are more likely to be healthy and able to withstand pest pressure, thus they invest considerable time and resources maintaining fertile soils. "One of our greatest challenges as organic growers, since we do not use synthetic fertilizers, is to create fertile and healthy soils. It requires constant attention," says Jim.

Cover crops are key to this endeavor because when they are incorporated into the soil they add nutrients and organic matter. Nitrogen is important to plant growth. Legume crops fix atmospheric nitrogen in nodules at their roots and when incorporated into soil can improve soil nutrient levels. However, when a cover crop is first incorporated into the soil in the spring, microbes in the soil utilize available nitrogen in the process of decomposing the incorporated cover crop, making the nitrogen unavailable for the newly planted crop. Thus the Dursts usually side dress their vegetables with organic fertilizer early in the season, until the nitrogen provided by the cover crop becomes available. Cover crops can also improve soil's physical structure by adding organic matter.

In addition to using cover crops, the Dursts often need to apply soil amendments -- agents that bring depleted soil back to top form -- during land preparation to produce a successful tomato crop. Depending on the results of soil tests, manure and composted manure are added to the soil as well as nitrogen and other essential plant nutrients. Jim has found in recent years that he uses less compost due to high costs and inconsistencies in quality and relies more on bone meal and other sources of organic nitrogen. He also adds rock phosphate annually to maintain phosphorous levels, and gypsum to provide an additional source of calcium and sulfur.

Economic Issues

Average yields for conventionally grown processing tomatoes are approximately 33 tons per acre. Yields for organic processing tomatoes range between 20 and 38 tons per acre. The Dursts, who produce high quality tomatoes that must meet the same industry standards for quality as those of conventionally grown tomatoes, maintain average organic production yields of 28 tons per acre.

In 1994, the Dursts' per acre input costs were compared to conventional input costs -- costs for land preparation, soil fertility and pest management in organic processing tomatoes were estimated at $467 while similar practices for conventional processing tomatoes cost were estimated at $399. Though these costs have most likely increased in recent years, conventional input costs are generally at least 15 percent less than organic production costs. The Dursts have found that the biggest difference in cost between conventional and organic production systems to be the cost of maintaining soil fertility. The Dursts spend between $150 and $250 per acre to maintain soil fertility whereas conventional growers, who rely primarily on synthetic fertilizers for soil nutrients, spend $53 on the average. The Dursts, however, generally spend less on pest control than conventional processing tomato growers.

Despite higher production costs, the Dursts' organic production can realize *higher* per acre profits than conventional production systems. In 1994, the Dursts' organic production system brought in roughly $230 more per acre than conventional production systems.

Despite higher production costs, the Dursts' organic production can realize higher per acre profits than conventional production systems.

Challenges and Recommendations

There are a number of challenges associated with growing a cover crop in combination with vegetables. For example, the Dursts note that sometimes they have had to increase their use of water to grow cover crops in the fall and winter months. If it does not rain in time to help germinate cover crop seed, the Dursts will irrigate. Also, fall-planted cover crops do not mature until later in the spring, which makes it difficult to work the land for an early spring planting such as direct-seed tomato plants. Most organic tomato growers avoid this dilemma by using transplants, which can be planted later in the spring. When early planting is desired, the Dursts use a flame weeder or mechanical cultivations in the fall to keep their fields as weed free as possible until spring.

One reason for the Durst's success is that they aggressively market their product and have learned to be vigilant in their development of innovative packaging and marketing ideas. They now sell 75 percent of their produce in the San Francisco Bay Area and the rest in the Pacific Northwest, Los Angeles, Texas and Japan. Approximately 50 percent of their produce is sold organically and the rest on the conventional market. Jim's advice for growers who want to reduce pesticide use is to start out slowly and never jeopardize farm profitability. This means experimenting with organic or alternative pest control strategies on a small amount of acreage at first, and expanding along lines that experience suggests.

Table 2: Durst's Organic Pest Management System

Weed Control	Mechanical cultivation 3 to 7 times depending on the crop. 3 hand hoeing trips through the field, burning weeds with propane-powered flamer, cover crops, crop rotation.
Insect Control	Monitoring, cover crops, crop rotation, B.t. baits, soaps, and pyrethrins. The big pest of tomatoes, the tomato fruitworm, is avoided by planting early in the year.
Disease Control	Tomato fields are monitored throughout spring for signs of powdery mildew or bacterial speck; sulfur and copper hydroxide are applied as needed.
Soil Management	Either a cover crop such as Sudangrass is planted in the summer and disked into the soil in the fall, or a winter cover such as vetch is planted in the fall and disked into the soil in the spring.

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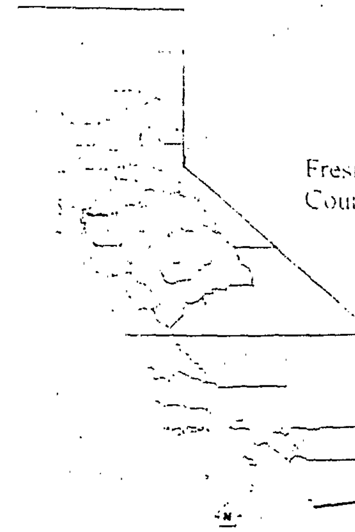

Reducing Agricultural Drainage

PANOCHE DRAINAGE DISTRICT
FRESNO COUNTY, CALIFORNIA

Panoche Drainage District is made up of four water districts that cover a total of 44,000 acres on the west side of the San Joaquin Valley -- a region that has been directly confronted with the necessity of reducing selenium loads into the San Joaquin River. Panoche historically discharged its drainage through sloughs and man made channels running through the Grassland Water District and the surrounding area, which contain many federal and state wildlife refuges and private duck hunting clubs. These channels then drained into the San Joaquin River.

As part of a recent agreement on drainage issues, Panoche, along with six other water and drainage districts, has agreed to get drainage water out of Grassland's sloughs and channels in order to allow increased flow of freshwater to the wildlife refuges and to avoid possible selenium contamination of the wetlands. The agreement allows the districts to use a section of the existing portion of the San Luis Drain, which had been closed since selenium-laden drainage delivered by it from Westlands Water District to Kesterson Reservoir was found to cause death and deformity of waterfowl. In exchange for use of the Drain, the districts have agreed to reduce their selenium loads substantially.

Over the past 5 years Panoche has reduced the volume of drainage leaving the district by 50%.

As discussed earlier, EPA's ambient freshwater aquatic life water quality criterion for selenium is 5 ppb. According to Dennis Falaschi, general manager of Panoche Water and Drainage District, concentrations of selenium in Panoche's subsurface drainage water have ranged from as low as .002 parts per billion (ppb) to as high as 3,000 ppb at some tile sumps (internal collection points) and drainwater leaving the district is less than 140 ppb. Panoche has tried to focus its recent source control efforts on the areas with the highest selenium concentrations. The district's drainage system formerly provided an outlet for both tailwater (surface drainage) and subsurface drainage. Over the past five years Panoche has reduced the volume of drainage leaving the district by 50 percent, primarily by taking tailwater out of the system, encouraging irrigation improvements, and recirculating subsurface drainage water. While the tailwater water does not contain selenium, which is found in subsurface drainage, the reduction in overall volume has made it easier for the district to deal with the subsurface drainage.

Panoche has used a variety of techniques to deal with the remaining subsurface drainage, including blending it with surface water for reuse on fields. The salinity level, rather than the selenium, is the limiting factor for the reuse of drainage water. Some crops, however, have a high tolerance for saline water.

Panoche has adopted a policy that requires each farmer to commit to using efficient irrigation practices and eliminating any discharges of tailwater into the District's system, as a precondition to receiving water deliveries. Panoche has also implemented a tiered pricing program to encourage efficient water use, and a separate tiered pricing program for pre-irrigation. Farmers are charged $56 per acre-foot for the first 9 inches of water that they use to pre-irrigate their crops. For any pre-irrigation water over that amount farmers are charged $112 per acre-foot. For the remainder of the irrigation cycle farmers are again charged $56 per acre-foot, until they exceed a total of 2.4 acre-feet per acre (including the nine inches allowed for pre-irrigation). For any water use above 2.4 acre-feet per acre farmers are again charged $112 per acre-foot.

Panoche currently measures water at each farm turnout, and has the goal of measuring deliveries to each field.

Panoche currently measures water at each farm turnout, and has the goal of measuring deliveries to each field. In the 1998 growing season the District will be implementing a crop-specific tiered pricing program that ties water rates to the water needs of different crops. Under this system, the amount of water delivered at the rate of $56 per acre-foot will vary by crop.

Panoche also helps its farmers with irrigation scheduling by providing information on crop water needs. The district accesses information from the California Irrigation Management Information System (CIMIS), which is an integrated network of more than 85 computerized weather stations located throughout California. Weather data including temperature, humidity and wind strength and direction are collected from each station and transmitted via satellite to a central computer in Sacramento. The computer then uses this data to estimate water needs (evapotranspiration) for a reference crop. The district then translates this information into crop-specific water needs, and provides that information on a weekly basis to farmers in the district. The irrigation manager can then precisely give the amount of water the plants require.

To facilitate improvements in irrigation efficiency, the District has made available to its farmers low interest loans from the Revolving Loan Fund of the State Water Resources Control Board for the purchase of gated pipe, sprinkler, and drip irrigation systems that will enhance water management and reduce drain water volume.

Mike Stearns of Hammond Ranch and Steve Smith of Turlock Fruit are two of the many Panoche farmers that have changed their irrigation water management in order to improve on-farm water management and reduce drainage.

MICHAEL STEARNS
HAMMOND RANCH, INC.
FIREBAUGH, CALIFORNIA

⇒ *8500 acres of asparagus, garlic, onions, grapes, walnuts, cotton, tomatoes, melons, and almonds*

⇒ *Reduced water use by 25 percent on cotton, 40 percent on grapes, 22 percent on asparagus*

Michael Stearns is the general manager of Hammond Ranch, which includes 7400 acres in Panoche Water District, and 1100 acres in San Luis and Firebaugh Water

D-039821

Districts. Mike has implemented a variety of water conservation measures to reduce drainage from Hammond Ranch.

Irrigation

Mike grows cotton, tomatoes and asparagus using buried (subsurface) drip irrigation on 560 acres. He is growing cotton with 2.1 acre-feet of water per acre, instead of the 2.7 acre-feet per acre typical in the region. Yields have been very good on the subsurface drip fields, producing 3.8 bales of cotton per acre, which is one-half bale or approximately 15 percent above the region's average.

On the Hammond Ranch asparagus fields Mike produces 185 crates per acre on a three-year old field and he expects it to produce 300 crates per acre when it is mature at five years. These yields are 50 percent higher than what is typically produced in the region using furrow or sprinkler irrigation. Mike believes these dramatic yields in the asparagus fields are due to a combination of irrigation, climate, and soil factors.

The use of subsurface drip is still very unusual on row crops. Many people believe that subsurface drip cannot be used on row crops, because the buried tape has the potential to be damaged when the field is tilled. Mike says that he modified the farm's equipment to minimize the damage, and invested in special equipment that allows him to reshape and work beds without tilling to the depth of the tape. He also points out that it is possible to pinpoint and patch any damage that does occur. Mike has tried subsurface drip on an experimental basis, which he considers to be a limited success so far and is considering expanding the acreage. He expects the subsurface tape to last six years on the cotton fields, and 10 to 12 years on the asparagus fields. The tape used for the asparagus will last longer because it is thicker and heavier than the tape used for the cotton.

Mike also grows grapes with a drip irrigation system, and uses 2.4 acre-feet per acre instead of the 3½ to 4 acre-feet per acre that a furrow system would require.

Mike has a full time agronomist on his staff who is responsible for irrigation scheduling, fertilizer applications, and soil chemistry programs. The agronomist monitors soil moisture using a neutron probe as well as the hand probe method. The agronomist also uses CIMIS data and computer software to provide weekly recommendations to the foreman on irrigation timing and amount.

Soil salinity monitoring shows that using drip and subsurface drip irrigation has not caused soil salinity to increase to damaging levels for the crops Mike grows. While farmers are concerned with providing enough water to leach salts out of the soil, drip irrigation is able to do this by pushing the salinity away from the crop root zone or root ball, in effect creating a salt free zone only where the salinity could kill crops or reduce yields. Winter rains also help leach salts from the soil, although in a dry winter Mike may also use sprinklers to apply 4-6 inches of water for leaching purposes.

Economic Issues

Hammond Ranch took advantage of the State Revolving Loan Fund (SRF) to pay for the drip system as well as for a portable pump, sprinklers and gated pipe. The overall cost of the system was approximately $1400 per acre. The system was expensive to install, but Mike believes that the investment will repay itself if higher yields can be achieved and maintained. Mike achieves extra savings from applying fertilizer through the drip system because the more efficient application method allows him to use less overall. However, energy costs have increased with the drip system, compared to the furrow and sprinkler systems that it replaced. Labor costs are currently the same, but Mike feels that they may eventually decrease as the kinks are ironed out of the system. There is also an added cost of periodically flushing the drip system with small amounts of sulphuric acid and chlorine to prevent algae and roots from clogging the drip emitters.

Challenges and Recommendations

Mike considers these irrigation management changes to be a necessary effort in the process to manage water and drainage. He believes that there is still a lot to learn about operating these subsurface systems. He also believes that given time farmers can continue to make progress in their efforts to address drainage problems.

STEVE SMITH
TURLOCK FRUIT
FIREBAUGH, CALIFORNIA

⇒ *5,000 acres of apricots, almonds, asparagus, cherries, cotton, melons, Safflower, tomatoes, and wheat*

⇒ *Water use reduced by 20-30 percent on fields converted to drip irrigation*

⇒ *Synthetic pesticide use reduced 50 percent and synthetic fertilizer use reduced 30 percent on fields converted to drip irrigation*

The Turlock Fruit Co. was founded by James H. "Cantaloupe" Smith in 1923 as a melon packing and growing operation. The company is now run by his son Don and two grandsons Steve and Stuart Smith.

The company farms a wide variety of crops on the Westside of the San Joaquin Valley. The majority of the acreage is in the Panoche Drainage District. Melons are the company's primary crop and are grown, packed and marketed throughout the US, Canada, and Pacific Rim.

The Smiths are implementing new strategies of minimum tillage, integrated pest management and irrigation to their farming operation. They are committed to implementing water efficiency improvements on their farm in order to reduce drainage and water costs as well as increase yields.

Irrigation

The Smiths have installed subsurface drip systems to service 300 acres of asparagus, 150 acres of melons and 150 acres of cotton. They began by converting 80 acres to subsurface drip in 1993, and have converted more acreage each year since then. Through the use of drip irrigation the company has increased yields on these fields by 30-40 percent, reduced water usage by 20-30 percent, and eliminated drainage from their fields. Turlock Fruit monitors soil salinity and has seen no increase in soil salinity on their drip irrigated fields.

Turlock Fruit's conversion to subsurface drip was motivated by the need to reduce both water use and subsurface drainage. When asked why they hadn't converted earlier, Steve noted that the technology has greatly improved in recent years. In

Through the use of drip irrigation the company has increased yields on these fields by 30-40 percent, reduced water usage by 20-30 percent, and eliminated drainage from their fields.

particular, it is now possible to have a quarter mile run of subsurface drip tape, which was not possible five or six years ago. The longer runs are easier to install and maintain.

Steve monitors soil moisture using a tensiometer, as well as by just feeling the soil with his hands. He uses information on soil moisture in conjunction with CIMIS data provided by the district to determine his irrigation scheduling. The goal is to match the water delivered exactly to the plant needs thereby eliminating any excess drain water.

Turlock Fruit also has a tailwater return system which recirculates any surface runoff for reuse on the field.

Pest Management

Subsurface drip also provides for more efficient application of fertilizers and pesticides since these inputs can be injected directly through the drip line and taken up directly by the plant. Steve estimates that fertilizer use has been reduced by 30 percent and pesticide use by 50 percent on his fields that are irrigated with drip compared to similar fields irrigated by furrow. He notes that drip has allowed him to reduce aerial pesticide applications significantly -- doubly important in that such aerial application which can damage beneficial insects and create the need for even more pesticide use. In addition to using less overall, Steve feels that the drip application method is superior because it is more direct, thus less pesticide is dispersed into the environment, and there is less worker exposure.

The subsurface drip system has also enabled Turlock Fruit to use less toxic compounds to combat pests. One such material is an aphicide that is derived from nicotine. This compound can only be used effectively in conjunction with a drip irrigation system.

Another method used by the company to reduce reliance on pesticides is the planting of cover crops between the rows of their orchards. New clover mixes are now available that provide habitat for beneficial insects and allow for natural control of many pests.

Turlock Fruit uses an independent pest control advisor rather than one employed by the chemical companies who produce agricultural chemicals. Steve feels that this automatically reduces his pesticide use, noting the inherent conflict of interest of having pesticide application schedules set by someone with a financial interest in promoting their use.

Cover Crops

Turlock Fruit Co. has implemented new methods of minimum tillage that have reduced the number of times farmers must work the ground. Minimum tillage is required when subsurface drip is used because the dripper line is expected to last up to six years underground and cannot be disturbed. In order to succeed with minimum tillage, the Smiths have helped develop a disc implement that will till the soil to destroy weeds and plant residue and at the same time not disturb the underground drip system.

Another element of Turlock Fruit's minimum tillage program includes the planting of Sudangrass as a cover crop after the melon harvest. Sudangrass has a very aggressive root system which serves the dual purpose of opening up (tilling) the soil and also, after it is chopped, provide "green manure" for the next crop. The Smiths mow the Sudangrass, and then use the bed disc to rip the furrows for water

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penetration, leaving the drip tape undisturbed. While Sudangrass planted for harvest is a very high water-use crop, Turlock Fruit plants it very late in the season and irrigates it using subsurface drip, requiring only one acre-foot of water per acre. However, Steve does not plant it in years when water supply is very limited.

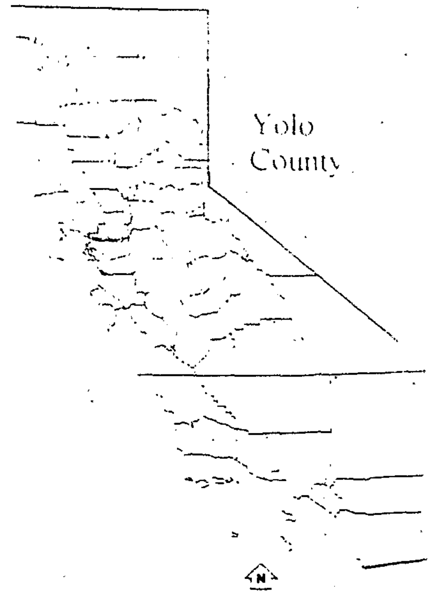
Economic Issues

The installation of the drip system cost approximately $1,000 per acre. Turlock Fruit was able to use a low interest (3.5 percent interest) loan from the State Revolving Fund (SRF) program to pay for these improvements. Steve supports the SRF program: "that's how we were able to justify these changes."

The drip system results in savings from the reduced fertilizer and pesticide applications, as well as in labor savings, and the minimum tillage system reduces costs of diesel and equipment use. Overall, Steve estimates that these combine to approximately $100 per acre savings in production costs. The costs of the drip system are also partially offset by the dramatic increases in yields.

Challenges and Recommendations

The Turlock Fruit Co. is committed to pursuing new strategies for reducing the amount of water it needs to farm. These new strategies are expensive, and Steve voices concern that the willingness of other farmers to invest in irrigation system upgrades may depend on how reliable their water supplies are. He would support a program that gave preference in water supplies to farmers who demonstrate water use efficiency and reduced reliance on chemicals.



A BIOLOGICALLY INTEGRATED ORCHARD SYSTEM

CRAIG MCNAMARA
WINTERS, CALIFORNIA
YOLO COUNTY

⇒ *525 acres of walnuts and tomatoes*
⇒ *Synthetic herbicide use reduced 35 percent on half of acreage*
⇒ *Synthetic nitrogen fertilizer use reduced 50 percent on half of acreage*
⇒ *Synthetic pesticides and fertilizers eliminated on organic acreage*
⇒ *Water use efficiency improved from 60 percent to 80 percent*

Craig McNamara lives with his wife and three children on a 525-acre walnut and tomato farm not far from the busy Interstate 80 corridor near Sacramento. Craig began farming in 1980 after completing undergraduate work at the University of California, Davis in Plant and Soil Science. Somewhat of a newcomer to farming, Craig typifies a new generation of farmers. He is highly educated, operates a sophisticated central office, and is enthusiastic about pesticide use reduction and sustainable farming.

Craig grows walnuts on 250 acres; 15 of these feature organic growing methods. His orchards are planted with several varieties of English walnuts which are grafted to a black walnut rootstock that is resistant to a number of plant diseases. The trees are planted in a grid-like pattern with 69 trees per acre. Walnut trees produce crops within six years of planting and can be productive for approximately 40 years.

"On the one hand, I was farming as a way of creating a lifestyle and livelihood conducive to family life. And on the other hand, I was using chemicals that might endanger the health of my family."

Craig has always believed in farming with fewer chemicals: "To me, sustainable farming is life farming," says Craig. His education, however, prepared him to farm conventionally. During his first nine years of farming, Craig relied on conventional synthetic pesticides and fertilizers supplemented with the less conventional IPM techniques. But eight years ago Craig became concerned about the impact of chemical use so close to his home and decided to look for methods of farming that would be safer for his family. "I felt like there were a lot of contradictions in my day-to-day life. On the one hand, I was farming as a way of creating a lifestyle and livelihood conducive to family life. And on the other hand, I was using chemicals that might endanger the health of my family. I tried to keep the equipment far away but it never seemed far enough," says Craig.

Weed Management

Craig was particularly concerned about herbicide contamination of ground water. Some pre-emergent herbicides are more likely to leach to ground water due to their physical chemistry and because they are applied in the late fall and early winter when rain fall is heaviest. Craig had previously relied on a pre-emergent herbicide such as Karmex or Princep, applied to an eight foot strip underneath tree rows as insurance against possible weed problems. Pre-emergent herbicides were used to create a weed free orchard floor, a standard that many nut growers work hard to maintain.

To move away from these pre-emergent herbicides, Craig started out growing a cover crop mixture of legumes and grasses between tree rows on a small percentage of his acreage. He discovered that allowing some leguminous vegetative growth in the orchard actually provided numerous benefits beyond natural suppression of weed growth, including providing a habitat for beneficial insects and fixing atmospheric nitrogen, which becomes available to the trees once the cover crop is incorporated into the soil. Due to this success, Craig now plants a cover crop on all his acreage and has eliminated his use of a pre-emergent herbicide. Craig estimates that by eliminating his use of a pre-emergent herbicide and growing a cover crop between tree rows that he has reduced his herbicide applications by 37 percent. However, because a weed free orchard floor around the base of the trees at harvest time is critical, Craig continues to use Roundup (glyphosate), a contact herbicide, on his non-organic acreage during the spring and summer and right before harvest. Walnuts are harvested by mechanically shaking the trees so that the nuts fall to the ground at the base of the tree. The nuts are then blown and swept out to the center of the row to be picked up mechanically. If there is substantial vegetative growth at the base of the tree, the nuts are difficult to blow into row centers.

Because no synthetic herbicides are allowed in organic walnut production, Craig controls vegetative growth at the base of his trees on his organic acreage by mowing and mechanically cultivating on his organic acreage. He is also experimenting with the use of a flame weeder, a propane-powered weed killer that burns plant tissue and leaves.

Insect and Disease Management

The most serious insect pest in walnuts is codling moth. Codling moth has no natural enemies, and multiple generations of the pest occur each season. Craig has installed a pheromone monitoring device to track codling moth development, and has an independent pest management consultant scout his fields during the growing season. When necessary, he usually treats this pest with two applications of Guthion (azinphos-methyl) or Lorsban (chlorpyrifos).

Cover crops provide habitat for beneficial insects which are natural enemies to pests such as aphids and mites. Thus Craig is careful never to mow an entire cover crop at once, planting cover crops that blooms at various moments in the season, and leaving an eight foot wide strip of cover crop every third row or so in the orchard as a means of habitat enhancement for beneficial insects. This kind of cover crop habitat enhancement does not offer much benefit for codling moth control, unfortunately, due to this pest's lack of natural predators or parasites.

Cover crops provide habitat for beneficial insects which are natural enemies to pests such as aphids and mites.

In his organic orchard, Craig relies extensively on biological methods of pest control. In the past Craig released *Trichogramma* wasps, a naturally-occurring egg parasite. More recently he has relied on pheromone mating disruption techniques to help control codling moth. As discussed in previous case studies, pheromones, chemicals released by female moths to attract male moths for mating, can be incorporated into twist-tie-like dispensers on trees throughout the orchard. When pheromone levels are high enough, male moths become confused and exhaust themselves chasing the pheromone, thus failing to mate with females. The females subsequently lay infertile eggs and populations decline over time.

Craig also treats his orchards for the bacteria, walnut blight, with two applications of copper, as needed throughout the growing season. Copper, a naturally-occurring material, may also be used in organic orchards.

Soil Fertility

Beyond these benefits of offering weed and insect control with fewer synthetic pesticide applications, planting a cover crop improves soil fertility. In particular, legume plants in a cover crop mixture are able to transform atmospheric nitrogen into a form of nitrogen that becomes is available to plants in the soil. This is particularly important in his organic orchard, where Craig cannot use synthetic fertilizers. In all of his orchards, he relies on the nitrogen provided by cover crops, compost and animal manure. In the past three years, Craig has reduced the amount of synthetic nitrogen fertilizers he uses by 50 percent. "I recently calculated that -- orchard wide -- I am applying 25 tons less ammonium sulfate per year than I used to. Now that's something I am proud of," says Craig.

Despite all of its benefits, growing a cover crop has its challenges. When the cover crop is planted in the fall, it needs to be irrigated -- often at the same time trees need to be pruned. A wet orchard floor is not compatible with heavy pruning machinery. Sometimes the cover crop performs too well and creates porous conditions in the soil that actually make it difficult to irrigate a field. In some cases Craig's cover crops have increased water penetration so much that the water is absorbed into the soil before it has a chance to move all the way across the orchard floor. Craig usually solves this problem by disking and land planning to make the ground more firm.

Craig mentions another management challenge: "In the late spring, I have to decide whether or not to incorporate the cover crop into the soil. I usually decide to disc in the cover because of the nutrients and organic matter it provides. But this ends up temporarily destroying habitat for beneficial insects. This is one area where I think we need a lot more research. There should be a way to grow a cover crop to both manage pests and build up soil fertility."

Irrigation

Craig pumps his water from wells, and use to use flood irrigation. When he switched to sprinklers, he noticed tremendous cost savings and reductions in water use. While conservation was foremost in motivating Craig's switch to sprinklers, he notes that "I'm so much more pleased with every aspect of the system. There is greater ease of operation, even application, and better uniformity." Of particular value to Craig is the increased control and responsiveness the sprinkler system offers. The system enables Craig to deliver irrigation quickly when necessary, if, for example, temperatures skyrocket or plummet. Under a flood system it would take a lot longer to irrigate a crop.

Craig uses tensiometers and gypsum blocks to monitor soil moisture, and records the readings regularly. These soil-reading stations are integrated with IPM stations throughout the orchard, so that he can check readings of pest populations and soil moisture at the same time.

Economic Issues

Craig's yields have remained the same since he stopped using pre-emergent herbicides and began planting a cover crop. His yields, including those in his organic orchards, are roughly two tons per acre and the quality of his produce has been maintained.

Craig's operating costs have not changed much under this new approach to weed management. While there are additional costs for establishing an annual cover crop, there is a concomitant reduction in herbicide and nitrogen fertilizer costs. His organic pest and nutrient management costs are about 15 percent higher than his conventional and cover-cropping systems, an increase he easily recoups due to the higher prices paid at market for his organic walnuts as opposed to those he earns for walnuts sold on the conventional market.

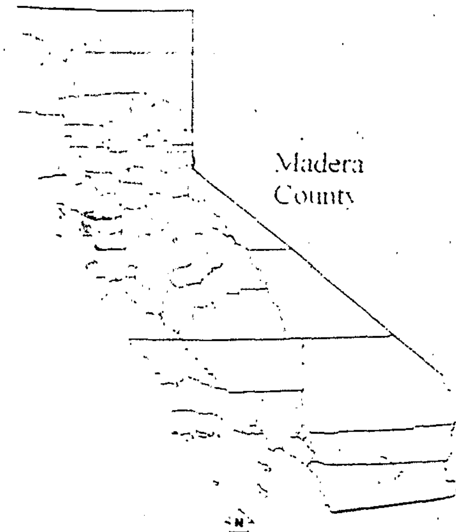
Challenges and Recommendations

Craig sees himself on a path to farming more and more sustainably over time. "It's safer for my family and workers; it protects the environment, and over the long term it pays off financially." A few years ago, Craig joined the management team for a biologically integrated orchard system (BIOS) program in walnuts in Solano and Yolo counties. "I'm very impressed with the BIOS program because it's a hands-on approach to resolving difficult and sometimes risky management issues. It has the potential to really help walnut production become more sustainable," says Craig.

Craig has not gone completely organic because he is not confident enough in the technology available for controlling codling moth and believes that, at this time, it is too big a risk to convert 250 acres to organic production. There are also barriers associated with the marketing of organic walnuts: organic growers need to market their product directly to the consumer, while conventional growers often sell their nuts to a cooperative that takes responsibility for marketing.

Table 3: Comparison of McNamara's Pest Management on Conventional, Low-Input, and Organic Walnut Production

	Conventional	Low-Input	Organic
Weeds	Late winter, early spring application of preemergent herbicide to entire orchard floor; strip herbicide applications along tree rows at harvest and occasionally during summer as needed; mowing of weeds.	Cover crop planted in fall and mowed in the spring and early summer; harvest-time application of contact herbicide at base of trees.	Cover crop; propane-powered flamer; mechanical weedeater and mower.
Insects	Hires PCA that uses pheromone trap for monitoring for codling moth; 1-2 insecticide applications for codling moth control.	When cover crop is mowed periodically, remnant strip is left for beneficial insects; PCA utilizes pheromone traps for monitoring and insecticides still used for codling moth control on an as needed basis.	Cover crop; PCA recommendations; monitoring for codling moth; pheromone confusion to disrupt codling moth mating.
Diseases	Use resistant varieties and spray copper 1-2 times for bacterial blight.	Same as conventional.	Same as conventional (copper is allowed in organic production).
Soil Management	180 units per acre of ammonium sulfate for nitrogen.	Soil incorporation of cover crop and less synthetic nitrogen fertilizer use.	Cover crop and composted turkey manure provides necessary nutrients.



GOING ORGANIC WITH KING COTTON

CLAUDE AND LINDA SHEPPARD
CHOWCHILLA, CALIFORNIA
MADERA COUNTY

⇒ *11,000 acres of organic cotton and grains*
⇒ *Synthetic pesticide use reduced 100 percent*
⇒ *Water use reduced 25-50 percent*

Claude and Linda Sheppard grow organic cotton and grains in the San Joaquin Valley, where they have been farming cotton most of their lives. Claude's family started growing cotton in Texas before the turn of the century -- his great-grandfather moved to California during the Dust Bowl.

What made the Sheppards start reducing pesticide use four years ago? The Sheppards live right in the middle of their fields, and when Linda was pregnant with their fifth child, they began to feel uneasy about using hazardous materials so close to their home. "I would watch the planes going over all the time, not knowing what was being sprayed. No one knows what the long term health effects of these chemicals are," Linda notes. They first decided to skip using insecticides -- and they saw their yields increase and their costs go down by $20,000. Within four years they saved enough on their insecticide bills to build a new house.

Pest Management

Before they began growing organically, over eight tons of chemicals were applied on their crops each year. All pesticide applications were made on a calendar schedule as recommended by their Pest Control Advisor. Typically, this involved at least six insecticide applications, including a preplant application of the acutely toxic insecticide, Aldicarb. Their worst pests were mites and lygus bugs. Weeds were controlled with one preemergent herbicide and one or two applications of an herbicide for grasses during the growing season. A variety of pesticides were also used to defoliate the plants prior to harvest to prevent plant residues from becoming tangled in cotton fibers.

The Sheppards now approach pest problems from a completely new perspective. First and foremost, they walk their fields constantly, looking for pests and verifying that a problem exists before treating it. The experience of monitoring his fields closely has given Claude a feeling of knowledge of and control over his operation that he didn't have previously.

Claude relies entirely on biological control mechanisms to control insect pests.

Claude relies entirely on biological control mechanisms to control insect pests. If pest populations reach a damaging level, he makes a weekly release of 12,000 to

15,000 beneficial insects per acre. They purchase beneficial insects from an insectary in Chowchilla and, in order to maintain the beneficial insect population, the Sheppards preserve weeds and grasses along ditches to provide habitat for naturally-occurring beneficial insects. Claude has trained his irrigation staff, who are closest to the fields on a day to day basis, to recognize pest problems. His staff can identify specific pests and beneficial insects on cotton leaves, recognize signs of plant stress, and release the appropriate beneficial species on an as-needed basis.

Biological control on the Sheppard's farm is made easier by the presence of a variety of crops grown in this region. Instead of the typical monoculture environment, cotton production in the northern end of the San Joaquin Valley is intermixed with alfalfa and grain production.

These alternate crops act as hosts for beneficial insects and trap crops for certain cotton pests. According to Sean Swezey, an entomologist with the University of California, instituting more diversified rotations and eliminating crop monocultures would allow for significant reductions in pesticide use in California cotton production.

Crop rotation has proven invaluable in controlling pests such as nematodes (microscopic worms that feed on plant roots) and soil-borne diseases. A typical rotation for the Sheppards is two to three years of cotton followed by a year of either alfalfa, wheat, or tomatoes.

For weed control, the Sheppards have stopped using herbicides by adding two or so additional mechanical cultivations and two hand weedings to their cultivation schedules. Instead of using defoliants, the Sheppards cut off their irrigation early so that plant foliange dies naturally.

Irrigation

The Sheppards receive their water from Chowchilla Water District, which contracts for federal water supplies from Friant Dam and Buchanan Dam. Their water is measured in weirs and is delivered through a canal. The Sheppards have access to some deep wells but they try to conserve groundwater and rely primarily on surface supplies. Current surface water costs are $35 per acre-foot, and a $12 per acre flat charge. The District charges farmers for 1.5 acre feet per acre, whether or not they use it, which can be a disincentive to conserve.

Water conservation and organic production are interrelated and complementary in the Sheppard's operation. Their primary water conservation methods include the following:

- For the first three waterings (out of a total of eight) they irrigate every other row. This allows them to rely on hoeing for weed control, and also prevents cotton from growing too quickly. Conventional growers irrigate every row, and use chemicals to stop growth once the cotton has achieved the appropriate height.
- The Sheppards stop irrigating earlier in the season than conventional farmers because they use cessation of irrigation as a defoliant. Again, conventional growers use chemicals for this purpose.
- The Sheppards irrigate for 12 hours at a time instead of 24 hours at a time. This keeps growth in check and doesn't allow weeds and grasses to grow. Conventional farmers use herbicides to control weed and grass growth.
- Laborers who irrigate the fields carry beneficial insects with them and are trained to recognize problems and release the insects as appropriate.

In 1996, the Sheppards used 1.5 acre-feet per acre, which was 25 percent to 50 percent less than the average use for other cotton growers in their area. Actual watering practices and use vary from year to year.[62]

Economic Issues

Cotton yields under the Sheppard's organic pest management system have matched, if not exceeded, average yields in their region at two bales or one-half ton per acre. The quality of their cotton does not differ significantly from their conventional neighbors. The biggest difference in cost is weed control: hand weeding is more expensive than applying herbicides. Overall, production costs for organic cotton are approximately $60 more per acre than conventional production costs. Often this difference can be mitigated by a higher selling price on the market.

Cotton yields under the Sheppard's organic pest management system have matched, if not exceeded, average yields in their region.

The average price per pound for organic cotton can be more than twice that of conventional cotton. Some years, particularly early on, the Sheppard's cotton was in high demand and they received a premium price that compensated for increases in production costs. However, the organic cotton industry is still developing and currently may not offer the same guarantees of buyers that for conventional cotton offers. For example, last year the Sheppards had to put their cotton in storage for months before they found a buyer. When they finally sold their cotton, the cost of storage reduced their profit to the point where they would have been better off selling it on the conventional market.

Challenges and Recommendations

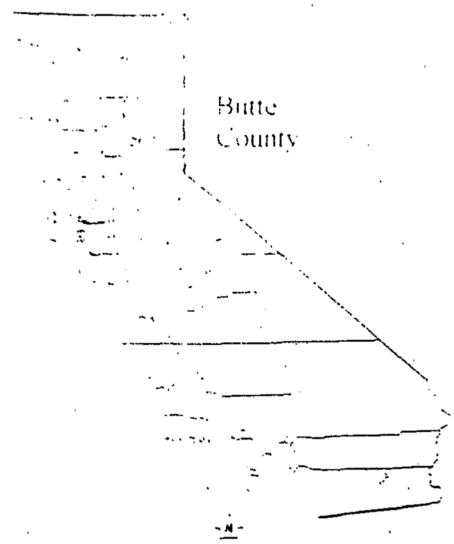
The Sheppards love farming and are cautiously optimistic about the future of organic cotton. Their success has even propelled them into new ventures: they have started their own business to help other farmers monitor crop and pest conditions, purchase beneficial insects and make the transition away from chemical intensive farming.

The Sheppards hope that, in the future, retailers who are committed to buying organic cotton will enter into a "forward" contract that assures them that they have a buyer before they plant the cotton. This is a common practice for conventionally grown cotton. According to Claude, "There are a lot of growers out there interested in reducing pesticide use and trying to go organic, but progress will be slow until we have forward contracts."

A recent article in the New York Times indicates that the market outlook for organic cotton may be growing brighter.[63] The Sustainable Cotton Project has entered into an agreement with Levi Strauss, the Gap, and Nike to purchase a large percentage of the California's organic cotton, which they will mix in with conventional cotton they buy. The outdoor-gear company Patagonia has already shifted its entire line to organic fibers.

Table 4: Comparison of the Sheppard's Conventional and Organic Production Methods for Cotton

	Conventional	Organic
Insects	At least 6 insecticide applications.	Scouting, monitoring, crop rotation, weekly release of beneficial insects.
Weeds	Three herbicide applications; mechanical cultivation.	2-3 additional mechanical cultivations and 2 additional hand hoeing.
Defoliation	Defoliants applied.	Later season irrigation is curtailed to limit plant growth.



LUNDBERG FAMILY FARMS
RICHVALE, CALIFORNIA
BUTTE COUNTY

⇒ *3200 acres of rice*
⇒ *Synthetic pesticide use reduced 100 percent on organic fields and 50 percent on Nutra-farmed fields*
⇒ *Water use reduced 25 percent*

The Lundberg family has been growing rice in the Sacramento Valley for over 60 years, having left western Nebraska during the Dust Bowl. The Lundbergs are committed to growing organic rice, and preserving natural resources. While other farmers in the Sacramento Valley are slowly adopting more ecologically friendly practices, the Lundbergs have not been afraid to experiment, be it with weed control, irrigation practices, cultivation of new varieties of rice, or new product development. They have never burnt their rice stubble, have constantly sought to minimize chemical use, and remain committed to soil building, water conservation and natural wildlife habitat preservation.

The Lundbergs farm 3200 acres of their own land, working also with adjacent farmers who grow rice according to the Lundbergs' specifications on approximately an additional 3500 acres annually. The total pool of land on which rice is grown for the Lundbergs is much larger, however, as they allow much of it to lay fallow each year. All aspects of production, including research and development, growing and harvesting, storing, milling and packing, and product development and marketing, are done on site.

Weed Management

The Lundberg family has been farming organically since 1967. Today, close to 60 percent of their acreage is farmed organically, without the use of synthetic pesticides and fertilizers. The remainder is farmed under a system they call "Nutra-Farming," that uses a variety of cultural and biological farming practices as well as synthetic pesticides on an as-needed basis.

The greatest challenge the Lundbergs face in farming organically is managing weeds without herbicides. There are two types of weeds that present a particular problem for rice: grasses and sedges. Grasses prefer dry land which means they are candidates for control with water; the trick is to keep water in the rice fields at a depth that discourages grasses but does not harm the rice. Sedges, however, prefer a wet environment, and are best controlled by a no-till/drill seed system in which seeds are planted with a drill directly into dry land, allowing time to dry out the sedges.

Over the past twenty years, the Lundbergs have experimented with both of these approaches and now believe that weed control is best achieved by alternating these two planting systems depending on whether grasses or sedges are the greater problem.

The second greatest challenge for organic rice production arises from the need to supply adequate nutrients to plants without synthetic nitrogen fertilizers. A winter cover crop of vetch can accomplish this in that it adds nitrogen to the soil and, once it is incorporated into the soil, augments the supply of much needed organic matter. The Lundbergs plant a winter cover crop in their organic and Nutra-Farm acreage. When needed, they add composted manure to their organic acreage or conventional fertilizers to their Nutra-Farmed acreage.

As Bryce Lundberg notes, "a weedless field is not our goal."

In their Nutra-Farmed acres, the Lundbergs may use herbicides to control grasses and sedges. Before they spray, however, they check their fields manually to determine whether or not treatment is necessary. As Bryce Lundberg notes "a weedless field is not our goal." The Lundbergs often allow some weeds to grow, and when they do apply herbicides, they usually do not apply at the label-recommended rate. As a result, the Lundbergs have reduced overall herbicide use approximately 50 percent compared to other rice growers in their area.

In conventional rice production, rice straw left in the field after harvest is usually burned, polluting the air with silica-like fibers. The Lundbergs have never burned their rice straw but instead incorporate it into the soil, creating additional organic matter. In 1987, the Lundbergs were recognized for their rice decomposition practices with an American Lung Association Clean Air Award.

Stem rot, a disease that usually becomes a problem when rice straw is not burned, is rarely an issue for the Lundbergs because they employ a crop rotation system. A typical rotation under the organic system involves leaving the fields fallow every other year, while under the Nutra-Farm system the fields are fallowed every three to five years. During these fallow periods, cover crops of oats and vetch are grown, allowing the soil time to regenerate. The Lundbergs usually do not irrigate these cover crops.

The Lundbergs are rightfully proud of the wide variety and large numbers of waterfowl and other birds that use their fields. Thousands of waterfowl take refuge in the Lundberg farms during the winter. The Lundbergs cooperate with wildlife groups in bird counts, and do not allow hunting on their lands. The role of birds is vital to the Lundberg's soil building program, as they provide natural fertilization. By not burning their rice stubble, the Lundbergs not only prevent air pollution, but also provide a food source to migrant birds.

Pest Management

The two biggest pests of rice are the rice water weevil and tadpole shrimp. Under their organic system, the Lundbergs cultivate rice strains that are known to be resistant to pests. Under the no-till/drill system, because the rice is planted dry and then flooded later in the season, the rice has time to establish itself before the shrimp appear and the water weevil cannot become a problem until the fields have been flooded permanently. At times, under the Nutra-Farm system, the Lundbergs have had to rely on the use of carbofuran, an insecticide, for water weevil, and copper sulfate, for control of tadpole shrimp.

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Irrigation

Prior to the construction of Oroville Dam by the state of California, the Lundbergs irrigated their land with water directly from the Feather River. Now the Lundbergs receive their water from the Western Canal Irrigation District, which has a contract for 295,000 acre-feet from Lake Oroville to irrigate 56,000 acres in the District. Water is delivered from Oroville through irrigation ditches and then to the fields either through gravity feed if the grade is right, or through low-lift pumps. The Lundberg Farm, like the rest of the Western Canal Irrigation District, is metered at every turnout. The district inherited the meters from the former water supplier, Pacific Gas and Electric (PG&E).

The Lundbergs strongly support water metering, noting that farmers are going to be "a little more judicious" if they are paying for water on a per acre-foot basis. They also feel that water measurement enables districts to allocate supplies more equitably, and to reward those who use water more efficiently. They note that in districts that do not measure, in drought years, supplies are often allocated by limiting each farmer to a set number of productive acres, and requiring them to fallow the remaining land -- even if a farmer can irrigate all of their land with a reduced supply because of efficiency improvements, he or she is required to fallow fields if there is no measuring mechanism to record water use performance.

Water measurement enables districts to allocate supplies more equitably, and to reward those who use water more efficiently.

The Lundbergs also have access to groundwater supplies, which they were able to use during the 1986-1992 drought, even selling some of their surface water supplies to the drought water bank.

Through careful water management the Lundbergs use at least 25 percent less than the district average. The Lundbergs have reduced their water use through the following techniques:

- All fields are laser leveled to assure even water application. This practice, which is widespread, reduced water use from 5 to 6 acre-feet per acre to 3.5 acre-feet per acre.
- A ring-roller is used to flatten clods of earth and provide a groove to protect the rice seeds. This avoids having to raise the water level over the top of the biggest clods.
- Under the no-till/drill seed planting method, after planting and flushing the fields to germinate the rice, the fields are left to dry for two weeks so that the weeds will die. Only then is permanent flood applied. Under the organic water-seeded planting method, after the fortieth day fields are left to dry up for 21-28 days. The primary purpose of these irrigation patterns is for weed control, however the Lundbergs believe they save water as well.
- Water levels on the fields are measured with stakes and carefully monitored.
- Irrigation is curtailed early in the season, allowing fields to dry, often without releasing any water.
- The Lundbergs also grow more early varieties of rice which need to be covered for only 135 days as opposed to 160, with a corresponding reduction in consumptive water use. These varieties have the same yields as the full season varieties, and are less subject to damage by early or late rains.

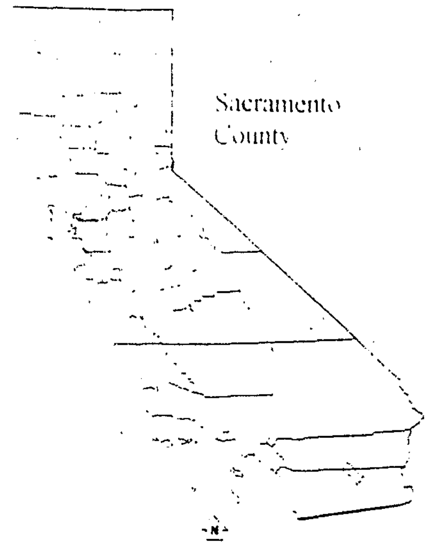
Challenges and Recommendations

With regard to increasing the viability of sustainable agriculture, Bryce Lundberg has suggested that pesticides be taxed at different rates depending on their toxicity. He believes that chemicals that are being phased out should be taxed at a higher rate, to hasten their disappearance, while non-toxic compounds should be taxed at a lower rate to create an extra incentive both to use them and to find new non-toxic alternatives.

To promote water conservation, Bryce believes that meters should be required to measure surface water deliveries, and that the government should support research and development on early varieties of rice which, due to their shorter growing season, use less water.

Table 5: Comparison of the Lundberg's Organic and Nutra Farming Operations for Rice

	Organic	Nutra-Farming
Weeds	Alternate planting strategies using flooded fields to control grasses and a no-till/drill seed approach for controlling sedge.	Scouting for weed problems; herbicide applications only when necessary and at below label rates.
Diseases	Fallow rice fields every other year and plant a cover crop.	Fallow rice fields every three to five years and plant a cover crop.
Insects and Invertebrates	Plant resistant varieties.	Plant resistant varieties; occasional application of carbofuran and/or copper sulfate.
Soil Management	Winter legume cover crop; manure; waterfowl.	Winter legume cover crop; synthetic nitrogen fertilizers; waterfowl.



FIGHTING CODLING MOTH WITH PHEROMONES

DOUG HEMLY
GREENE AND HEMLY, INC.
COURTLAND, CALIFORNIA
SACRAMENTO COUNTY

⇒ *Pears*
⇒ *Insecticide use reduced 50 percent*

Doug Hemly's family first planted fruit trees in 1850 and has been in the business ever since. Doug grew up on the family farm and although he went off to college in pursuit of a non-farming career, he was soon drawn back to his roots. On the banks of the Sacramento river in the heart of the Delta, Doug's farm is the picture of tranquility. In reality, however, Doug barely has time to enjoy his peaceful surroundings. Producing 10,000 tons of Bartlett pears a year is a time-consuming and often risky business.

Pest Management

Doug has long been a pioneer in the development of Integrated Pest Management (IPM) strategies for pear production. IPM requires careful and close monitoring of pest populations, use of economic thresholds to determine whether pest levels are high enough to warrant treatment, and an emphasis on preventing pest problems. His interest in IPM stems from his long-standing efforts to control codling moth, the most serious insect pest of pears. Codling moth populations are particularly high in the Delta because of the relatively warm weather year round. With few nights below freezing, codling moths can over-winter in fruit orchards. When Doug started farming, he sprayed insecticides for codling moth control on a calendar basis. In the late 1960s and early 1970s, he stopped automatically applying insecticides and began to monitor his fields to determine whether or not spraying was necessary in the first place. With that action alone, Doug cut his insecticide use in half, principally by reducing the volume of organophosphate and organochlorine insecticides used for codling moth control.

During the late 1970s and early 1980s, however, Doug began to increase his use of insecticides. Over time, Doug found that he needed to use higher and higher rates of Guthion (azinphos-methyl) to control codling moth because it had become resistant to the lethal effects of the chemical. Despite applying heavier and heavier amounts of Guthion, the moth still caused extensive damage to his crop. According to Doug, "We were barely achieving control and it became a tenuous and scary situation." The next season, he tried pyrethroid insecticides, based on the logic that the moth would not be

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Pheromones have the effect of confusing male moths such that they do not mate with female moths.

resistant to an entirely different class of compound. This strategy failed because, as it turned out, the moths had developed resistance to both compounds.

Utterly frustrated, and willing to try anything, Doug hooked up with University of California researchers interested in experimenting with mating disruption techniques. As previously discussed, mating disruption involves placing throughout the orchard small dispensers which release extremely low rates of pheromones -- naturally-occurring chemicals emitted by female codling moths to attract male moths. Once released, pheromones have the effect of confusing male moths such that they do not mate with female moths. After four years of using pheromones, Doug has been able to reduce Guthion use at least 50 percent and bring levels down to what they were before resistance developed.

In his continuing project to eliminate Guthion use, he has devoted 15 acres to a research experiment to determine the efficacy of tebufenizide, an insect growth regulator.

Disease and Weed Management

For pests other than insects, Doug utilizes conventional agricultural practices. Early in the season Doug applies a preventive application of a chemical that reduces bacterial infections to control the airborne disease fireblight. Though he also uses several fungicide applications to combat the disease known as scab, this year he is experimenting with the use of a naturally-occurring colonizing bacteria to prevent damage from scab. For weed control, Doug applies an herbicide along the tree rows in the winter and the contact pesticide Roundup (glyphosate) along the orchard floor during the growing season.

Irrigation

Doug's farm gets water from the Sacramento River. Although Doug utilizes a wide variety of irrigation methods, whenever he plants new trees he installs either microsprinklers or above ground drip tubing. Both the microsprinklers and the drip system use less water than traditional furrow irrigation and are more efficient in delivering the water in a uniform manner only where it is needed. The sprinklers, which operate at low pressure and thus require only half of the pumping energy also help Doug achieve energy savings. Finally, to help assure appropriate water use, he plans irrigation scheduling based on soil moisture readings from tensiometers.

In recent years, Doug has installed a system that uses drip irrigation for the first four years of a newly planted orchard, after which time he converts it to a microsprinkler system. Doug, through experimentation and experience, has come to believe that drip technology works well when the trees are young and the root system is still small, while the microsprinklers are more effective with larger, more mature root systems. The start-up costs for the equipment and installation of this system cost him between $600 and $800 per acre, an expense Doug believes is very worthwhile because it applies water more accurately and uniformly, saving on energy costs and water use, with the added benefits of preventing excess soil runoff.

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Economic Issues

The transition period necessary for converting insect management on Doug's farm from a chemical-intensive program to a pheromone-based technology took three years. The first year required that Doug use the pheromone technology in combination with a complete chemical program. Thus his costs the first year tripled from roughly $148 per acre to $440 per acre. In the second year, Doug began to reduce his Guthion applications and in the fourth and fifth years of the program, he used -- at most -- one Guthion application for a total cost of roughly $327. Compared to a conventional chemically-intensive control program, however, Doug's overall costs for insect management are roughly equal. Doug is working with his Pesticide Control Advisor (PCA) to figure out how to reduce rates of application and otherwise bring down the cost of the mating disruption technology.[64]

Doug's use of mating disruption has had no negative impact on yields or quality -- both have remained high. Doug sells his pears directly to the grower-owned cooperative Tri-Valley Growers, where most of his pears are canned or made into juice.

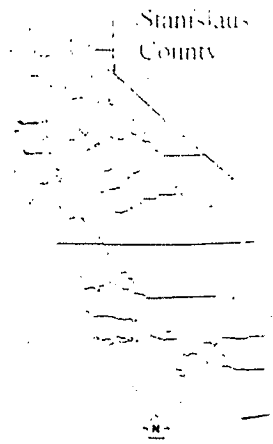
Challenges and Recommendations

Doug attributes his success as a grower to being willing to experiment. He has 14 acres of apples under organic production and is learning how to work with cover crops and other non-traditional methods of pest control. He keeps abreast of new research and listens to and learns from other growers. Doug made the commitment 20 years ago to hire an independent PCA who would implement IPM methods aggressively. He is also a participant in the University of California's Randall Island Pear Project, which studies and assists pear growers in the adoption of mating disruption as a means of reducing reliance on Guthion in achieving codling moth control.

Doug believes his real inspiration for developing IPM techniques boils down to not wanting to be bothered with government regulations. Although he believes that government should be in the business of protecting the environment and public health, he would like nothing better than to find farming techniques that allow him to escape the need for regulation. Says Doug, "I just want to do the right thing and be left alone."

Table 6: Comparison of Hemley's Conventional and Organic Insect Management Methods for Pears

	Conventional	Low-input
Insect management	Extensive use of organophosphate and pyrethroid insecticide use for codling moth control.	Pheromone mating-disruption techniques, scouting, monitoring, insect growth regulators.



BIOLOGICALLY-BASED PEST MANAGEMENT

SHERMAN BOONE
DENAIR, CALIFORNIA
STANISLAUS COUNTY

⇒ *296 acres of almonds*
⇒ *Synthetic insecticide use reduced 100 percent*
⇒ *Synthetic herbicide use reduced 33 percent*
⇒ *Synthetic nitrogen fertilizer use reduced 50 percent*

Sherman Boone is a fourth generation farmer and has been farming for 33 years. He oversees his own 36 acre almond orchard and manages another 260 acres for absentee landowners. In 1979, Sherman adopted what he refers to as a modified Integrated Pest Management (IPM) program that involved monitoring for pests and application of pesticides on an as-needed basis and often at half the recommended label rate. Over the years, Sherman became increasingly concerned with the number of pests developing a resistance to pesticides. As the reliability of pesticides declined, Sherman saw the need to develop other tools. He felt the greatest promise lay in developing a biologically-based system of pest management.

Cover Crops

In 1993, Sherman hired a licensed independent pest management consultant to help him adapt his old IPM program to include natural, biological approaches to pest control. Before he embarked on this venture, he made sure to receive permission from the landowners who, fortunately, welcomed his innovative efforts. Sherman and the consultant decided that the first change Sherman should make was to plant a cover crop of legumes and grasses instead of keeping his orchard floor bare. Like most growers, Sherman's standard weed control practice had been to eliminate plant life and keep a "clean" orchard floor. The decision to implement a cover crop has provided multiple benefits.

The leguminous plants fix nitrogen in the soil providing an essential nutrient for tree growth. The nitrogen provided by the cover crop has allowed Sherman to reduce synthetic nitrogen fertilizer use by 50 percent. Sherman also adds nutrients to his soil by applying compost when the cover crop is first planted and then again every three years.

While some growers incorporate their cover crop into the soil for the added organic matter, Sherman prefers to leave his cover crop alone. This cuts down on the cost of seed as the cover crop re-seeds itself without having to be replanted. By maintaining a cover crop Sherman also spends less time in the orchard on a tractor. which reduces soil compaction, thereby facilitating water penetration. Maintaining a self-seeding cover crop can be a challenge, however, and Sherman would like to see more research devoted to identifying cover crop species that re-seed effectively.

Pest Management

Sherman used to control insects with at least two applications of an organophosphate insecticide during the spring when almonds are most vulnerable to infestations. He has eliminated this practice and replaced it with biological controls. Sherman has found that the nectar in flowering cover crop species attracts beneficial insects that prey on pests. In essence, Sherman has created a habitat for the beneficial insects. The only insecticide now in use on his farms is B.t., a natuarally-occurring bacteria that helps control worm pests but does not damage beneficial insects. In addition, Sherman releases beneficial insects such as *Trichogramma* and *Goniozus Legeri* at least three times before harvest.

The practice of maintaining a cover crop has also helped Sherman reduce his herbicide applications. When he farmed conventionally, Sherman applied a pre-emergent herbicide at least twice per season to the entire orchard and used a contact herbicide such as Roundup at least once, and would mow the weeds an average of seven times. Maintaining a cover crop has allowed Sherman to eliminate use of pre-emergent herbicide applications on an entire-orchard basis: now he limits pre-emergent herbicide use to one application along a strip underneath the trees, while using contact herbicides on an as-needed basis. In total, Sherman has reduced his herbicide use 33 percent. He believes that cover crops are easy and economical and that more farmers should give them a try. According to Sherman, "They're cost effective and not a big risk."

Sherman has not yet figured out how to grow almonds without the use of fungicides for disease control. The major disease pests are brown rot, shot hole and rust. If rains come in the spring, diseases can wipe out the crop within days. He hopes to see more research directed toward the development of non-toxic methods of control for these diseases. Until then, he feels he has little choice but to spray.

Economic Issues

Since making the switch to a more biologically-based system, Sherman's almond yields and quality have been equal to or better than those of the county average. Production costs initially increased but within three years came back down to match the costs of his previous conventional system. The initial increase was related to the cost of ground preparation, the addition of compost, and seeding of the cover crop. By seeding immediately following the last irrigation in the fall, however, Sherman has reduced some of these initial costs. Over time, Sherman's labor costs have actually decreased because the cover crop system requires less mowing.

Sherman's almond yields and quality have been equal to or better than those of the county average.

Challenges and Recommendations

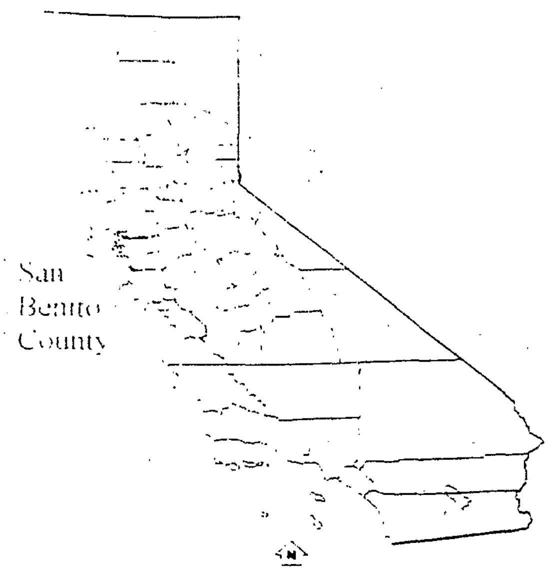
Sherman is an innovative grower who chooses to be involved in as many research and technology transfer programs as his busy schedule permits. He is currently employed on a part-time basis by the Management Team for the Biologically Integrated Orchard Systems (BIOS) project developed by the Community Alliance with Family Farmers. Through breakfast meetings and farm tours, Sherman assists in the development of pest management systems that help almond farmers adopt alternative technologies. If farmers are going to try alternative practices, they will need to see demonstrations that these alternatives can work. It is critical to expand research efforts to address cover crop management and other issues relevant to growers interested in reducing pesticide use.

For Sherman, there are many benefits of farming with fewer chemicals. Overall, the greatest benefit he has seen is an increase in soil fertility. The greater amount and diversity of microrganisms in the soil, encouraged by the presence of the cover crop, helps to build a balanced soil for nut production. Sherman is also encouraged by the increasing numbers of earthworms in his soil and a greater variety of birds on the farm.

Table 7: Comparison of Boone's Conventional and Low Input Pest Management Practices for Fresh Market and Processing Tomatoes

	Conventional	Low-Input
Weeds	Two preemergent herbicide applications; one broadcast application of Roundup at harvest; approximately seven mowings after every irrigation.	Cover crop; three to four mowings; one preemergent strip spray; one broadcast application of a contact herbicide such as Roundup at harvest time after cover crop has reseeded and not yet emerged.
Insects	Two organophosphate insecticide applications (bloom time and again at hull split).	Two applications of *B.t.*; three releases of *Trichogramma* and *Goniosis.*
Diseases	Three to five fungicide applications.	Three fungicide applications.
Soil Management	225 units of nitrogen fertilizer.	Half as much synthetic fertilizer; cover crop and compost applications.

A MIDWESTERN IRRIGATION TECHNOLOGY HEADS WEST



STEVE NISHITA
NISHITA FARMS
SAN JUAN BAUTISTA, CALIFORNIA
SAN BENITO COUNTY

⇒ *200 acres of leaf lettuce*

Steve Nishita is a third generation family farmer. He grows eight types of leaf lettuce on his 200 acre farm, 25 miles inland from the Central Coast. Steve was the first farmer in his area to try a linear move irrigation system, and has reduced water use, improved irrigation efficiency, reduced labor costs, and improved yields.

Irrigation

Linear move irrigation is a form of Low Energy Precision Application (LEPA), as described in Chapter 2. The linear move system uses tubes extending down from a pipeline to deliver water at a low pressure to locations where the plant can use it most efficiently. Unlike a center-pivot system, in which water is delivered from a solid-set sprinkler placed above the machinery frame, the linear system includes a series of "spinners" – sprinklers that throw water out in a spinning motion – fed from pipes dropped from an overhead line that emit water close to the ground. This cuts water loss from evaporation and wind and increases application uniformity.

Linear move systems, while widely used throughout the mid-west, are relatively rare in California.

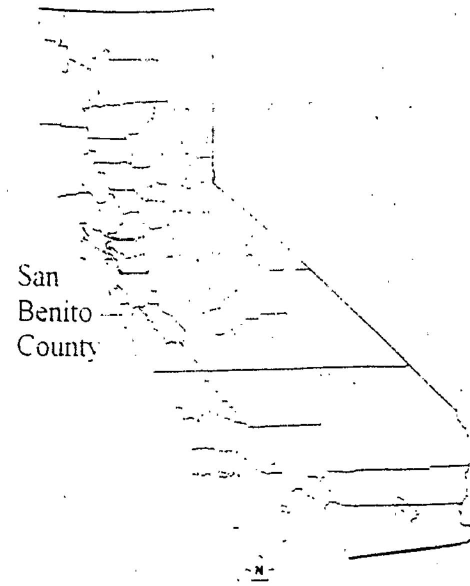
These linear move systems, while widely used throughout the mid-west, are relatively rare in California. A 1996 study done by the Center for Irrigation Technology (CIT) found that there are currently only 40 growers irrigating with 100 linear systems in California. As the machines may be and are used under a wide variety of soil conditions and cropping patterns, the high initial cost of the technology appears to be the primary obstacle to wider adoption. However, when this cost is amortized over five years, the annual cost over that time is around $250 per acre, which is comparable to the cost growers are paying for rented aluminum pipe sprinkler systems.[65]

Steve has said that for him, the decision to purchase a linear system was based on straight economics. He estimates that the linear system saves about $700 per crop on labor costs, and his linear irrigated field commonly gets better yields than his flood-irrigated fields.

While Steve has not measured his water savings, the CIT study found that the systems did reduce water use. According to that study, "The widely held belief of the high efficiency of these systems is supported by water savings, increased germination and higher yields, reduced cultural costs and reduced runoff."[66]

Steve acknowledges that improved efficiency was a motivating factor in purchasing the system. With the region's tight clay loam soil, water can form ponds on fields and flood lettuce plants. Steve notes that, "there is no runoff with the linear system. That's extremely important in my area. Obviously, we want to use water carefully. We want to protect our environment. So far, we aren't having problems with salinization and we want to keep it that way."[67]

GROWING A COVER CROP FOR MULTIPLE BENEFITS



MARK GIBSON
HOLLISTER, CALIFORNIA
SAN BENITO COUNTY

⇒ *80 acres of organic walnuts and 80 acres of apricots*
⇒ *Synthetic pesticide use reduced 100 percent in walnuts*
⇒ *Synthetic insecticide and herbicide use reduced 100 percent in Apricots*
⇒ *Synthetic fertilizer use reduced 100 percent in walnuts and apricots*

When he started farming 20 years ago, Mark Gibson's farm was on the outskirts of the town of Hollister, on the northwest side of the Gavilan mountains. The town has grown up around his farm and today his 30-acre home ranch sits right across from the Calaveras Elementary School. This proximity to town is one reason Mark started thinking about reducing pesticide use and farming organically.

In addition to growing walnuts and apricots, Mark has established a walnut processing and storage facility. Many farmers in the area pay him to shell and store their walnuts after harvest. Several years ago, Mark started shelling organic walnuts and much to his surprise, he noticed that organic walnuts had, on the average, no more insect damage than conventionally-grown walnuts. "In fact, in many cases, the organic walnuts were of higher quality than the conventional walnuts," says Mark. He began to wonder whether it would be possible to eliminate the use of harmful chemicals and still maintain a profitable business. Four years ago, after talking and meeting with organic walnut growers, Mark decided to take the plunge.

Cover Crops

Although he claims to be on a huge learning curve when it comes to farming organically, Mark's operation is working well. The cornerstone of his new pest management system for both walnuts and apricots revolves around maintaining a cover crop of legumes and grasses along the orchard floor. The cover crop is planted in the fall and irrigated with rainwater. Mark mows it at least twice before incorporating it into the soil later in the summer. For his cover crop he plants a mixture of flowering plants that attract beneficial insects and plants that help add nitrogen to the soil. Mark has seen a tremendous increase in the number of beneficial spiders in his orchards, sometimes on the order of 50 to 100 in each tree.

Another benefit of the cover crop is that once it is incorporated into the soil, it supplies organic matter, which helps keep soils highly productive by improving soil

ı and facilitating water penetration. As some of the plants decay, they provide
ɡen and other important soil nutrients. Mark is a strong believer in soil health.
don't build them up the natural way, our soils will become more and more
l."

Pest Management

Because he sells his walnuts as organically-grown, Mark cannot use synthetic pesticides or fertilizers. When he grew walnuts conventionally, Mark would apply an herbicide at least twice around the base of the trees and spot treat and mechanically disc weeds on an as-needed basis. His cover crops have replaced his previous use of herbicides, and now, to control codling moth, Mark releases the beneficial wasp *Trichogramma* on an as-needed basis. Mark also uses naturally-occurring copper-based compounds, the same fungicides he used when he farmed conventionally, to control diseases such as blight. Instead of fertilizers, he applies compost as a source of nutrients and organic matter in addition to those offered by his cover crops.

Cover crops have replaced his previous use of herbicides.

Although Mark does not grow his apricots as organically, he has learned that he can make dramatic reductions in pesticide use and still achieve the yields and quality necessary for selling on the conventional market. Mark uses the same weed and insect control techniques in his apricot orchards that he uses on his walnuts, and has completely eliminated the use of synthetic herbicides, insecticides and fertilizers. In addition, he controls pests such as the peach twig borer with the naturally-occurring bacteria, *B.t.*. Mark has not been able to find a reliable substitute for controlling diseases such as brown rot without the use of fungicides. This year, he hopes to be able to out-compete diseases by using high nutrient foliar feeds that boost the trees' ability to withstand disease pressure. Mark also believes that nutrient foliar feeds will increase the quality of his apricots by giving them a longer shelf life and a higher sugar content.

Economic Issues

Organic and low-input production systems have been more expensive than farming conventionally but have remained profitable for Mark: yields for both walnuts and apricots are the same as when he farmed conventionally. Production costs have increased initially, particularly for compost and other components of his soil-building program, but Mark expects this extra expense to diminish over time as he regains the fertility of his soils.

In 1995, Mark sold some of his organically-grown walnuts on the conventional market and made a profit in part because the overall walnut market was strong. Last year, for the first time, Mark sold his walnut crop on the organic market and received an additional 20 to 30 percent return compared to what he has received on the conventional market. Mark continues to sell his apricots on the conventional market at a profit.

Challenges and Recommendations

Mark is excited about the changes happening on his farm. Now that he isn't using broad-spectrum pesticides, he has witnessed an increase in the number and variety of wildlife species present. On his thirty acre home ranch, he now sees numerous bats that help keep insect pests in check, as well as many more barn owls and hawks.

When asked what needs to be done to help more farmers reduce chemical inputs, Mark suggests that, "everyone involved in agriculture, including farmers and policymakers, should embrace the idea of reducing pesticide use and farming sustainably. This should be the goal that influences all decisions. Government and industry need to cooperate to jump-start the development of science and technology to make natural biological farming systems work on a grand scale."

His advice for other farmers is to be open-minded and find ways to learn about alternative farming practices from other farmers. He got hooked on these ideas when he attended a breakfast meeting sponsored by the Community Alliance with Family Farmers, a non-profit organization based in Davis, California.

Table 8: Comparison of Gibson's Pest Management for Conventional vs. Organic System for Walnuts and Apricots

	Conventional	Organic
Weed control	One application of a contact herbicide around base of trees and spot treatment as necessary; discing of weeds.	Cover crop planted in fall, rain is sufficient irrigation, mowed once in the spring and early summer, flail and disc incorporated.
Insect control	Two or more sprays of an organophosphate insecticide for codling moth control.	Cover crop hosts beneficials; trichogramma wasp released several times for control of codling moth; B.t. is also used in apricots to control peach twig borer.
Disease control	Several fungicide applications at bloom time in apricot orchards for control of brown rot; one or two copper sprays used for blight control in walnuts.	Copper sprays for blight in walnuts; compost teas and foliar feeds for disease resistance.
Soil management	Synthetic nitrogen fertilizer on an as needed basis.	3 to 10 tons per acre of composted manure cover crop is incorporated.

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The primary lesson from these case studies is that farmers *can* successfully reduce their water and pesticide use while maintaining economically viable farms. Our public policies should encourage them to do so.

Many of the farmers interviewed for this report were adventurous, and eager to experiment with new ways to reduce water and chemical use. In some cases they undertook these efforts on their own; in other cases they were motivated by actual or potential regulatory actions. At this time, however, the farmers who use the techniques described in this report are still in the minority. To assure widespread adoption of these techniques, a mix of voluntary and regulatory approaches will be necessary.

Sustainable agriculture does not compete on a level playing field at this point in time. Farmers are often faced with: water rates that do not reward conservation; tax policies that encourage the use of pesticides; processing and marketing infrastructure that penalizes organic growers; and other disincentives to sustainable agriculture. The National Research Council has noted that "As a whole, federal policies work against environmentally benign practices and the adoption of alternative agricultural systems."[68]

While there are many factors that affect the choice of farming techniques, there is much that can be done on a policy level to encourage increased use of sustainable farming techniques such as water conservation and pesticide reduction. We recommend shaping policies and incentives to promote sustainable agriculture techniques by focusing research and development on these farming techniques, and providing technical and financial assistance for these approaches. Critical to the success of these efforts will be maintaining, strengthening, and enforcing existing environmental laws, to create accountability for water quality improvements.

Based on our research, we recommend the following enforcement, monitoring, research and development, technical assistance, and economic incentive programs to promote sustainable agriculture.

Enforcement

⇒ Congress should maintain and strengthen key environmental laws. In particular, Congress should amend the Clean Water Act to provide tougher controls on polluted runoff and more aggressively promote pollution prevention. The Administration should vigorously implement and enforce these laws.

⇒ The Bureau of Reclamation should implement the water conservation planning requirements of the Reclamation Reform Act and the Central Valley Project Improvement Act. The case studies in this report illustrate that there are a wide range of cost-effective techniques available to farmers that would help achieve the conservation goals embodied in these laws. The government must use its authorities to provide meaningful leadership.

⇒ States have an affirmative responsibility under the Clean Water Act to identify impaired waters and to establish Total Maximum Daily Loads (TMDLs) for stressors of concern for those waters. In cases such as California where the state has failed to meet its responsibilities, the law requires EPA to act. Therefore, EPA must establish TMDLs for all impaired waters in California, including implementation plans to achieve the limits set forth in each TMDL. The State has long failed to meet its responsibilities under the Clean Water Act to develop TMDLs, and EPA intervention is warranted and overdue.

⇒ EPA should enforce the new Food Quality Protection Act which protects infants and children from exposure to particularly hazardous pesticides.

⇒ The CALFED program, a joint federal/state planning effort for the Bay-Delta, should make conservation and pollution prevention programs the central approach to achieving water quality and water supply reliability goals. These programs should include performance targets and enforcement mechanisms to assure compliance.

Monitoring

⇒ The state should develop a comprehensive water quality monitoring program, with uniform testing protocols, to develop better baseline information regarding the source and level of pollutants throughout the state's waters, and over time to evaluate the impacts of targeted pollution prevention programs.

⇒ Water quality monitoring should include tracing pollutants back to their source, to facilitate development of targeted source reduction programs. Current testing frequently focuses on evaluating the toxicity of a water source to various indicator species, but usually fails to isolate the cause of the toxicity, and to trace it back to its source.

⇒ The state should assure stable, long-term funding for water quality monitoring programs in order to develop meaningful data on pollutant trends. Interruptions of data collection due to inadequate funding or other reasons can make it difficult or impossible to perform meaningful analysis of water quality trends.

Technical Assistance

⇒ Site specific information is of great value for selecting appropriate water conservation or pesticide use reduction measures. The state and federal governments should fully fund a Mobile Irrigation Lab Program to do site specific evaluations and follow up. Funding for these labs has been extremely limited in recent years.

⇒ The state should fund on-farm demonstration projects incorporating water conservation and chemical use reduction strategies.

⇒ Farmer to farmer networking programs such as the Biologically Integrated Orchard Systems (BIOS) program coordinated by the Community Alliance with Family Farmers (CAFF) have played a pivotal role in providing farmers with the information and technical assistance they need to adopt alternative pest management systems. Programs such as these should be supported and expanded.

⇒ Resource Conservation Districts (RCDs) are a valuable, underutilized resource. RCDs were formed as an independent local government liaison between the federal government and private landowners. When motivated and given the necessary resources, RCDs can play a valuable role in offering technical assistance and promoting sustainable farming practices. However, many RCDs do not have any source of income and are thus severely limited in the conservation assistance that they can offer. The state and federal governments should consider providing a permanent source of funding for RCD pollution prevention and resource conservation programs.

⇒ USDA should increase its efforts to identify and disseminate alternatives to particularly hazardous pesticides.

Research and Development

⇒ Research should be conducted on alternative pest management strategies that are designed to prevent pest problems from developing and reduce reliance on pesticides. Research priorities include the use of cover crops, crop rotations, biologically-based materials such as pheromones and enhancement of natural predator populations.

⇒ Research should be done to determine the relationship between cover crops and water-use, and to develop low water use varieties.

⇒ Additional research is needed on the relationship between soil fertility, pest management and water use. Farmers in these case studies found that soil fertility was key to reducing chemical inputs. Some also found that an extensive soil building program could reduce water use.

⇒ Additional research dollars should be directed towards improving efficient irrigation technologies. Dramatic improvements in technology, especially in drip and subsurface drip irrigation, have been made in recent years. Continued advances in technology are possible and should be aggressively pursued.

⇒ Further research should be done to develop early varieties of rice and other water-intensive crops that benefit from winter and early spring rains and that can be harvested after a shorter growing season and less applied irrigation.

Economic Incentives

⇒ The federal government should phase out irrigation subsidies, which encourage wasteful use of water as well as cultivation of marginal quality lands where irrigation especially contributes to water quality problems.

⇒ Water deliveries should be measured to each farm, and farmers should be charged only for water they use. Although some farmers interviewed for this report adopted water conservation technologies despite water rate structures that discouraged conservation, many spoke disparagingly of rate structures that charged farmers on a per-acre basis regardless of water use. These rate structures promote waste, not conservation.

⇒ The state should renew and expand its system of revolving fund loans for irrigation system upgrades. Such assistance can help overcome the obstacle of high up-front capital costs, which may otherwise dissuade farmers from adopting cost-effective technologies.

⇒ Financial incentive programs should be tied to a whole farm approach that addresses water use, water quality, soil health and erosion, and chemical use reduction. This will avoid shifting environmental problems from one medium to another, and will also help focus resources on measures and techniques that have multiple benefits. The USDA program described in the West Stanislaus case study demonstrates that such an approach can be extremely effective in achieving water conservation and water quality benefits.

⇒ The CALFED Bay-Delta Program should condition the receipt of any program benefits by agricultural water users on implementation of conservation measures, including water measurement and volumetric pricing to promote conservation.

⇒ Pesticides should be taxed according to their toxicity. Higher taxes should be placed on the more toxic chemicals, including those that are scheduled to be phased out, to give extra incentives for early replacement with less toxic alternatives.

⇒ Congress should appropriate full funding for the President's Clean Water Action Plan. The fiscal year 1999 funding initiative calls for a total increase of more than $568 million for improved polluted runoff controls, watershed restoration, and public health protections.

⇒ Federal resources for polluted runoff, in particular new money under the USDA's Environmental Quality Incentives Program (EQIP) and the EPA's Clean Water Act funds (both slated for increases in the President's Clean Water

Action Plan), should be targeted to high priority watersheds for which watershed restoration programs have been developed.

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