California Water Stewards:
Innovative On-farm Water Management Practices

photo credit: Hedgerow Farms

photo credit: © Tori Wilder 2007

California Water Stewards:
Innovative On-farm Water Management Practices

By Lisa Kresge
California Institute for Rural Studies

Katy Mamen
Polaris Institute
California Agricultural Water Stewardship Initiative

January 2009

This report is available on the California Institute for Rural Studies Website: www.cirsinc.org

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The California Water Stewards case study research was made possible with funds from the Compton Foundation. We are grateful for their financial support and their interest in contributing to improving the sustainability of California's agricultural systems.

A number of people worked on various aspects of this project and collaborating with them has been a particularly gratifying part of this work. We are especially grateful to the California Agricultural Water Stewardship Initiative members over the past year including Renata Brillinger, Polaris Institute; Brock Dolman, WATER Institute of the Occidental Arts & Ecology Center; Craig Ficenec, formerly of Agriculture and Land-Based Training Association; Dave Runsten, Community Alliance with Family Farmers; Ron Strochlic, California Institute for Rural Studies; Tim Sullivan, formerly of the Ecological Farming Association; and Kristin Rosenow, Ecological Farming Association for inspiring this research and providing valuable guidance. Special thanks to Erin Hardie of the California Institute for Rural Studies for reviewing and providing feedback on an earlier draft of the case studies. We are also grateful to the Benziger Family Winery, Sunlight Electric, Colleen Proppé, Terry Joanis, Meg Smith, Kathy Voth, Hedgerow Farms, Suncrest Nursery, and Straus Family Creamery for providing us photographs (unless otherwise noted, photographs are courtesy of Lisa Kresge) and Amymade Graphic Design (amymade.com) for layout design. In addition, we are grateful for the assistance of David Zoldoske, California State University Fresno for graciously taking the time to provide feedback on drafts of this report.

Several key informants provided invaluable insights and information that helped shape this work, including: Sam Aslan, Natural Resources Conservation Service; Khaled Bali, University of California Cooperative Extension; Gary Bender, University of California Cooperative Extension; Casey Walsh Cady, California Department of Food and Agriculture; Amigo Cantisano, Organic Ag Advisors and Heaven and Earth Farm; Arturo Carvajal, Natural Resources Conservation Service; Heather Cooley, Pacific Institute; Rex Dufour, National Center for Appropriate Technology; Brock Dolman, Occidental Arts & Ecology Center; Allen Dusault, Sustainable Conservation; Ben Fahrer, Permaculture Designs; Larry Farwell, Water Consultant; Craig Ficenic, formerly of Agriculture and Land-Based Training Association; Rich Flammer, Hidden Resources; Steve Gleissman, University of California Santa Cruz; Chris Goodson, Central Coast Agricultural Water Quality Coalition; Justin Haessly, Mission Resource Conservation District; Blane Hanson, University of California Davis; Bob Hewitt, Natural Resources Conservation Service; Parry Klassen, Coalition for Urban/Rural Environmental Stewardship; Lisa Lurie, Monterey Bay National Marine Sanctuary; Mike Morris, National Center for Appropriate Technology; Mark Niblack, Bureau of Reclamation; Jovita Pajarillo, United States Environmental Protection Agency Region 9; Brandon Ross, Ella Bella Farms; Blake Sanden, University of California Cooperative Extension; Erik Schmidt, Sustainable Conservation; Tracy Slavin, United States Bureau of Reclamation; Stuart Styles, California Polytechnic State University - San Luis Obispo; and Kathy Thomasberg, Monterey County Water Resources Agency.

Finally, we are particularly indebted to the California farmers that shared their time, stories and insights regarding their farming practices, including: Lucy and Vito Adragna of Adragna Ranch; John Anderson of Hedgerow Farms; Mike Benziger, Mimi Gatens and Matt Atkinson of Benziger Family Winery; John Deiner of Red Rock Ranch; Ely Key, Gus Gunderson and Chris Della Maggiore of Limoneira Company; Frank Leeds of Frog's Leap; Jim Marshall of Suncrest Nursery; Israel Morales of American Farms; Peggy Rathmann and John Wick of Marin Carbon Farm/Nicasio Native Grass Ranch; and Albert Straus of Straus Family Creamery.

INTRODUCTION

As water becomes increasingly scarce in California, the role of agriculture in the use of this essential resource has come under growing scrutiny. Reduced access to water has threatened the livelihoods of many California farmers and consequently, the state's $36 billion agricultural sector. Nonetheless, we hear much less about the many California growers that have been taking important leadership roles with respect to improved agricultural water management. Their efforts have served as important strategies for stewarding the state's limited water resources, while ensuring the continued viability of their farm operations.

With the exception of water use efficiency technologies, there has been little documentation of the broad and growing range of innovative on-farm practices that many growers are increasingly implementing to conserve water and improve water quality. These practices hold great potential for reducing reliance on increasingly expensive and scarce water and informing state policy that supports long-term agricultural viability and a secure food supply.

This report represents an effort to identify some of the leading agricultural water stewards in California and to highlight a range of innovative water-wise approaches. We hope these case studies provide inspiration and information for growers wishing to explore new risk management strategies and improve water management in a time of ever-tightening supply.

The case studies in this report highlight a range of innovative on-farm water management practices. In addition to water conservation and improved water quality, they reveal a host of additional benefits for these farm operations, including improved soil health and air quality, increased carbon sequestration, improved energy efficiency, enhanced wildlife habitat and reduced water, energy, labor and other costs.

CALIFORNIA WATER STEWARD CASE STUDY MAP

The featured growers represent a wide range of farm types and agroecological regions. They include large and small farms, conventional and organic production, coastal and inland ecosystems and a wide variety of crop types. The case studies show how farms of all types and scales can take action to increase resiliency to changing water conditions. Some of the featured growers have long-standing water-saving infrastructure in place while others are in the process of getting established.

The case studies cover specific water management practices as well as the motivations that led growers to make these changes. They discuss the benefits, costs, and lessons learned. They also highlight a variety of collaborations that have helped growers implement these practices, along with sources of technical assistance.

These case studies are not intended to represent every available strategy for on-farm water conservation, nor are they intended to provide precise measurements of water savings. Instead, the intent of this report is to showcase growers that are implementing innovative practices to optimize on-farm water use, avoid waste and improve water quality as a strategy to reduce risk in a climate of water insecurity. We hope this information will provide useful information and resources that will inspire and encourage other growers interested in becoming better water stewards.

ADRAGNA RANCH
Gilroy, CA

SOIL MOISTURE MONITORING
COVER CROPS
LOW-FLOW SPRINKLERS

Vito Adragna

Thirteen years ago, Vito Adragna and his wife Lucy purchased land in Gilroy, CA, to build a house and raise their sons. They soon acquired another lot and planted a twenty-four acre walnut grove. Over the years, Adragna Ranch transformed from the early days of Lucy hand-watering the walnut trees to Vito moving gated pipes in the morning before he left for his "day job" with his family's vending company.

The first year of return on their organic walnut crop arrived just in time for Vito's "retirement" from the family business. Finally, Vito had time to make some changes on the ranch. "My friend was telling me to contact NRCS and finally I got tired of moving those pipes so I called them up. I used to move a mile of pipe a day." Not only was he tired of moving pipes, he was also tired of the continuous battle against pipe leaks. In fact, Vito notes that the water from the leaks in his gated pipes provided enough water for his neighbor to grow willows next to the pump. Soon they had a team of technical advisors helping them make some needed changes on the ranch. "They all worked together. It was a big party out here. It was good."

WATER-SAVING PRACTICES

- Adragna Ranch shifted from using a gated pipe sprinkler system to low-flow buried pipe sprinklers that distribute water uniformly throughout the walnut grove. The sprinkler system design includes an adjustable flow rate for different soil types and provides the flexibility to irrigate in multiple configurations, which allows Vito to mow and irrigate different blocks simultaneously.
- Last year, Adragna Ranch planted a permanent cover crop of drought-tolerant grasses, which helps increase water infiltration and avoid run-off.
- Vito tracks soil moisture levels with an electrical resistance-type moisture monitoring system that helps him determine how much moisture is available at the root zone, "where the tree drinks." He tailors irrigations accordingly. The system includes four field stations, each with three sensors placed at different depths in the root-zone. He uses a handheld meter that gives him a digital reading of moisture levels at each depth.

Vito checking soil moisture levels

Adragna Ranch walnut grove

BENEFITS

- Permanent cover crops help retain water, reduce surface evaporation, and reduce or eliminate run-off and erosion.
- Cover crops help improve air quality by reducing dust pollution during harvest and field operations.
- Cover crops improve water infiltration because the root systems reduce compaction.
- Switching to buried-pipe sprinklers reduces water losses associated with leaks in the gated pipe sprinklers and helps apply water more efficiently.
- With permanent cover crops, fuel use is reduced and time is saved on tractor work for weed control and tillage.
- Using less water means less pumping costs.
- Cover crops provide habitat for beneficial insects that help control pests.
- Irrigation scheduling based on soil moisture levels helps prevent over-watering.

COSTS

- The low-flow sprinkler system cost $120,000 to install on their twenty-four acre walnut grove. Ninety percent of it was covered through the Natural Resources Conservation Service (NRCS) water conservation cost sharing and incentives programs.
- The Santa Clara County Water District donated four soil moisture monitoring sensors; the handheld soil moisture meter cost $300.
- Cost-sharing assistance through the NRCS helped pay for drought-tolerant grass seeds and drill planting.

LESSONS LEARNED

- **Technical advice.** Seek out the technical advisors and resources in your area. "There is a lot of technology out there and they took all the brainwork out of figuring it out," Vito explains.
- **Tailor sprinkler system design.** Design a sprinkler system that allows you the flexibility to run sprinkler sets to accommodate different soil types and different rows "instead of being committed to a locked set."

Adragna Ranch

AMERICAN FARMS
Salinas, CA

MINIMUM TILLAGE
PERMANENT PLANTING BEDS
PERMANENT SET SPRINKLERS
VEGETABLE TRANSPLANTS

Israel Morales

Israel Morales has been farming in California for almost forty years. He has worked for American Farms for nearly twenty of those years, where he currently holds the position of Ranch Manager.

American Farms grows approximately 7,500 crop acres of vegetables, including broccoli, spinach, specialty lettuce, and salad mix on approximately 1,800 acres of leased land in the Salinas Valley. More than 60 percent of their crops are organically grown.

Drawing from his experience growing asparagus in permanent beds during the 1960s and early 1970s, Israel decided to apply the same approach to other crops to minimize input costs while improving crop quality. In addition to cutting costs, Israel is able to reduce water use with wider permanent beds and a system of minimum tillage and solid set – or permanently placed – sprinkler pipe. As Israel explains, "In order to economize, it made sense to make the beds wider and use a solid set."

WATER-SAVING PRACTICES

- Permanent 80-inch beds sit lower and have less exposed surface area between beds than the standard 40-inch beds, which reduces evaporative losses due to wind and sunlight. The wider beds also retain soil moisture more evenly and require less irrigation to achieve proper distribution uniformity.
- Minimum tillage reduces soil compaction, which impairs water infiltration and deep root development. It also increases soil organic matter and maintains a healthy environment for microbes and other organisms that are essential to soil nutrient cycling.
- The permanent solid set system allows Israel to irrigate based on plant moisture needs, rather than set scheduling or the availability of labor. It also provides the flexibility to water less and for shorter periods, which reduces runoff. "If you have a system where you have to move your mainline, you can't afford to come back. You have to go on a schedule and can't follow soil moisture levels. A lot of people overwater because of that. We have the luxury of watering based on soil moisture levels and can irrigate multiple fields at one time," explains Israel.

Minimum tillage at American Farms

- The solid set sprinklers reduce mainline leaks common with mobile systems, a major cause of water losses.
- American Farms also uses vegetable transplants to reduce the amount of water necessary to establish a crop from seed.

BENEFITS

- Minimum tillage increases soil organic matter, protects microbes essential for disease suppression, and reduces soil compaction, nutrient depletion, and sedimentation. "I try to work the ground as fast as I can and then irrigate so I don't lose all of the moisture and the microbes have a chance to eat up the disease in the soil," notes Israel.
- Solid set sprinklers reduce crop damage caused by walking on the beds to move irrigation pipes.
- With the solid set system, it is possible to plant multiple crops per year –as many as 3 to 4 crops per field per year for American Farms. Israel explains, "I can plant 10 acres in a hurry. I can harvest today, knock it down, prepare it, irrigate it, and come back next week and plant the field, whereas it takes 3 or 4 weeks to plant for somebody else."
- Transplants save time in between crops and help establish the plant early without weed pressure and related herbicide expenses.
- Minimum tillage practices and permanent sprinklers reduce labor costs, fuel use and time, and help improve air quality.

COSTS

- The solid set sprinkler system requires extra pipes for permanent installation – it takes up to twice as many pipes per acre.
- Tractor drivers use a GPS system for minimum tillage (to maintain the permanent beds), solid set sprinkler placement and planting vegetable transplants. The guidance technology reduces the amount of time and exhausting concentration it takes for tractor drivers to cultivate and place the solid set sprinklers.
- Israel builds his own cultivation equipment with a modified design to accommodate his minimum tillage and permanent bed planting system.

LESSONS LEARNED

- **There are some tradeoffs.** According to Israel, "You lose a little ground because you are not farming it – 8 percent of the ground is dedicated to the solid set - but I can come back pretty fast and plant it. I do triple crops because of the solid set system."
- **Focus on the long term savings.** "You have to pay more money upfront for the additional pipes, but once you do it, you are done," explains Israel.
- **Control the water.** "With minimum till and solid set sprinklers, you control the water. That is the key. The key is to not leach all of the nutrients out with too much water."

Frisee with beneficial plants

BENZIGER FAMILY WINERY

Glen Ellen, CA

TERTIARY WATER RECYCLING SYSTEM
COMPOST & COVER CROPS
WATER CONSERVATION EDUCATION
MINIMUM TILLAGE

The Benziger Family

Preserving the history and beauty of their Sonoma Mountain winery is a high priority for the Benziger Family. The 85-acre ranch, purchased in 1980, features 42 acres of wine grapes and 40 acres of gardens, wetlands, ponds, and olive groves. Driven by a concern over the decline in wildlife and insect populations on their conventionally farmed ranch, coupled with inconsistent fermentations in their wine production, they decided to research strategies to repair the health of their property. As family member Mike Benziger explains, "Through our research we found that biodynamics was the form of agriculture that had the ability to heal the land the fastest and continuously." They began using biodynamic farming practices in 1996.

Biodynamic farming focuses on creating healthy soil and plants with deep root systems, which helps vines better tolerate drought. As Mike explains, this is important because, "Let's face it, the number one problem that we see going forward in our area is water supply. The water tables are dropping quite a bit on Sonoma Mountain here, our wells are producing less water every year and we have to be very efficient in the way we grow our plants."

Additionally, in the process of converting to biodynamic farming, the family decided to develop a tertiary wastewater treatment system with constructed wetlands to cleanse the winery wastewater for reuse in irrigating the vineyards and gardens. Water recycled though the treatment system supplies 50 to 60 percent of their irrigation needs.

WATER-SAVING PRACTICES

- Benziger Winery recycles water used in the harvest and wine making process through constructed wetlands and a pond treatment system. The recycled water is used to irrigate vineyards, landscaping, and gardens.
- Winery workers receive education on water conservation. "We are becoming much more efficient on the front end," explains Mike. "When we started out in 1998, we were using about 7 or 8 gallons of water for every gallon of wine. Now we are down to around 3 gallons."
- The biodynamic farming system includes cover crops and compost use, which help with water infiltration, soil moisture holding capacity, and reduction of runoff. "Our plants have to become as self-sufficient as possible. We do that by growing deep root systems

Primary treatment lagoon

with the philosophy of never feeding the plant, but taking care of the soil. The plant feeds from the soil when it needs to," Mike describes.

- They are able to use less water through a "fine tuned tillage program." "A well-timed tillage is comparable to an irrigation," says Mike.

Constructed wetlands tertiary treatment system

Wastewater from the wine production facilities flows via gravity into a "balance tank" that collects wastewater. A rotary sieve separates solids - skins, seeds, stems – for use as compost. The remaining water flows into a facultative lagoon for aerobic and anaerobic processing. After 60-80 days, the treated water filters through constructed wetlands - reeds and aquatic plants that serve as a habitat for microorganisms that further treat the water. The final pond stores the treated water until it is recycled as vineyard and garden irrigation. Azola, an aquatic fern, covers this holding pond - preventing algae growth that can clog filtration equipment and drip emitters.

BENEFITS

- Benziger Winery recycles an average of 2 million gallons of water a year using the constructed wetlands.[1]
- The wetlands increase biodiversity and provide an improved aesthetic to the winery.
- The compost application has helped reduce erosion, which was a significant issue at the winery.
- The constructed wetlands clean wastewater to a very high level, resulting in water with a low nutrient content. Reducing the nutrient content provides them with more control over plant growth, reduces odors, and reduces reliance on wastewater pond aerators and associated energy use.
- The constructed wetlands provide habitat for beneficial insects, birds, and other wildlife. "It completes the arrangement of habitat areas on the property to make a self-regulating insect population doable," says Mike.

[1] The amount of water that they recycle ranges from 1_ to 3 million gallons of water per year depending on how many grapes they process. Additionally, the amount of water that they are recycling has decreased due to their conservation practices at the source.

COSTS

- Installation costs for the constructed wetlands - including consulting and contractor fees – were about $80,000.
- The constructed wetlands require very limited maintenance and have low operating costs.
- According to Matt Atkinson, Benziger's Ranch Manager, "The only downside is that it has a big footprint, which cuts down on vineyard planting."

LESSONS LEARNED

- **Look to the long-term.** "People need to realize that water is going to become an incredibly rare commodity. We are not going to have access to water like we have in the past. Meaningful conservation practices are a long-term investment. It takes several years to implement these kinds of strategies, so the sooner people get a water conservation plan together, the better it will be for their business," notes Mike.
- **Conservation results in improved quality.** "From my perspective, [water conservation and biodynamic farming] have made us much more conscientious about the way we farm. That has had a pay off in higher quality olives, higher quality vegetables that we produce, less disease in the animals that we raise here and, most important, higher quality wine," says Mike.

"We know that we are running out of water and we know that in the big picture of things that we have to be able to create plants that have a very conservative demand for water."

—Mike Benziger

Constructed wetlands

FROG'S LEAP
Rutherford, CA

photo credit: © Meg Smith 2004

DRY FARMING
COMPOST & COVER CROPS

Frank Leeds, Vineyard Manager

For Frank Leeds, Director of Vineyard Operations at Frog's Leap winery, dry farming runs in the family. Frank grows 250 acres of organic wine grapes on the Napa Valley ranch that his grandfather purchased during prohibition in 1926. The ranch has never had irrigation. Twenty-five years ago, when Frank started farming, his uncle Roy taught him how to dry farm – a tradition brought over from the "old country" by early Napa Valley pioneers from Spain and Italy. Dry farming, a technique employed in Northern California, the Central Coast, and parts of the Central Valley, relies only on annual rainfall rather than irrigation for a crop's moisture needs. The soil is cultivated to store winter rains to supply moisture to the crop throughout the growing season. In Napa Valley, dry farming grapes can save as much as 16,000 gallons of water per acre.

According to Frank, "Most of Napa Valley was dry farmed for years and years and then people lost it. The old-timers dry farmed tomatoes before everything was planted in grapes."

Apart from reduced water use, Frank's motivation for dry farming is the high quality of grape produced. As Frank explains, "Dry farmed grapes are better quality – more concentrated, great color, balanced fruit, wine in balance with its surroundings, all the "terroir,"[2] with roots deep down. All the components of a quality healthy grape you can get with dry farming."

WATER-SAVING PRACTICES

- Frog's Leap relies only on annual rainfall to provide moisture to their wine grapes. They prepare the soil to store natural precipitation, which supplies plant moisture needs.
- Natural soil amendments - compost and cover crops – are used at the beginning of the season to improve soil structure and moisture holding capacity and provide essential nutrients to the soil and plants.
- Sprinklers for frost control are used as infrequently as possible. Frog's Leap waits until it is 32 degrees before applying water, regardless of humidity levels.

BENEFITS

- Frank estimates that Frog's Leap saves an estimated 16,000 gallons of water per acre.[3]
- Forcing the root structures to grow deeper in the soil in search of water produces healthy, vigorous vines and reduces susceptibility to nematodes and diseases, such as phylloxera, that thrive in the top layers of soil.
- Forcing a vine to get moisture deep in the soil also produces vines that last longer. "You get a nice big, healthy, strong grapevine by not giving it a bunch of surface water."
- Less moisture in the top layer of soil reduces weeds and mildew.

> "Cultivating - that is the difference - the old timers used to say that one cultivation was worth two irrigations."
>
> —Frank Leeds

[2] "Terroir" is used to describe the characteristics of place – soil, climate, topography – that contribute to the flavor of a wine.

[3] This is a conservative estimate of 20 gallons of water per vine per year with a planting density of 800 vines per acre.

- Continuous cultivation decreases problems from gophers and other pests.
- Dry farming produces intensely colored fruit with concentrated flavor that reflects the local character of the soil – the "terroir."

Digging in the dirt— photo credit: ©Terry Joanis 2007

What is dry farming?

- Soil preparation is the key component to dry farming.
- Dry farming uses tillage and mulching to create a dry layer of soil, or dust mulch, which acts as a barrier to evaporation and seals the moisture into the deep sponge-like soil.
- The plant must develop deep root structures to absorb the trapped moisture well below the soil surface.
- Other crops besides grapes can be dry farmed, such as tomatoes, melons, squash, olives, and potatoes.

- Cultivating the soil and using organic farming techniques such as cover cropping and mulching provide the necessary nutrients for healthy soil and vines with fewer chemical inputs.
- Depending on the crop and region, dry farmed crops can garner higher prices due to consumer recognition and demand.

COSTS

- The annual operating costs of dry farming versus irrigating are about the same. Labor costs and fuel use are comparable, since tractor use for the additional soil work required by dry farming is similar to tractor use for herbicide, pesticide and fertilizer applications on non-dry farmed (conventional) vineyards.
- Nonetheless, the costs of establishing a dry farm vineyard are lower due to fewer vines, stakes, and supplies.
- Dry farming requires lower density planting, but the trade-off of lower yields is more intense concentration of flavor and character, which can bring higher prices

LESSONS LEARNED

- **Watch planting density.** 40-50 square feet are required per vine – 8x5 at the minimum. According to Frank, "The old-timers said it should be 7x7 – any tighter than that and you will run out of water."
- **Check soil type.** The soil structure and moisture holding capacity should be compatible with dry farming.
- **Check annual rainfall.** Average annual precipitation must be greater than crop moisture needs.
- **Focus on drought-resistant varieties.** Frank plants with a drought tolerant rootstock, such as St. George, rather than a riparian variety.

Frog's Leap Winery— photo credit: Sunlight Electric

HEDGEROW FARMS
Winters, CA

HEDGEROWS

NATIVE SPECIES PLANTS

John Anderson

John Anderson's love of wildlife and concern about disappearing wildlife habitats is what drove him to become a farmer. He and his wife Marsha bought their Yolo County farm in 1974 and started doing habitat work on the edges of the fields they leased to their neighbor. Over the years, John became increasingly interested in native grasses, and by the late 1990s - after an early retirement from his career as a veterinarian - he started Hedgerow Farms. As John explains, "I became interested in grassland and grasses, recognizing that our native grasslands were one of our most imperiled ecosystems."

Today, Hedgerow Farms grows over 60 species of native grassland seed and transplants for various bioregional ecotypes. Now John leases land from his neighbor, with over four hundred acres in production. Hedgerow Farms is one of just a few native seed growers in the state. They are one of California's leading advocates for native grassland habitat restoration.

While hedgerows do not necessarily reduce water use, they improve water quality significantly and provide important benefits for wildlife. According to John, "Some people would argue that hedgerows are using more water, especially when you start putting in trees. Our feeling is that the amount of water being used on these small-scale riparian corridors is insignificant when you start talking about the big picture and how much riparian ground has been lost."

Field border hedgerow

WHAT ARE HEDGEROWS?

- Hedgerows are vegetation strips planted along farm edges, field borders, fences, and waterways.
- They incorporate a diversity of perennial grasses, sedges, rushes, forbs, shrubs, vines and trees that provide multiple on-farm and environmental benefits.
- Hedgerow Farms grows native species specifically selected for use in habitat restoration, reclamation, and water quality protection.

BENEFITS

- Vegetated systems play a significant role in improving water quality. Filter strips/buffers capture and prevent sediment, nutrients, and pesticides from entering waterways and groundwater. Trees provide shade that cools water to appropriate levels for aquatic species and reduces evapotranspiration.

- Plant roots help build soil structure, enhancing water infiltration and groundwater recharge. "Vegetation enhances groundwater recharge," explains John. "Native species provide a biodiverse system that is actually cleaning the water. Vegetation enhances infiltration, compared to a compacted roadside, where irrigation water runs off rather than into the ground."
- Hedgerows provide wildlife habitat for animals and beneficial insects such as predators and pollinators. "Hedgerows are incredibly important because you need a continuous supply of pollen and nectar to maintain healthy populations of beneficial insects such as lacewings, ladybugs, wasps, native bees and butterflies," says John. By providing the habitat, native bee populations can be bolstered, in turn increasing crop yields.
- Well-established perennial sedges, grasses and rushes provide stabilization, making ditch banks less prone to erosion and lowering the labor costs associated with ditch bank maintenance.
- Vegetated systems such as hedgerows provide biodiversity to the farm ecosystem and help maintain soil quality.
- Hedgerows function as windbreaks, redirecting the wind and reducing crop damage from wind, dust, and pesticide drift.
- Once established, native species plants suppress weed growth, minimizing dependency on herbicide.

COSTS

- According to John, "Nobody has done a good cost benefit analysis, but it absolutely needs to be done. My feeling is that it is going to cost the same, but the vegetated system is going to have so many more benefits: biodiversity, aesthetics, and wildlife watching."
- Vegetated systems have a three-year establishment period with set-up costs including plants, labor, and possibly irrigation for two to three years.
- With established plants, maintenance costs may include labor and fuel for mowing, and in some cases spot herbicide application.

LESSONS LEARNED

- **Know your soil and drainage conditions.** Choose the proper plants for the site.
- **Soil preparation is extremely important.** John explains, "Do it right the first time so you are not fighting the weeds. Do your ground prep and initial herbicide spray to reduce weedy competition."
- **Do it all at once.** "Don't plant your shrubs and expect to come back and plant your understory later - do it all at once and do it right."
- **Use local technical expertise.** There are many programs available to help plan and establish a hedgerow or vegetated system. (See Resources section.)
- **Look at other projects.** John recommends investigating projects that have been in the ground for a while to get an idea of what a mature system looks like. For example, Hedgerow Farms planted hedgerows, grassland roadsides, vegetated canals, vegetated tail water ponds, and riparian habitats over fifteen years ago.

Wildlife at Hedgerow Farms — Photo credit: Hedgerow Farms

LIMONEIRA COMPANY

Santa Paula, CA

MULCH & COMPOST
LOW-FLOW MICRO-SPRINKLERS
NO-TILL FARMING METHODS

Gus Gunderson (left) and Ely Key (right)

Sustainability is a high priority to Limoneira Company, as the Ventura County based company's 115-year history can attest. They grow a variety of fruit and nut crops on 7,000 acres in Southern California, including approximately 3,000 acres of lemons and avocados grown in Santa Paula, CA. Part of Limoneira's success lies in their dedication to building partnerships with the community and other companies that share their vision.

In response to the Integrated Waste Management Act of 1989, Limoneira Company formed a partnership with Agromin Corporation to help Ventura County meet required reductions in waste delivered to landfills. The partnership, formed in 2004, mutually benefits both companies. Limoneira provides Agromin with access to five acres of land, on which Agromin produces organic mulch and compost from municipal green waste collected from Ventura County residents. In exchange, Agromin provides Limoneira with valuable soil amendments for their farming operations.

According to Gus Gunderson, Head of Southern Farming Operations, and Ely Key, Special Projects Manager, the organic mulch helps improve both soil structure and water efficiency. As Gus explains, "We are confident that the Agromin product has been helping improve orchard health because after applying mulch to the orchard floor we have seen an increase in overall tree health and productivity. As we add the organic matter, we are adding benefits to the soil structure; improving soil tilth and microbial populations. We are getting better intake of water and better intake of nutrients, which in turn gives us better root systems."

WATER-SAVING PRACTICES

- Limoneira applies organic mulch/compost on their lemon and avocado orchards. Organic mulch reduces the need for water by holding moisture in the soil and reducing the amount of water lost through evaporation.
- Limoneira contracts with Fruit Growers Laboratory to help monitor their soil and water quality, which helps them evaluate soil moisture levels and avoid ground water contamination.
- Limoneira converted to low-flow micro-sprinklers and modified furrows with micro-tubes (spaghetti-tube) emitters to irrigate crops.
- Using no-till farming methods in the orchards, they are able to reduce soil erosion and improve soil moisture holding capacity.

Limoneira lemon grove

BENEFITS

- Compost improves soil structure by reducing bulk density in clay soils and increasing water-holding capacity in sandy soils. Improved soil structure produces better root structures and improves air and water infiltration.
- Mulch holds the soil in place, reducing soil erosion and associated negative impacts on water quality.
- Mulch increases organic matter in the soil, which in turn increases the amount of nutrients available to the trees and plants and reduces the need for chemical fertilizer.
- Organic mulch is beneficial for the maintenance of microorganisms. It provides food and a stable environment, with a constant soil temperature, in which the microorganisms thrive.
- Organic mulch dramatically reduces weed growth and herbicide use.
- Mulch improves tree and plant health, leading to increased plant yield and improved fruit quality. Research conducted by the University of California Cooperative Extension also indicates that mulch can suppress the growth of Phytophthora and reduce the appearance of avocado thrips which cause scarring of immature fruit, thereby reducing the need for chemical pesticides.[4]
- The partnership between Limoneira and Agromin has had significant impacts on reducing the amount of green waste entering landfills.

Agromin green waste shredder

[4] See resources list for research regarding the effects of mulch on Phytophthora and Avocado thrips.

> "Economic efficiency is always driven back to the ranch because irrigation is probably our second largest input, after labor. If you include the cost of water, the energy to pump the water and the time to go out and check the sprinkler systems, it adds up really quickly."
>
> —Gus Gunderson

COSTS

- The cost of spreading the mulch including equipment and labor is around $350 per acre.
- Limoneira receives the mulch free in exchange for providing Agromin with five acres of land to use for mulch production.

LESSONS LEARNED

- **Develop partnerships.** By developing a partnership, Agromin Corporation and Limoneira help recycle the community's green waste while providing mulch for Limoneira's orchards and a marketable product for Agromin.

Applied mulch at Limoneira

NICASIO NATIVE GRASS RANCH
(MARIN CARBON FARM)—Nicasio, CA

© Colleen Proppe, 2008

KEYLINE DESIGN & YEOMANS PLOW
NATIVE GRASSES

Peggy Rathmann and John Wick

Becoming cattle ranchers was far from what John Wick and Peggy Rathmann imagined when they bought their 539-acre Marin County ranch in 1998. John and Peggy wanted a "piece of wilderness," but discovered that grazing was essential to maintaining native grasses and wildflowers. Peggy realized that "the native flowers co-evolved with huge herds of elk, so native flowers need to be grazed." John explains that "cows are the reason we now have native flowers on our ranch." Ten years later, they seasonally graze 150 certified organic, certified grass-fed cows and steers using a "Tall Grazing" plan designed by Abe Collins from Carbon Farmers of America. Tall Grazing employs short-duration, ultra high-density stocking to mimic ancient elk herds. The short duration ensures that the cows only have time to "cream" off the nutritious tops of the grass plants. With plenty of leaf area left intact, photosynthesis can continue and the grazed plants recover rapidly. Not only that, but much of what the herd tramples becomes compost. The result is a rapid increase in soil organic matter.

Through their experiments in preserving native grass species, John and Peggy discovered Keyline design principles of soil conservation and water harvesting. They were happy to learn that they could recharge the groundwater and potentially see the dried-up creeks on their ranch start to flow year-round. John says that by using Tall Grazing practices along with remediation of compaction with a Yeomans plow, "it is possible to build a sponge of soil that absorbs rainwater rather than allowing it to rush away with our topsoil. Every year there are more and more delicious native grasses and forbs. The cows love it here and so does the wildlife."

Yeomans plow

WHAT IS KEYLINE DESIGN?

- P.A. Yeomans developed the Keyline system to address decreasing water supplies and soil erosion on Australian rangeland.
- Keyline systems use natural landscape contours and cultivation techniques to harvest rainwater and build soil.
- The idea behind Keyline design is to reverse the pattern of water flowing away from ridges and concentrating in valleys. Redistributing the flow of water to the ridges using precise plow lines slightly off contour slows the spread of water and maximizes absorption into the soil.
- Keyline plans include hedgerows and swales – depressions that divert and capture water runoff for soil absorption.
- Yeomans designed a special chisel plow that loosens the sub-soil without inverting the soil. The rip patterns from the plow direct the movement of water across the land. Water slows and spreads to the ridges where the land is drier and the water can be more easily absorbed.

- Small ponds of surplus runoff water can be placed at the natural intersection of a ridge and a valley, known as a key point. This stored water can provide gravity-fed irrigation later in the season for pastureland or crops.

BENEFITS

- Keyline cultivation practices increase water infiltration by slowing and directing water to drier land (ridges) where it can be absorbed. Peggy explains, "Slowing and spreading running water prevents the formation of gullies that lower the water table and dry out soils. When running water moves at walking speed, soil particles settle out rather than wash away."
- The sub-soil loosening plow helps to increase soil depth and fertility. According to John, "The Yeomans plow is a remedy for compaction – it breaks up the root barrier. The roots can now grow deeper because air, warmth, and moisture can go deeper. Perennial grasses love it."
- With the Marin Carbon Project, they are working to verify the carbon sequestration benefits of managed grazing, compost application, and compaction remediation with enhanced water infiltration using the Yeomans plow and Keyline planning.
- Keyline practices reduce soil erosion by slowing and directing the movement of runoff water to the ridges and away from the valleys.

Yeomans plow

Nicasio Native Grass Ranch (Marin Carbon Farm)
photo credit: © Colleen Proppé 2008

COSTS

- Implementing a Keyline design plan requires an understanding of the concepts explained in P.A. Yeomans's books, which are available online. (See Resources section.)
- The cost of a Yeomans plow starts at around $8,000. However, Yeomans plows are becoming available for rent in some areas of California.

LESSONS LEARNED

- **Use the Yeomans plow as a remedy for compaction and as a rainwater-harvesting tool.** John explains, "Use it before three growing seasons and don't graze plowed areas for 6 weeks. Once soils are thriving, the plow can move out into the community. In Marin, our RCD is considering buying plows as rental units."
- **Attend a workshop.** Keyline workshops are periodically available through local permaculture organizations. (See Resources section for more information.)
- **Consult with an expert before using the plow.** Severe erosion can occur if you do not use the plow properly.

RED ROCK RANCH
Five Points, CA

INTEGRATED ON-FARM DRAINAGE MANAGEMENT SYSTEM
LOW-PRESSURE CENTER PIVOT SPRINKLERS
MINIMUM TILLAGE

John Diener
with his Forever Water Machine

John Diener's family started farming in the Central Valley in 1929. After pursuing a degree in Agricultural Economics at UC Davis, John decided to follow his passion and returned to the Valley to farm. In 1980, John started Red Rock Ranch in Five Points, CA, located southeast of Fresno. He currently farms 7,000 acres of fruit and vegetable crops including almonds, grapes, wheat, alfalfa, sugar beets, tomatoes, and spinach.

Many factors threaten the future of farming on the west side of the San Joaquin Valley, where John farms. The soils are naturally rich in selenium and the combination of continuous irrigation and poor drainage has resulted in concentrated levels of salinity and selenium in the soil and drainage water. Drainage issues also plague this area. An impermeable layer of clay prevents the irrigation water from filtering deep into the ground and the trapped irrigation water forms a shallow, or perched, water table. With nowhere to go, the salty water rises closer to the surface and affects the productivity of the land. The selenium levels in the drainage water are toxic to wildlife and impede safe off-farm drainage and disposal of the water. The result is a zero-discharge parameter and the need for innovative strategies to deal with the build-up of nutrient-rich drainage water and land that is no longer productive.

John has been working on a solution to this dilemma. As he explains, "Ultimately, the goal is not exposing the drain water to the community at large, whatever that is – the ducks, people or whatever - and be able to have total utilization of the water resource that has been dedicated to the long-term sustainability of the farmer. This whole project - whether it is water, whether it is human, whether it is soil - is a matter of how we treat resources that we all have at our disposal and how we manage those things for the best benefit of everybody."

Driven by a passion for learning, John has developed a number of innovative projects that he hopes will help the farm move forward, stay in business and allow John to pass it on to the next generation. He is in the last phase of completing the design for an Integrated On-Farm Drainage Management (IFDM) system that addresses drainage problems, rehabilitates the land back into high-value production, and creates resources from the wastewater. (See IFDM text box.)

WATER-SAVING PRACTICES

- The Integrated On-farm Drainage Management System (IFDM) reduces irrigation water use by about 20%. With this system, John is able to rehabilitate the saline and selenium saturated land while creating an economic resource from drainage water traditionally considered waste.
- John uses new-generation center pivot sprinklers equipped with smart controllers for precise irrigation scheduling. These low-pressure sprinklers apply large diameter droplets that reduce evaporative losses.
- John's irrigation management team checks soil moisture levels with an inductance probe to ensure that their CIMIS based irrigation scheduling system is accurately set.
- Through minimum tillage techniques, John has cut tractor work by approximately 80 percent, while improving water infiltration.
- John irrigates his permanent almond and grape crops with drip tape.

BENEFITS

- The Integrated On-Farm Drainage Management system returns land into productivity, improves water quality and protects wildlife.
- The selenium and salt harvested through the land reclamation system provide value-added products.
- The solid set center pivot sprinklers "eliminate quite a bit of labor, the type of labor that you have a hard time finding – the hand-moved sprinkler labor."
- The center pivots are low pressure, reducing the amount of energy needed to irrigate.
- Minimum tillage reduces tractor use and related energy and labor costs. Employing minimum tillage also reduces Nitrogen Oxides (NOx) and particulate matter air pollution.

COSTS

- "The center pivot system is considerably less - an installed drip systems cost about $1,200 to $1,400 an acre, whereas the center pivot systems cost about $500 an acre to put in. At the end of the day, it is a lot cheaper not only from a capital cost, but from an operational cost than a traditional stand. Pivots give you much broader latitude as far as what crops you grow, so you have much more diversity in responding to the economics of the day," explains John.
- The drain tiles for the integrated on-farm drainage management system cost about $600 per acre. John is still trying to get exact figures on the capital costs for the water distillation machine, the brine shrimp processor, and salt harvesting equipment. (See text box.) However, these expenses are offset by the increase in value of the reclaimed land by approximately $1,600 per acre and a net return on higher-value crops of $150 - $375 per acre per year.

LESSONS LEARNED

- **Create resources out of waste.** John explains that "another part of the puzzle for sustainability is getting the item to produce some revenue so that it isn't just all subsidies at the back end to take care of the waste products. We are taking the products that people want to treat as toxic substances, creating, and making them into resources."
- **Keep changing.** "I am of the opinion that you have to move with the times. I always keep moving – you might turn into a pillar of salt if you stand still."
- **Become energy independent.** John's goal is to farm with passive energy – solar, wind, and concentrating solar and avoid buying energy from the grid. He explains, "My goal in life is to be self-sufficient in power. I think we will be in ten years."

Integrated On-Farm Drainage Management System

With a subsurface drain tile system, salt is leached out of the soil and perched water table and the land is returned to production for high-value crops. The drainage water is then sequentially re-used several times to irrigate blocks of increasingly salt-tolerant plants (halophytes), including pasture grasses that are used as winter feed for rangeland cows. The canola and mustard seed that John grows as one of the salt tolerant crops help remove selenium from the soil. These seeds contain oil that John extracts with pressing equipment to produce biodiesel to fuel farm vehicles. After the oil is removed, what remains is a selenium-enriched seed meal that John intends to market as a feed supplement for dairy cows. Finally, the salt-saturated water enters a solar evaporator or a salt-water pond filled with brine shrimp, which remove selenium from the water. John is currently designing a second-generation Integrated On-Farm Drainage Management system with a water distillation machine that will harvest available water by mining the salt out of the tiled drainage water. This new machine, the "Forever Water Machine," will effectively replace the solar evaporator and the system of recycling the water through successive lesser value crops. The final system will include a three-stage process that produces distilled water, brine shrimp and salt while reclaiming the land for higher value crops. Ultimately, John plans to market the brine shrimp as fish food or as selenium supplements for animal feed. He hopes to market the harvested salt as a product for dust suppression.

Low-pressure center pivot sprinklers

STRAUS FAMILY CREAMERY
Marshall, CA

Photo credit: Straus Family Creamery

WATER RECYCLING
NO-TILL PLANTING
COMPOST

Albert Straus

With a focus on the future, Albert Straus, owner of Straus Family Creamery, is continuing the legacy of the 660-acre dairy farm his father started in 1941. The Marin County dairy is located in Marshall, CA, on the rolling hills next to Tomales Bay. After growing up on the farm and working alongside his father, Albert decided to dedicate himself to the survival of the dairy. He received his dairy science degree from Cal Poly in 1977 and returned home to work with his father. The next step was to figure out how to ensure the future viability of the dairy.

Water availability and runoff were perhaps the most significant issues affecting the future viability of the farm. "Water is a precious resource for us.... I don't think that we've had an abundant source in my lifetime. We live on Tomales Bay, a big salted water body, but there is very little fresh water. There is no water table. We do not have water to use to irrigate the land other than the collected liquid manures. It is always something that we focus on and it is a bigger issue all the time," explains Albert. In fact, they haul water from Petaluma for use in the creamery, since their well only provides enough water for the dairy.

© California integrated waste management board

WATER-SAVING PRACTICES

- Straus Family Creamery collects 30,000 gallons of water per day from the dairy and creamery. They process and treat the wastewater with a covered lagoon anaerobic digestion system and reuse 10,000 gallons of recycled water to flush and clean the free-stall barns every day. (See Water Recycling text box.)
- They do not irrigate their feed crops, but instead rely on winter rains to provide enough water for their no-till planted silage crops and minimum tilled native grass pastureland.
- Separated manure solids provide excellent compost for pastureland and silage crops. The compost improves water infiltration and soil moisture holding capacity and helps reduce soil erosion.
- They seek equipment that does not use water for the creamery, such as the milk-cooling equipment.
- In the creamery, they use high-pressure, low-flow systems and try to reuse water and chemicals with custom-designed water reclamation systems.
- The creamery boilers have a condensate return line so that the condensed steam returns to the boiler.

BENEFITS

- Storing and processing manure and wastewater prevents runoff from leaving the farm and contaminating the local watershed.
- Composted solids and excess liquids provide organic fertilizer and irrigation to pastures and silage crops and reduce associated costs.
- Electricity generated from the anaerobic digestion system powers 90 percent of the dairy in addition to employee housing, on-farm vehicles, and a company car.

Straus saves approximately $50,000 a year on energy costs.

- A net metering agreement with PG&E allows Straus to offset electricity costs at the creamery.
- The lagoon covers trap air-polluting emissions.
- Lagoon covers greatly reduce odors and fly populations on the farm.

Water Recycling

- They collect wastewater from the creamery to flush the milking barn and free-stall barn. A tractor then scrapes manure and wastewater toward a storage pond and a screw press separator separates solids for composting.
- In a second covered lagoon, anaerobic digestion breaks down the bacteria in the remaining liquids.
- A lagoon cover captures the methane gas released from the manure and anaerobic digestion process and a generator converts the gas into electricity.
- Pumps transport the treated water into storage tanks until it is needed to clean the free-stall barns.
- Excess heat produced by the electricity generator heats the treated water to 180 degrees for reuse in cleaning the free-stall barns.
- A series of additional ponds store excess wastewater if necessary.

COSTS

- The cost of refurbishing the existing lagoon to a covered lagoon anaerobic digestion system was $340,000.
- The farm received $140,000 in grants from the California Energy Commission (CEC) and the US Environmental Protection Agency (EPA).
- With electricity generation, the payback period was 5 years.
- By reusing water, they save thousands of gallons of water per day and enjoy lower water delivery costs.
- Minimum tillage practices cut fuel and labor costs.
- The methane digester reduces greenhouse gas emissions by capturing and converting biogas into electricity.

LESSONS LEARNED

- **Start small.** With processing plants, start small; try things out and scale up later, unless you need to do so immediately.
- **Get help.** Get the expertise and technology needed to do the job right.
- **Choose equipment wisely.** Make sure that equipment is designed properly so that it does not have to be replaced early. In the case of Straus Family Creamery, the corrosive salt air forced them to replace electrical and metal equipment that had corroded.
- **Form strategic partnerships.** Albert recommends forming strategic partnerships between key agencies, organizations, and individuals to identify and test various practices as a group.

Straus Family Dairy on Tomales Bay—Photo credit: Straus Family Creamery

Straus Family Dairy cows—Photo credit: Straus Family Creamery

SUNCREST NURSERIES
Watsonville, CA

WATER RECOVERY SYSTEM
IRRIGATION SCHEDULING

Jim Marshall

Suncrest Nurseries, located on the outskirts of Watsonville, is a wholesale nursery growing over 3,000 varieties of containerized ornamentals for independent garden shops throughout California. The nursery grows two million plants a year on three properties with a total of 60 acres in production.

Suncrest Nurseries was established in 1989 when a group of investors purchased the historical Leonard Coates Nurseries, which was founded in 1870 and was one of the first nurseries to promote California native plants. With such a deeply rooted legacy, the primary goal of the new owners was to ensure the long-term sustainability of the business.

Jim Marshall, equipped with a background in hydrology and a history of working with the original nursery, took the position of General Manager. His highest priority in re-developing the nursery was to address the issue of water so the company would be prepared for the future. He designed a water recovery and computer-operated irrigation system that has cut their water use in half. As Jim explains, "It was just common sense that we didn't want our water to go down the drain and not use it as efficiently as possible. It was also very obvious that we would some day be facing a water crisis because there is so much development and we are all sucking from the same straw. By doing this, we are making every effort to help our future. The company has been in business as a nursery since 1878 and there is a lot of legacy that I would like to sustain."

WATER-SAVING PRACTICES

- A water recovery and recycling system captures nursery runoff and blends the nutrient-rich water with fresh water for reuse as nursery irrigation water. (See Water Recovery System text box.)
- Suncrest irrigates based on plant needs by means of a computer-operated irrigation delivery system that precisely controls irrigation scheduling and timing. As Jim explains, "We have very precise control over the amount of time that we water. We are pumping approximately 1,800 gallons a minute and the consequence of being much more precise in our delivery time is that we are conserving water."
- The nursery is organized in irrigation zones based on plant water needs in order to maximize water distribution uniformity.
- They irrigate most of the plants in 5-gallon and 15-gallon containers with drip emitters.
- Overhead sprinklers with closely spaced low-pressure nozzles are used for plants in 1-gallon containers.[6]
- They are experimenting with capillary mats for the 1-gallon containers.[7]

BENEFITS

- The water recovery and recycling system provides greater control over nutrient management because it

[6] They do not use drip irrigation with 1-gallon containers because it is not cost effective – it is very labor intensive to put an emitter into each 1-gallon container. In addition, there are some benefits of overhead water application for syringing – the application of water to cool the plants down and prevent plant wilt - and washing the leaves to prevent dust accumulation and associated mite growth.

[7] A capillary, or aqua, mat is a multi-layered medium composed of drip tapes and an absorbent sponge in between a tarp and a non-permeable layer on the bottom. Plant roots uptake water into the pot through tiny holes in the top layer of the mat.

is a closed system. It promotes healthier plant growth and reduces inputs by capturing excess water used to leach salts that build up from fertilizer, and recycling the nutrients back through the system.

- By recovering and reusing water, the nursery is reducing its reliance on groundwater.
- The drainage and recovery system has eliminated soil erosion and kept nutrient-saturated run-off from leaving the nursery, which also prepares Suncrest for regulations that could arise in the future.
- Profiling land to maximize gravity flow for the drainage system reduces electricity costs. Additionally, pumping water from the storage ponds requires less energy than pumping water from the ground.
- Increasing input efficiency has allowed them to expand and grow the business.

COSTS

- The recovery system costs include engineering consulting fees for the general design of the drain system, ground preparation fees and supplies including ground cloth (impermeable barrier) and drainage and distribution pipelines.
- Equipment costs for water recycling include a filtration system, a variable frequency drive pump, programmable logic controller (PLC) system, and a computer and software package to operate the system.
- Operating costs include electricity to operate the pump.

Suncrest Nursery—Photo credit: Suncrest Nursery

"The nursery is a manageable unit. You see what is coming in and you know what is going out - hopefully what is coming in are raw products and what is going out are saleable products and you are also reducing the waste. Waste is not part of a profit package. It is something that you consume without getting the benefit of a sale. The water is a part of that too."

—Jim Marshall

LESSONS LEARNED

- **Think ahead.** Jim recommends addressing potential issues with a focus on the future. "We did not do it under the threat of regulation, we did not have somebody standing outside of the gates saying "you will do this and you have X amount of time, or worse, you have a ten thousand dollar fine until you do it."
- **Let gravity do the work for you.** Jim explains, "This is all common sense. The biggest concept that most people don't appreciate is gravity. Water flows downhill and that is the simplest thing – all you have to think is where am I going to collect it? You want to design it at the lowest part so that gravity does the work for you."
- **Buy a variable frequency drive pump.** According to Jim, "With these, you are only consuming the power that is required for the need that you have – a demand system."
- **Get a good filtration system.** It is a good idea to have a very high capacity, self-cleaning filter like the Amiad Filtration System. As Jim explains, "The filter is important because the pond is exposed to sunlight and runoff fertilizer. Algae quickly grow in the water and plugs up sprinklers and drip emitters."

Water Recovery System

An impermeable Visqueen 6-mm thick, polyethylene barrier lines the entire nursery and eliminates percolation losses and sediment erosion. Each nursery block is gravity profiled to direct the flow of surface runoff, and rainwater from the downspouts on all buildings. A network of drains and underground trenches transport runoff to recovery ponds at the low end of the nursery blocks. After blending the recovered runoff with 50% fresh water, they recycle the water back through the irrigation system.

RESOURCES

Agricultural Water Resources

CALIFORNIA AGRICULTURAL WATER STEWARDSHIP INITIATIVE

http://agwaterstewards.org/

This website includes resources about practices that promote improved agricultural water stewardship in California.

SUSTAINABLE AGRICULTURE RESEARCH AND EDUCATION

http://www.sare.org/coreinfo/farmers.htm

This website is designed to share information for farmers about agricultural systems that are profitable and environmentally sound. You can also access a range of SARE publications at http://www.sare.org/publications/ or:

Sustainable Agriculture Publications

PO Box 753

Waldorf, MD 20604-0753

Phone: (301) 374-9696

ATTRA - NATIONAL SUSTAINABLE AGRICULTURE INFORMATION SERVICE

www.attra.ncat.org

Provides the latest in sustainable agriculture and organic farming news, events and funding opportunities, plus in-depth publications on production practices, alternative crop and livestock enterprises, innovative marketing, organic certification, and highlights of local, regional, USDA and other federal sustainable ag activities.

P.O. Box 3657

Fayetteville, AR 72702

Phone: (800) 346-9140

CENTER FOR IRRIGATION TECHNOLOGY (CIT)

http://cati.csufresno.edu/cit/

California State University, Fresno

5370 N. Chestnut Avenue

Fresno, California 93740-8021

Phone: (559) 278-2066

CIT is an independent irrigation technology research and testing facility. Their website features software packages, on-site testing services, and several online publications about irrigation efficiency in large and small-scale irrigation systems.

CALIFORNIA STATE UNIVERSITY - WATER RESOURCES AND POLICY INITIATIVES

www.calstate.edu/water/

CSU initiative focused on developing solutions for sustainable water resource management in California through education, applied research and policy development.

RESOURCE CONSERVATION DISTRICTS

www.carcd.org

Some of the regional RCDs assist farmers with agricultural water practices and act as a liaison with state agencies. You can locate your local RCD through the California Association of RCD's website or by calling (916) 457-7904.

UC COOPERATIVE EXTENSION

http://ucanr.org/ce.cfm

Cooperative Extension Farm Advisors work with farmers and others to identify current and emerging agricultural opportunities and problems, field-test agricultural improvements or solutions and promote the use of these research findings. Visit the UC Cooperative Extension website to locate County Cooperative Extension offices and contact information.

USDA NATIONAL AGRICULTURAL LIBRARY (NAL) ALTERNATIVE FARMING SYSTEMS INFORMATION CENTER

http://afsic.nal.usda.gov/nal_display/index.php?info_center=2&tax_level=1&tax_subject=293

The National Agricultural Library is a comprehensive resource list featuring information on conservation tillage composting, soil conservation, crop rotation, mulching, and cover crops.

USDA NATURAL RESOURCES CONSERVATION SERVICE (NRCS)

http://www.ca.nrcs.usda.gov/

Richard E. Lyng USDA Service Center

430 G Street #4164

Davis, CA 95616-4164

(530) 792-5600 (California NRCS State Office)

NRCS offers several cost sharing programs that assist with on-farm conservation projects.To find your local service center, visit this site and click on your county:

http://offices.sc.egov.usda.gov/locator/app?state=CA

General On-farm Water Conservation Resources

SMART WATER USE ON YOUR FARM OR RANCH

http://www.sare.org/publications/water/water.pdf

This free bulletin provides information on innovative practices for on-farm water conservation including soil management, water management, and plant management techniques.

ATTRA WATER QUALITY, CONSERVATION, DROUGHT AND IRRIGATION PAGES

http://www.attra.org/water_quality.html

This website features several free handbooks (available online) covering topics including water use, soil moisture management, water quality, and water conservation.

Soil Resources

USDA - NRCS WEB SOIL SURVEY

http://websoilsurvey.nrcs.usda.gov/app/

The Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It provides soil maps and data available online for more than 95 percent of the nation's counties.

BUILDING SOILS FOR BETTER CROPS, 2ND EDITION

By Fred Magdoff and Harold van Es

Handbook Series Book 4 $19.95 (Available for free online)

http://www.sare.org/publications/bsbc/bsbc.pdf

This 241-page book covers the basics of soil organic matter as well as soil and crop management with compost, manure, cover crops, crop rotation, reduced tillage, and nutrient management.

UC (SAREP) SOIL QUALITY RESOURCE LIST

http://www.sarep.ucdavis.edu/soil/websites.htm

This website provides a list of websites and resources providing information about soil quality.

Mulch & Compost Resources

FARM-SCALE COMPOSTING RESOURCE LIST

By Steve Diver

http://www.attra.org/attra-pub/farmcompost.html

ATTRA Publication #IP026/128 (Available for free online)

This online publication features a resource list of reference books and manuals, websites on farm-scale composting.

NATURAL RESOURCE, AGRICULTURE, AND ENGINEERING SERVICE (NRAES) ON-FARM COMPOSTING HANDBOOK

http://www.nraes.org/nra_index.taf

NRAES Publication # NRAES-54 $25.00

This 186-page handbook presents a thorough overview of farm-scale composting and explains how to produce, use, and market compost. It includes information on the benefits and drawbacks, the process, raw materials, methods, operations, and management of on-farm composting.

Biodynamic Farming Resources

BIODYNAMIC FARMING & COMPOST PREPARATION

By Steve Diver

http://attra.ncat.org/new_pubs/attra-pub/PDF/biodynam.pdf?id=California

ATTRA Publication #IP137 (Manual available online)

This manual presents an overview of biodynamic farming systems with a detailed description of biodynamic compost preparation.

BIODYNAMIC FARMING AND GARDENING ASSOCIATION

http://www.biodynamics.com/

This website provides a comprehensive book list resources for biodynamic farming.

Cover Crops Resources

MANAGING COVER CROPS PROFITABLY, 3RD EDITION

http://www.sare.org/publications/covercrops/covercrops.pdf

Handbook Series Book 9 $19.00 (Available for free online)

This is a comprehensive 244-page manual detailing the benefits of cover crops and their use in building soil tilth, managing pests, and conservation tillage. It includes a detailed review of seed species including non-legume, legume and seed blends.

UC (SAREP) COVER CROP DATABASE

http://www.sarep.ucdavis.edu/ccrop/index.htm

This is an extensive database of information about the management and effects of more than 32 species of plants usable as cover crops.

Conservation Tillage Resources

UC COOPERATIVE EXTENSION CONSERVATION TILLAGE WORKGROUP

http://groups.ucanr.org/ucct/

This website details the practice of conservation tillage including case studies, equipment contacts, multi-media presentations and publications.

MINIMUM TILLAGE VEGETABLE CROP PRODUCTION IN CALIFORNIA

By Jeffrey Mitchell, Louise Jackson, and Gene Miyao

http://anrcatalog.ucdavis.edu/VegetableCropProductioninCalifornia/8132.aspx

Publication #8132 (Available online)

This article covers reduced-tillage, or minimum-tillage, production systems for vegetables as a strategy to control costs and manage soils.

CONSERVATION TECHNOLOGY INFORMATION CENTER (CTIC)

http://www.ctic.purdue.edu/Core4/CT/CT.html

This is a website dedicated to conservation tillage. It features articles and publications covering the basics of conservation tillage, new research and technologies, and listing of conservation tillage organizations throughout North America.

Water Management Resources

EVALUATING SPRINKLER IRRIGATION UNIFORMITY

ByTim P. Wilson and David F. Zoldoske

http://cati.csufresno.edu/cit/rese/97/970703/

CATI Publication #970703 (Available online)

A step-by-step guide to help determine sprinkler system distribution uniformity.

USDA – NRCS NATIONAL ENGINEERING HANDBOOK ON IRRIGATION

http://www.wsi.nrcs.usda.gov/products/w2q/downloads/Irrigation/National%20Irrigation%20Guide.pdf

This is an exhaustive 754-page manual outlining the details of on-farm irrigation including an overview of soil, crops, irrigation systems, water management, energy requirements, and environmental concerns. (Available online)

On-Farm Drainage Management Resources

DEPARTMENT OF WATER RESOURCES INTEGRATED ON-FARM DRAINAGE MANAGEMENT

http://www.sjd.water.ca.gov/drainage/ifdm/index.cfm

This website provides an overview of Integrated On-Farm Drainage Management including information on salt management, the components of a IFDM system, plant selection, monitoring wildlife issues, and economics.

http://cast.csufresno.edu/faculty/sbenes/Research/Final%20Rep,%20ARI,%20IFDM,99-02%20(Benes%27%20website).pdf

Constructed Wetlands Resources

CONSTRUCTED WETLANDS

By Preston Sullivan

http://attra.ncat.org/new_pubs/attra-pub/PDF/wetlands.pdf?id=California

ATTRA Publication (Brochure available online)

This brochure provides a listing of resources that provide information about constructed wetlands.

Soil Moisture Monitoring Resources

MEASURING AND CONSERVING IRRIGATION WATER

http://attra.ncat.org/attra-pub/PDF/irrigation_water.pdf

By Mike Morris and Vicki Lynne

ATTRA Publication (Manual available online)

This manual describes how to find the net water application rate for any irrigation system and how to calculate the number of hours the system should be operated. It also describes several ways to measure flowing water in an open channel or pipeline, and offers suggestions for irrigating with limited water supplies.

SOIL MOISTURE MONITORING: LOW COST TOOLS AND METHODS

http://www.attra.org/attra-pub/PDF/soil_moisture.pdf

By Mike Morris

ATTRA Publication (Manual available online)

This manual explains how soils hold water and surveys some low-cost soil moisture monitoring tools and methods, including user-friendly electronic devices.

Irrigation Scheduling Resources

IRRIGATION SCHEDULING: A GUIDE FOR EFFICIENT ON-FARM WATER MANAGEMENT

http://anrcatalog.ucdavis.edu/Irrigation/21454.aspx

By David A. Goldhamer

UC ANR Publication Number #21454 $7.00 (Available for purchase online)

This guide discusses how to measure soil, atmospheric, crop, and irrigation factors to determine the most efficient irrigation schedule.

SCHEDULING IRRIGATIONS: WHEN AND HOW MUCH

http://anrcatalog.ucdavis.edu/Irrigation/3396.aspx

By Blaine Hanson, Larry Schwankl, and Allan Fulton

UC ANR Publication Number #3396 $25.00 (Available for purchase online)

This is a comprehensive 204-page manual providing information about irrigation scheduling, estimating evapotranspiration, procedures for developing an irrigation schedule, and measuring soil moisture levels.

Hedgerows & Native Grasses Resources

AUDUBON CALIFORNIA - LANDOWNER STEWARDSHIP PROGRAM

http://ca.audubon.org/lsp/

5265 Putah Creek Road

Winters, CA 95694

(530) 795-2921

The Landowner Stewardship Program helps landowners to restore wildlife habitat and implement conservation practices on farms and ranches in a manner compatible with existing agricultural operations. The program operates in Colusa, Imperial, Napa, Solano and Yolo Counties.

COMMUNITY ALLIANCE WITH FAMILY FARMERS (CAFF)

www.caff.org

P.O. Box 373, Davis, CA 95616

(530) 756-8518

CAFF provides information to assist growers in adopting a whole systems approach to farm management. This approach focuses on conserving water, soil, and air resources while maintaining long-term profitability.

YOLO COUNTY RESOURCE CONSERVATION DISTRICT (RCD)

http://yolorcd.org/

221 West Court Street, Suite 1,

Woodland, CA 95695

(530) 662-2037

The RCD assists growers to implement practices that protect, improve, and sustain agricultural and natural resources. This website includes books and online articles about hedgerows and other on-farm conservation practices.

HEDGEROWS: BENEFITS TO FARMERS, BENEFITS TO WILDLIFE

By the Resource Conservation District of Santa Cruz County and CAFF

http://www.caff.org/publications/Hedgerow_Brochure2.pdf

This pamphlet provides a brief overview of hedgerow design, installation and maintenance and includes a resource list. (Brochure available online)

BRING FARM EDGES BACK TO LIFE! LANDOWNER CONSERVATION HANDBOOK

Designed and edited by Paul Robins, Rebecca Bresnick Holmes, and Katherine Laddish

http://yolorcd.org/resources/manuals/Farm%20Edges%20v5.pdf

This is a compilation of articles addressing conservation strategies using hedgerows with information on planting techniques, insect and wildlife habitat formation and resources. (Book available online)

HEDGEROW FARMS

http://www.hedgerowfarms.com

21740 County Road 88

Winters, CA 95694

(530) 662-6847

Visit the farm to see established hedgerows. They specialize in single species and seed mixes for native grasses and forbs and provide consultation services.

HEDGEROWS FOR CALIFORNIA AGRICULTURE: A RESOURCE GUIDE

By Sam Earnshaw

http://www.caff.org/programs/farmscaping/Hedgerow.pdf

This comprehensive 70-page manual provides specific information for developing hedgerows on your property. It includes a resource list of native plant nurseries and technical consultants for assistance with implementing hedgerows and other restoration projects. (Manual available online)

Keyline Design Resources

A KEYLINE PLAN

By P.A Yeomans

This is the original text outlining the principles of Keyline design.

For an online version of the book, visit Soil and Health digital library:

http://www.soilandhealth.org/01aglibrary/010125yeomans/010125toc.html

WATER FOR EVERY FARM

By P.A Yeomans

This book details the principles and techniques for implementing Keyline design on agricultural lands.

The fourth edition of this book is available for purchase on Amazon.com:

http://www.amazon.com/Water-Every-Farm-Yeomans-Keyline/dp/1438225784

KEYLINE DESIGNS

http://www.keyline.com.au/

Ken Yeoman's (P.A Yeomans' son) website featuring information, resources and services for Keyline design.

YEOMANS PLOW COMPANY

http://www.yeomansplow.com.au/yeomans-plows.htm

This website features a wealth of information on Keyline design and Yeomans plows.

DARREN DOHERTY

Australian Keyline Designer & Educator

http://permaculture.biz/index.php

Darren is an avid Keyline design educator and consultant. He can create a remote Keyline design using GoogleEarth for a very reasonable fee.

UC AGRICULTURE AND NATURAL RESOURCES RANGELANDS, SOILS, AND CARBON WEBSITE

http://groups.ucanr.org/RangeSoilsCarbon/Carbon%2C_Soils_%26_Your_Ranch/

This is a website about the UC research on soil carbon sequestration on California grasslands.

RAINWATER HARVESTING FOR DRYLANDS AND BEYOND

By Brad Lancaster.

http://www.harvestingrainwater.com/books/

These books describe how to conceptualize, design, and implement sustainable water-harvesting systems.

Dry Farming Resources

(Although there are few, if any, current dry farming resources available, the following resources provide interesting and useful information regarding dry farming.)

DRY-FARMING: ITS PRINCIPLES AND PRACTICE

By William Macdonald

This is a fascinating 1909 text about dry farming including information on the history of dry farming, conservation of soil moisture, rainfall and evaporation, tillage and crops.

For a free online version of the book, visit The Internet Archive digital library and choose preferred reading format:

http://www.archive.org/details/dryfarmingpriples00macdrich

ARID AGRICULTURE; A HAND-BOOK FOR THE WESTERN FARMER AND STOCKMAN

By Burt C. Buffum

This is a 1909 text about farming in an arid climate with information about dry farming and moisture conservation and management techniques.

For a free online version of the book, visit The Internet Archive digital library and choose preferred reading format:

http://www.archive.org/details/aridagriculturеh00buffrich

DRY-FARMING: A SYSTEM OF AGRICULTURE FOR COUNTRIES UNDER A LOW RAINFALL

By John A. Widtsoe

This is a 1911 text about dry farming including information on dry farming conditions, soils, root systems, soil water storage, evaporation & transpiration, crops, and cultivation implements.

For a free online version of the book, visit The Internet Archive digital library and choose preferred reading format:

http://www.archive.org/details/dryfarmingsystem00widtuoft