

CONTENTS

SOIL MANAGEMENT 2
COMPOST 3
CONSERVATION TILLAGE 4
COVER CROPS 5
PLANT MANAGEMENT 7
CROP ROTATION 7
WATER-CONSERVING PLANTS 8
RANGELAND DROUGHT STRATEGIES 11
WATER MANAGEMENT 12
SMART IRRIGATION 12
WATER RECYCLING 15
RESOURCES 16

Smart Water Use on Your Farm or Ranch



A low-energy, precision watering device irrigates an alfalfa field in Newberry Springs, Calif., part of a SARE grant project teaching farmers how to use soil moisture sensors to conserve water. – Photo by Ron Daines

Published by the Sustainable Agriculture Network (SAN), the national outreach arm of the Sustainable Agriculture Research and Education (SARE) program, with funding from the Cooperative State Research, Education and Extension Service, USDA.

Also available at:
www.sare.org/publications/water.htm



ON A STEEP FARM HILLSIDE WHERE HIS PARENTS HAD previously grown hay, Tim Gieseke planted black walnut trees. While he expects to harvest valuable timber in two decades or more, Gieseke grows hay between the rows and will harvest walnuts and graze a flock of sheep in the grove. The enterprises, which make great use of a 15-percent slope that otherwise would have to be left in grass or forage, also feature an important, water-saving innovation to capture rainfall.

Gieseke designed his agroforestry system to maximize water availability. Walnut trees need 35 inches of water a year to thrive, but Gieseke's farm in southern Minnesota averages 30 inches of precipitation annually. To make up the difference, Gieseke, with help from a Sustainable Agriculture Research and Education (SARE) farmer grant, constructed a contour system featuring irrigation holes that trap hillside runoff and convey it to the tree roots. (See profile, p. 14.)

"The hillside obviously sheds water, and quickly in the spring when we have snow melt," said Gieseke,

who farms 50 acres. "We wanted to capture that runoff"

He planted tree seedlings in rows 20 feet apart, created earthen curbs on the contour and augured 9-inch-wide, 30-inch-deep holes between every other tree. The swiss-cheese infiltration system absorbs water from even torrential downpours with minimal runoff.

"If we get a sudden rain, we probably get all of the moisture into the ground, whereas without it, 90 percent of that would run down the hill," Gieseke said. In the first three seasons, he has not irrigated the walnut saplings.

All over the country, and especially in the desert Southwest and semi-arid Plains, farmers and ranchers worry about water. Agriculture accounts for about 85 percent of U.S. water consumption, a reality that contributes to declining ground and surface water quantity and quality. Severe long-term droughts and explosive population growth in dry, previously rural areas compound the problem.

In response, farmers, ranchers and agricultural researchers are designing innovative runoff collection

systems like Gieseke's, managing soil to improve infiltration, and selecting drought-tolerant crops and native forages that grow well with less water.

"The hard truth is that we're drawing down the aquifer," said Vivien Allen, a Texas Tech University researcher who received two SARE grants to study cotton systems that make better use of water. "When I came here in 1995, the clear message was that everything pivots around water."

Access to water has been controversial since settlers migrated west. Today, throughout the West, urban and suburban dwellers compete with one other and with farmers and ranchers over Colorado River withdrawals. Even in the Northeast, farmers face water challenges with annual, short-term droughts.

"Most field crop farmers will experience drought in most years," said Harold van Es, a Cornell crop and soil science professor, who is partnering on a SARE grant examining strategies to improve soil quality, including its ability to hold water. "They are absolutely concerned about water."

Yet, you can create systems that require less water or make better use of what's available via aquifers, streams, rivers, ponds or precipitation. This bulletin from the

Sustainable Agriculture Network is written for producers and agricultural educators who want to consider new approaches to agricultural water use. It showcases innovative research, much of it funded by the Sustainable Agriculture Research and Education (SARE) program, that identifies a range of promising water conservation options.

The bulletin is organized around the following broad tenets:

- **Managing soil.** Applying practices that build soil quality, resulting in a porous, well-structured soil that allows water to infiltrate and holds it there for use by plants. (Part 1)
- **Managing plants and livestock.** Selecting plants, such as drought-tolerant species and native varieties that maximize water availability in crop rotations or pastures. (Part 2)
- **Managing water.** Treating water like a precious resource, capturing, conserving and recycling it among farming enterprises. (Part 3)

For tips on applying some of these strategies on your farm or ranch, or more in-depth sources of information, consult the *What You Can Do* boxes at the end of each section and RESOURCES, p. 16.

PART 1 Soil Management

HOW YOU MANAGE YOUR SOIL CAN SIGNIFICANTLY IMPACT water availability. Some soil management practices increase the amount of water available to crops, while others will degrade soil and decrease available soil water.

Good soil structure improves water infiltration and decreases runoff and erosion. Well-structured soils are porous and allow water to enter easily, rather than running off to be lost to streams and rivers. While you are somewhat limited by your soil texture, you can improve soil structure and water-holding capacity, storing water for future use by plant roots. (See Figure 1) On the contrary, when a soil has poor tilth, soil aggregates break down, increasing compaction and decreasing aeration and water infiltration.

Most soil-improving strategies work slowly over several years, although some produce results sooner. In contrast, management practices that degrade soil are often apparent immediately. For example, working your soil



when it is too wet will compact the soil and degrade its structure.

Soil organic matter plays a vital role in soil quality and soil water availability. Organic material applied to soil and maintained on the surface protects the soil from the impact of raindrops, a major erosive force. Surface residue and mulches also reduce evaporation and smother weeds, leaving more water for plant use.

Studies show that as organic matter increases, soils develop more macropores. That happens because, as

Increasing soil organic matter makes more water available to crops by improving infiltration.

—Photo by Edwin Remsberg

plant residue and other organic amendments decompose, sticky substances bind soil particles and create pore spaces between them. Moreover, organic matter itself can hold water.

“You can change a soil’s pore size distribution, and with that, you can change the available water-holding capacity,” said van Es, a Cornell crop and soil science professor who co-wrote the book, *Building Soils for Better Crops*. (RESOURCES, p. 16.) “There’s more water available to plants when you have a well-structured soil than if it’s compacted.”

Strategies to increase organic matter content include:

- Spreading manure or letting livestock deposit their own manure in well-managed pastures.
- Applying composts (from a variety of materials ranging from poultry litter to leaves).
- Seeding cover crops, which provide nutrient-rich residue after they die.
- Reducing tillage, because plowing breaks down soil aggregation and accelerates organic matter loss.

Van Es is collaborating with other researchers at Cornell in a SARE-funded study examining ways to improve soil health. As part of the project, county extension educators collect data and demonstrate strategies such as reducing tillage, adding cover crops and diversifying from continuous corn to rotations with grass.

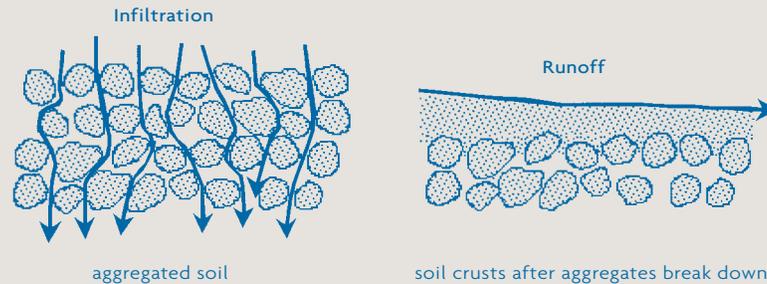
Results are promising. On average, and across a range of soil types from clay loam to loamy sand, the researchers found a 10- to 20-percent increase in the soil’s available water content by reducing tillage or adding another crop to the rotation. On a Cornell experiment station site, researchers saw soil improvements after just two seasons of adding a hairy vetch cover crop between cash crops.

COMPOST

SOME FARMERS, PARTICULARLY ORGANIC PRODUCERS, HAVE long applied manure and compost to meet their fertility needs. However, most non-organic vegetable producers rely on the quicker fix of annual applications of commercial fertilizer. SARE-funded researchers in Virginia tested compost on non-organic vegetable farms to demonstrate its ability to enhance soil quality, including water-holding capacity, bulk density, infiltration, organic matter and plant-available nutrients.

“Water stress is the most critical environmental factor limiting crop production in the southeastern United States,” said Greg Evanylo, professor of crops and soil environmental sciences at Virginia Tech. “After a few

Figure 1:
Changes in soil surfaces and water-flow pattern due to soil crusting



Source: *Building Soils for Better Crops*

drought years, farmers tend to better understand the importance of soil quality.”

Evanylo determined that applying compost (made from three parts yard waste to one part poultry litter) at rates designed to meet vegetable nitrogen needs reduced soil bulk density and compaction, and increased water infiltration.

Compost is relatively expensive. Yet, rising commercial fertilizer costs and nutrient management regulations that prevent confined livestock operators from land-spreading manure on high-phosphorus soils might prompt more producers to begin composting, Evanylo said.

On a previous study, Evanylo found that compost applications at high rates improved yields and water-holding capacity in sandy soils. “When you add cover crops or lots of organic matter, it maintains the structure at the soil surface, preventing the beating-down effect of raindrops that break up the soil,” he said. “It allows water to infiltrate and increases storage.”

You don’t have to use compost, however. Consider applying uncomposted organic material directly to the soil and also using cover crops. Bob Muth, who grows vegetables and hay on 52 acres in Williamstown, N.J., augments his soil organic matter by using cover crops and spreading the leaves collected by local municipalities on some of his fields each autumn. Over the years, he has vastly improved the soil’s infiltration, a must on his gravelly sandy loam that includes 15 percent clay and a tendency to crust.

Typically, Muth covers the ground with up to six inches of leaves, or 20 tons per acre. The following spring, he works in the decomposing leaves. He also plants a variety of cover crops, including sudangrass, a quick-growing high-mass summer cover that breaks up compacted soil. His fields test as high as 5 percent organic matter, unheard of for the mineral soils of southern New Jersey.



CAUTION: APPLY PHOSPHORUS WITH CARE

Managing soil phosphorus is a growing concern for both farmers and environmental regulators because over-applying P in composted or uncomposted animal waste may contribute to surface water pollution. Although phosphorus is an essential element for plant nutrition, excessive amounts can wash or leach into waterways.

Experts suggest analyzing the phosphorus and nitrogen contents of compost and considering it as part of your nutrient management planning. Routine testing is both recommended and widely available. Test your soil – as well as your organic amendments such as compost – for nitrogen and phosphorus levels, and test your compost for moisture content. Find your state’s soil testing lab, typically at your Land Grant University, and ask whether they also have a P index, a newly developed tool to measure phosphorus concentration.

Virginia Tech researchers study the effects of compost on experiment station vegetable plots to improve soil quality, including water-holding capacity and infiltration.

– Photo by Greg Evanylo

CONSERVATION TILLAGE

CONSERVATION TILLAGE LEAVES AT LEAST 30 PERCENT OF THE soil surface covered by residue after planting. No-till planters leave much more than that by placing seeds or transplants in narrow slots, the only area where farmers disturb the soil. No-till consistently improves water infiltration, with reports of up to three times the infiltration of moldboard-plowed soil. Infiltration is likely to continue to increase the longer the soil is under no-till.

In Indiana, SARE-funded researchers at Purdue University tested cover crop mixes in corn and soybean operations. They found that cereal cover crops like wheat and rye increased soil aggregation and thus, water infiltration thanks to a more stable soil structure. Changing to no-till methods rather than plowing also had a great impact.

“Leaving the residue at the soil surface improves the soil,” said project leader Eileen Kladviko, because it minimizes raindrop impact and compaction, and

increases earthworms that develop soil pores. “Either no-till or cover crops can be a benefit.”

Farmers in eastern Washington are adopting a no-till system co-developed by Diana Roberts of Washington State University (WSU) and grain farmer Karl Kupers. With a SARE grant, Roberts and Kupers devised a direct-seeding program where they drill alternative crops like hard red wheat directly into crops grown for seed, such as condiment mustard. The expanded rotation and no-till planting was a revolutionary shift from Kupers’ former wheat/fallow system.

Researchers building on Roberts’ study examined water use efficiency in the direct-seeding system and found that soil water storage and efficiency increased. “There was a trend for larger pore sizes under natural vegetation that would allow the soil to hold more water and provide increased soil aeration,” said lead researcher David Bezdicek of WSU.

In western Colorado, many farmers irrigate in furrows between crop rows plowed clean to facilitate water flow. Aided by a SARE farmer/rancher grant, Randy Hines, a crop farmer in Delta, Colo., wanted a better furrow irrigation strategy. Hines built a tillage tool that leaves vegetative residue on the soil, ripping the earth simultaneously to create irrigation furrows in every other 30-inch row.

Hines saved water by using half the typical number of irrigation furrows. He also protected the soil surface by retaining erosion-reducing corn stalk residue and reduced his tractor trips by half before planting corn, saving between \$35 and \$50 an acre. Corn yields remained similar to the previous year’s crop grown under conventional tillage.

Hines planted yellow beans in the field containing corn stalks using the same minimum tillage practices, comparing conventional plowing on an adjacent field. Hines noticed fewer weeds, used less water, and experienced no yield reduction in his bean harvest. In fact, in just two years, Hines boosted his soil’s organic matter.

Hines’ efforts have sparked interest among other area farmers, who have planted winter wheat in minimum-till corn, onions in hay, and other combinations. “Before our project, there was little minimum tillage done in our valley,” Hines said. After other farmers saw his results, every year “there are more acres not being plowed.”

Another no-till advocate, Steve Groff of Lancaster County, Pa., credits undisturbed soil combined with well-timed, year-round cover cropping, with improving soil quality and water infiltration. Groff, who grows a

NEW YORK FARMER REDUCES TILLAGE, CONSERVES SIGNIFICANT WATER



George Ayres
Vegetables, fruit, grain
Shortsville, New York

— Photo by Patricia L. Ayres

George Ayres is the kind of farmer who thrives on new ideas. Since 1977, he has, as he says, grown a bit of everything on his 600-acre farm in New York’s Finger Lakes Region: strawberries, raspberries, sweet and grain corn, pumpkins, soybeans, alfalfa for hay and small grains. His diversity in crops is matched by his markets, which include selling wholesale to a grocery chain under a low-pesticide label, selling products in his daughter’s farm market and offering pick-your-own berries.

It’s no surprise, then, that when his local Extension agronomist, Jim Capron, told him the next big production innovation was planting with zone till, Ayres was one of the first to try it. Zone till, also known as

strip till, focuses tillage in the crop rows, providing 4- to 5-inch slots into which a farmer later plants, leaving the rest of the soil undisturbed.

“Jim pushed it here in New York ahead of the curve,” said Ayres, who has been zone-till planting since 1996. “I don’t do any other tillage between the rows anymore; I leave all my crop residue on the ground.”

A main goal for Ayres was conserving moisture, and today the tillage system plays a huge part. The area between the rows retains soil cover with crop residue, which captures runoff and minimizes evaporation. Ayres plants cover crops like rye each winter, so the rye residue adds to soil organic matter, improving infiltration. Finally, the ridges, which cut across the contour, act as runoff curbs.

Each fall, Ayres gets to work strip-tilling. With a rotary spreader on his combine, he spreads crop residue as he harvests. Then he creates mini-ridges across the slope, each with a narrow slot, with a zone builder.

“It works really well,” said Ayres. “If we get a deluge of heavy rain in late winter or spring, the ridges stick up like a washboard and stop the water from running down.

If we get a real belly-washer, it goes down the slots, not the slope.”

Ayres spreads his labor using zone till, too. His extra field pass in the fall means less work in the busy spring, when all he does is burn down his weeds with an herbicide and plant.

Ayres is a farmer-collaborator with a team of Cornell researchers funded by SARE to examine ways to improve soil health. The team, which is conducting research on dozens of New York farms, including Fresh Ayr Farm, hopes to demonstrate how strategies such as cover cropping and reduced tillage can improve soil quality.

In spring 2005, upstate New York experienced an unusually dry May with little rain. At the end of the month, Ayres planted soybeans into his ridges and was surprised that it was almost too wet in the strips to run his planter. By contrast, a neighbor who had plowed, disked and cultivated that spring, kicked up so much dust during planting that Ayres couldn’t see him on his tractor seat.

“The secret to soil quality is never to have anything bare,” Ayres said. “I don’t have heavy rains and flooding taking the water and soil away.”

mix of market vegetables and grain crops, designed a no-till vegetable transplanter that allows him to plant seedlings directly into the thick residue of winter-grown cover crops. His annual vegetative residue has built organic matter and makes a noticeable difference when there’s too much or not enough rainfall.

“My crops seem to show drought stress a few days later than those around me,” Groff says. During the typical hot, droughty months of summer, his plants have an added vigor. “That’s when a good no-till system really shines,” he says.

With his video camera, Groff has documented his farm’s ability to absorb heavy rainfall in dramatic contrast to the steady streams of water pouring off his neighbors’ farms. Lancaster County runoff winds up in the Chesapeake Bay.

COVER CROPS

COVER CROPS, SEEDED BETWEEN OR AMID CASH CROPS, contribute a variety of conservation benefits. For water conservation, they offer a triple bonus. A living cover crop traps surface water. When killed and left on the surface, cover crop residue increases water infiltration, lessens erosion and reduces evaporation. Finally, when incorporated into the soil, residue adds organic matter that increases infiltration to the root zone.

Palm date growers in California’s dry Coachella Valley asked USDA Agricultural Research Service (ARS) researchers to help them improve their soil, which is both stratified with clay layers and compacted by frequent cultivation with deep plows. Led by now retired ARS researcher Aref Abdul-Baki, more than 40 growers helped test lana vetch, a heat-tolerant legume



Colorado crop farmer Randy Hines, shown with wife, Cheryl, designed a tillage tool that creates irrigation furrows every other row while retaining corn stalk residue, reducing water application.

– Photo by Ron Daines

cover crop, in their orchards, despite concerns that the cover crop would out-compete the trees for water.

The growers, flood-irrigating from the Colorado River, applied six inches of water every two weeks. Yet, much of that evaporated rather than infiltrated.

Research over a decade proved that adding lana vetch improved the soil and thus water availability, to the date trees. The study helped convince growers that cover crops aren't water hogs.

"Population growth in Los Angeles will demand that the water be channeled to the city of LA rather than to irrigate dates," said Abdul-Baki, whose lifetime of research on the soil-building benefits of hairy vetch cover crops attracted the date growers' attention. "We proved to them that the cover crop wasn't taking water."

Instead, by shading the soil, the vetch lowered the soil temperature by 7 degrees, reducing evaporation. Lana vetch also bound the soil at the surface, preventing erosion and evaporation-promoting cracks, while its root system opened up channels for infiltration. Perhaps

most important, the vetch also increased date yield by 15 percent and, growers said, improved fruit quality.

Soil compaction, and the water loss it allows, occurs all over the country. In Illinois, Ralph "Junior" Upton farmed poorly drained land that was constrained by a "plow pan," a tough clay layer six to eight inches deep. The plow pan was so thick, crop roots couldn't penetrate. It also affected his drainage, causing even moderate downpours to saturate his topsoil and run off. Crops quickly used up the small amount of moisture in the shallow top layer above the plow pan.

To break through, Upton began planting cover crops – rye grass, cereal rye and hairy vetch – after harvesting beans and corn. Following soybeans he now seeds rye grass, which breaks up his soil with its deep roots.

Combined with no-till planting, Upton's cover crops have enhanced the soil's ability to store water, and the additional water available to the crop during the growing season has improved grain yields. Short-term drought matters less, crop health has improved, and when water does leave the farm, it isn't carrying much soil with it.

To improve soil aggregation, consider adding grass, either as a hay crop or forage, into your rotation, since the complex root systems of grass loosen soil. Some grass cover crops have especially deep roots that do a yeoman's job of breaking up compacted soil. David Wolfe, a Cornell plant ecology researcher, studied the effectiveness of sudangrass to improve soil in vegetable systems. "As our research showed, the roots are relatively good at proliferating into soil that is moderately compacted," said Wolfe, who received a SARE grant. "This would tend to improve both water infiltration and drainage for subsequent crops."

University of California-Davis researchers funded by SARE measured as much as 50 percent higher water infiltration and 35 percent lower runoff in the cover crop-heavy organic plots in a long-term trial comparing organic and conventional cropping systems.

"Nobody could have possibly predicted such a dramatic difference in the water runoff and infiltration between the organic and conventional systems," said project leader Steve Temple. "It's given us a new appreciation of the importance of cover cropping and residue management."

While Florida enjoys bountiful rainfall, the challenge for growers is to capture precipitation for plant growth before it percolates through sandy soils. Vegetable farmers like Gainesville grower Rose Koenig and citrus farmer Lynn Steward in Arcadia use cover crops such as sunn hemp with a lot of biomass to build the soil.

WHAT YOU CAN DO...

- For additional information on soil quality visit <http://soils.usda.gov/sqi/index.html>. The Soil Quality Information Sheets at <http://soils.usda.gov/sqi/publications/sqis.html> supply additional information about the soil characteristics discussed in this section.
- Agronomy Technical Notes at <http://soils.usda.gov/sqi/publications/atn.html> discuss management impacts on soil quality, including residue management, crop rotations, legumes and sunn hemp.
- For more information on managing soil and integrating cover crops, consult *Building Soils for Better Crops* and *Managing Cover Crops Profitably*. (RESOURCES, p. 16)
- Most state Extension offices have published material on soil management. Contact your agent or go to the online Extension publication database, "E-answers," at <http://e-answers.adec.edu/>
- Consult RESOURCES, p. 16, for other in-depth materials about managing soil for water conservation.

PART 2 Plant Management

SELECTING PLANTS ADAPTED TO THE CONDITIONS ON YOUR farm or ranch can be an important water management strategy. Consider drought-tolerant varieties, often native species that perform well in your climate, for water efficiency. Plants with deep root systems, such as buffalo grass, can stretch to the water table. Finally, some rangeland species — such as cool-season grasses ideal for cool-climate pastures or their warm-season cousins for hotter zones — thrive in dry conditions.

CROP ROTATION

DEVISING AN APPROPRIATE PLANT ROTATION IS AN EFFECTIVE way to manage water resources. Since farmers began growing grain in the Great Plains, they've used long periods of fallow to conserve water for their wheat and other cash crops. The fallow system relies on the tenet that leaving the land bare over a year or more allows water to accumulate in the soil.

Farmers now commonly leave crop residues on the surface to protect the soil. Yet, a number of SARE projects examine crop alternatives to fallow to achieve better profits and soil benefits while conserving water.

SARE-funded Montana State University researcher Perry Miller tested Austrian winter peas as a fall-planted

cover crop grown throughout the winter, the typical fallow. He hoped to prove the nitrogen-building benefits of the crop, which also provides a second cash crop — a protein-rich forage for cattle.

Adding peas during the fallow period captures water, guards against erosion and feeds biomass to the soil. The rotation “is a much more sustainable practice, and economically positive, too,” Miller said.

In the Nebraska High Plains, researchers also are testing peas — as a forage or a grain crop — in wheat systems. Like the Montana researchers, they are responding to growers who want to improve their soil management and reduce their fertilizer and herbicide costs but not deplete soil moisture. Depending on soil moisture, growers may decide mid-season whether to harvest peas as a forage, saving 30 percent more soil moisture, or wait and harvest it as a grain.

Rather than the typical wheat/fallow system that yields a crop every other year, a team of University of Nebraska researchers are studying alternative dryland cropping systems with SARE funding.

“As we've looked to increase the intensity of the system — to two crops in three years — this water relations work has become very important,” said University of Nebraska researcher David Baltensperger.



left to right

Montana State University researcher Perry Miller found that planting peas in rotation with wheat captures water and provides an extra forage crop.

— Photo by Carol Flaherty

Planting no-till corn into soybean residue improves water infiltration and slows evaporation.

— Photo by USDA-NRCS



left to right

By adding commodities such as corn, small grains, forage and beef cattle to cotton systems, SARE-funded researchers at Texas Tech University cut water use by 23 percent and saw higher profits.

– Photo by David L. Doerfert

To relieve drought pressure, California rancher Steve Sinton adjusts stocking rates to improve rather than overpower his pasture.

– Photo by Jim Schoettler

SARE grantee Richard Tripp, with wife, Carol, planted heat-tolerant tall fescue in his Massachusetts sheep pasture, reducing the need for supplemental hay.

– Photo by Donna Leombruno

“We have become very excited about the potential for cool-season, short-growth crops that use less water and allow more time to accumulate water prior to planting wheat to replace fallow in the High Plains.”

Baltensperger’s colleague, Drew Lyon, has developed a flexible dryland cropping system that encourages producers to decide whether to plant a short-season crop or stay in fallow based on soil moisture availability just before planting. Some growers are planting cool-season oil crops such as brown mustard, canola and camelina, whose seeds are crushed for biofuel. The seeds contain 20 percent more oil than soybeans.

“They are short-season crops with most of their growth in the cool-season, high-rainfall period, with tremendous market potential,” Baltensperger said.

Cotton is a significant water-user. In Texas, about one-quarter of the total U.S. cotton supply comes from the state’s High Plains region. Yet, water levels are declining in the Ogallala aquifer, the main water source for northern Texas growers. Scientists such as Texas Tech University researcher Vivien Allen are seeking water-conserving alternatives to monoculture cotton.

Armed with a SARE grant, Allen developed an innovative cotton, cattle and forage rotation that reduced water use by about 23 percent. Of great interest to farmers, that system – which features the perennial, drought-tolerant forage old world bluestem – also doubles profitability. The forage, seeded in half of the alternative plot, required no irrigation for five months of the year, driving down average irrigation over four years to 372 mm compared to 481 mm in the continuous cotton system.

In early the 1900s, when Texas farmers began drilling wells into the Ogallala aquifer, cotton proved a reliable, profitable crop. As water levels in the Ogallala drop, however, cotton farmers face a few tough choices:

run out of water, drill deeper and extract water at greater cost, or diversify. Much of the High Plains region, including parts of Nebraska, Colorado, Wyoming, Oklahoma, Kansas, New Mexico, South Dakota and Texas, relies on the Ogallala for water.

“When we began to irrigate, we took a 10-million-year-old resource and virtually expended it in 100 years,” Allen said. “We need a cover on the land because of erosion, and that cover needs water.”

Allen’s new rotations were so promising that Allen and her management team won a \$6.2 million state grant to demonstrate water-conserving farming strategies across the Texas High Plains. Responding to public interest in the dropping water level in the Ogallala aquifer, Allen’s team, the Texas Alliance for Water Conservation, is using the opportunity to further test those systems across 4,000 acres on 26 farms and ranches. Under the state project, producers will test diversified systems and the conservation team will measure their water use. For instance, some farmers will rotate pasture grasses with cotton for forage or grazing; others will over-seed cool-season cereal crops into cotton for eventual harvest.

“The declining aquifer greatly affects us,” said Monty Dollar, an NRCS conservation agronomist and member of Allen’s team. “Irrigation water is instrumental in producing profitable yields that sustain our operations. Yet, we’ve got to learn to live with less water. We’re going to find out if we can do that.”

WATER-CONSERVING PLANTS

MOST PASTURE SPECIES ARE ADAPTED TO SPECIFIC CLIMATES, thus warm-season grasses perform better in Texas. Cool-season varieties, such as fescue, grow better in higher altitudes and cooler temperatures.

In the Texas Tech project, Allen and others are testing Bermuda grasses, Dahl bluestem and Tifton 85, which



are water-efficient and saline-tolerant. “It’s hot, it’s dry – that’s what’s adapted out here,” Allen said.

While, in general, a cool-season grass has better forage quality, Allen has seen excellent cattle gains on warm-season varieties. She says it is important to match stocking rates to the rate of pasture plant growth. “You can make a forage good quality through the way you manage it,” she said. Her sequenced grazing starts cattle on dormant bluestem, moves them to a small grain and rye, then wheat, then back to bluestem.

“Pasture conserves more water than a [cotton] monoculture because the grasses do not require as much water as the cotton,” Allen said. “As long as we’ve got a perennial grass that’s 50 percent of the system, we will use less water.”

Fescue is a grass valued by farmers for its ability to stay green, and thus palatable and nutritious, during drought. The secret is in fescue’s long, complex root system. Before he received a SARE farmer grant to improve pasture for his flock of sheep, Richard Tripp of Lakeville, Mass., used to see his fields peter out each August, the hottest part of the season. Each year, he would buy hay to supplement pasture for his three dozen sheep.

In his SARE project, Tripp took a crash course in soil chemistry. He learned that his soil has little organic matter and retains just a fraction of precipitation, explaining why his pastures performed so poorly in dry conditions. He treated the soil with lime and pelletized chicken manure and seeded tall fescue mixes with deep roots that are good for both water absorption and intense grazing.

With the tall fescue, his flock stayed on pasture three extra months, saving him about \$1,300 a season in what he would have spent on hay.

“Before the SARE project, my pasture management was sporadic and somewhat arbitrary,” said Tripp, who, with his wife creates handspun, hand-dyed wools for artisan products. “Since replanting and replenishing,

the invasive weeds have all but vanished, and I am much more careful to have a regime of care for the land.

“Both pastures continue to do well. Perhaps because so much study, time, energy, and money went into them, I have learned to value them more and take better care of them.”

In the Southeast, where scorching hot summers can wither pastures, dairy producer Tom Trantham of Pelzer, S.C., manages his fields like a chessboard, seeding five to seven forages a year in grazing paddocks to maximize nutrition, plant growth and water availability. To provide his cows with a nutritious forage, Trantham plants different varieties of millet for his herd to graze through seasonal late-summer droughts into early fall.

“Tiff Leaf 3” has proved a very palatable, thin-stemmed variety that withstands drought, a fortunate choice for the drought of 2000. Trantham mixes clover or alfalfa for added nitrogen as needed.

Certain varieties of grain crops also perform well in dry conditions. Consider new crops that might work in your climate and provide a market advantage.

Drought-resistant pearl millet is seeing a resurgence as a feed grain for cattle, swine, catfish and poultry. A warm-season annual grass, pearl millet’s high protein content has driven interest by poultry producers. Moreover, with its short maturing season, relative insensitivity to day length and good performance in dry conditions, pearl millet can fill a mid-summer niche. Originating in the arid Sahel region of Africa, pearl millet roots develop quickly, traveling laterally and down into the soil to suck up moisture and nutrients.

In Georgia, where most livestock producers import their grain from the Corn Belt, farmers growing pearl millet for feed are finding real market opportunities.

At the University of Georgia in Tifton, pearl millet researcher Wayne Hanna gets two or three requests a day for seed. Millet, an ancient food crop from West

“We have become very excited about the potential for cool-season, short-growth crops that use less water and allow more time to accumulate water prior to planting wheat to replace fallow in the High Plains.”

*– David Baltensperger
University of Nebraska*

DROUGHT-TOLERANT FORAGE KEEPS PASTURE ALIVE IN TEXAS HEAT



Rick Kellison
Beef, forage & seed
Lockney, Texas

— Photo by Kathy Kellison

In the intense heat of a Texas summer, Rick Kellison's cow/calf herd enjoys a daily diet of old world bluestem, a drought-tolerant, warm-season forage that performs well in hot conditions and on marginal soils. Kellison, who ranches in Lockney, about an hour north of Lubbock, did his research before selecting his main summer forage. He followed Texas Tech University's lead and chose WW-B. Dahl old world bluestem, a variety that meets his herd's needs and provides a valuable seed crop.

"It's the best forage producer, given our water situation, that we could plant," Kellison said. "More and more producers interested in growing improved grasses are looking at WW-B. Dahl."

Kellison divided his 300 acres into grazing cells separated with polywire.

Depending on the paddock, he uses flood irrigation, pivot and drip. Under the driest conditions, the bluestem stands up well and provides high levels of nutrition. Moreover, with the increased interest from other farmers and ranchers, Kellison harvests old world bluestem seeds each fall, selling them for \$7.50 up to \$15 a pound (in pure live seed) to a mix of retail and wholesale markets.

Kellison is committed to water conservation beyond his ranch borders. Early in 2005, he became project director for the Texas Alliance for Water Conservation, a unique state project that is demonstrating irrigation delivery systems on 26 farms and ranches. The project evolved from a long-term research project, partly funded by SARE, at Texas Tech University that explores water-conserving alternatives to continuous cotton.

The Texas water conservation project, funded with a \$6.2 million state grant, will further test Texas Tech's water-conserving cotton-cattle-forage rotation, which reduced water use by 23 percent and yielded higher profits in university research trials. By introducing commodities such as beef cattle and old world bluestem, a drought-resistant forage that is so popular its seed has become valuable, researchers saved water normally used to irrigate water-dependent cotton.

"It's impossible for us to be sustainable with irrigated agriculture in the High Plains, with us pumping out of the aquifer," Kellison said. "The object is to pump less water and make more money."

The variety of demonstration sites will mean a huge data-collection effort, but those involved in the project are excited at the opportunity.

"By measuring everything that's measurable on the farm – total water use, tillage systems, fertility programs – and having academics look at each site under a magnifying glass, we can see how producers can maximize their productivity," Kellison said. "Maximizing yield doesn't always maximize profits. Through demonstration, we can transfer information to show a producer that he can use less water and inputs and still make more money."

On his own farm, Kellison is pleased with his management-intensive grazing and old world bluestem.

"My opinion is that we all have some acreage not acclimated for row crop production. If we can take our marginal land and put it into a drought-resistant crop that's good for the land and ecology, and will generate income, that's a win-win situation," he said. "Of all the improved grasses, the bluestem fits us so well because it doesn't take as much water."

Africa, is also used for birdseed, food products and is even brewed into beer. Other drought-tolerant crop alternatives for the South include sesame and cowpeas.

Midwest farmers seeking to diversify from corn and soybeans into crops that perform well in dry conditions might consider sunflowers, sorghum, amaranth, pearl millet, foxtail millet, cowpeas and mung beans, according to Rob Myers, executive director of the Thomas Jefferson Agricultural Institute, which produces guides to promote alternative crops.

"In the arid West, safflower is known as a drought-tolerant alternative to wheat or alfalfa," Myers said. "Native grasses grown for seed, as annuals or perennials,

are drought-tolerant options in many regions of the country. For example, Indian rice grass, a drought-tolerant native, is being grown for gluten-free bread in Montana."

Some horticultural crops, too, perform well in dry or droughty conditions. The wild beach plum, a shrub native to the sand dunes between Maine and Maryland, has helped some Northeast farmers diversify and gain a niche-driven edge. Beach plums, the size and color of purple grapes, make a tasty, unusual jam.

After SARE-funded researchers at Cornell University planted beach plum stock on research stations and New York and Massachusetts farms in 2002, their field day and

resulting publicity encouraged 22 more farmers to begin growing beach plums. Adapted to harsh dune environments, beach plum plants performed well even during an extended summer drought in 2002. Growers, who wait three or four years for plants to bear fruit, can still expect a crop in dry years when other commodities might fail.

Similarly, producers of nursery plants who consider climate-appropriate perennials can raise healthy plants adapted to dry conditions, meeting a growing demand for low-water-use landscape plants. Utah State University researchers funded by SARE investigated an alternative growing method for perennial wildflower species native to the Intermountain West to meet demand for drought-tolerant plants that can be used in low water or xeric landscapes.

The Utah team led by Roger Kjelgren grew native wildflowers in a pot-in-pot production system, which places seedlings in containers inserted into holders permanently dug into the field. The pot-in-pot system results in nursery plants that grow more quickly because their root zones stay cooler in the summer. A cooler root zone also means the perennials use less water.

The study, which compared the pot-in-pot system to conventional container production, showed that the new system increased growth of native perennial wildflowers and lost less water. The difference was especially dramatic on hot, dry days. At least one nursery, which participated in the study in Clifton, Colo., plans to continue using the system.

RANGELAND DROUGHT STRATEGIES

TOO OFTEN, DROUGHTS GRIP THE WEST, BRINGING MISERY TO producers. Ranchers who perpetually manage their pasture, rather than reacting to drought with emergency measures, stand a better chance at staying viable through periods of little to no precipitation.

British Columbia's Ministry of Agriculture and Lands recommends matching herd size and breeds to the feed and water available on the ranch. Consider moving livestock to rented pasture or weaning early, which may help condition cattle to less feed. Knowing your area's average precipitation patterns and keeping an eye on rainfall patterns may help you stay ahead, as you can sell off part of your herd early before others flood the market and reduce prices for calves or beef.

Adding small ruminants such as goats and sheep to your cattle operation can deflect the effects of drought, since large and small ruminants have different forage requirements. Finally, when drought strikes, send your

herd to graze drought-stricken crops to salvage their value. (However, monitor residues from drought-stressed crops for prussic acid and high nitrate levels.)

Ranchers, contending with record droughts in recent years, have adopted such strategies. Mark Frasier, who ranches with his father on 29,000 acres in eastern Colorado, works hard to maximize the scarce precipitation. After educating himself in Holistic Management®, Frasier initiated a system of herd management that moves his cattle among 125 paddocks, depending on the availability of water and feed. Native plants, Frasier says, are the only species he can count on consistently.

The Frasier family also focus on soil management, using the animals to break up crusted soil surfaces and monitoring range productivity. "Even during a drought, rain does fall, and it is imperative that the soil surface be prepared so that rainfall is effectively conserved," Frasier said. Only once, during the most severe drought conditions, did the Frasier family sell off their stock.

Similarly, rancher Steve Sinton, who won American Farmland Trust's 2005 national Steward of the Land Award, applies keen herd management to his 18,000-acre ranch in central California. After a drought in the 1970s wiped out his pastures, Sinton and his father, Jim, overhauled how the family runs cattle. Today, Steve Sinton monitors range conditions and stocks the pasture at herd densities that support, not overpower his forages. He also changed the ranch's schedule, selling calves sooner – at the calf stage rather than yearling – if conditions so dictate.

"You have to graze at the right level," he said. "Our philosophy is to leave enough grass so that if it doesn't rain until February, the herd can make it."



At a field day, Texas Tech researcher Vivien Allen explains the innovative rotations she designed to help cotton farmers diversify, save water and improve profits.

– Photo by David L. Doerfert

WHAT YOU CAN DO...

- For information on alternative plants, visit The Jefferson Institute at www.jeffersoninstitute.org.
- For more information about water-saving rotations and drought-tolerant plants, visit Cornell University's "Beach Plum: A new crop for new markets" website at www.beachplum.cornell.edu.
- The "12 Aprils Grazing Dairy Manual" describes Tom Trantham's innovative grazing system. www.griffin.uga.edu/sare/twelve/trantham.html.
- Plants for a Future is a resource center for rare and unusual plants, particularly edible, medicinal or other uses. Search the database, which notes habitat preferences for each species. www.pfaf.org/
- Consider alternatives to fallow that keep the soil covered. See *Managing Cover Crops Profitably*, (RESOURCES, p. 16).
- Consult the PLANTS Database of USDA's Natural Resources Conservation Service (NRCS) <http://plants.usda.gov/>. Search under "drought-tolerant" and "native" plants.
- See Rangeland Soil Quality Information Sheets at <http://soils.usda.gov/sqi/publications/rsqis.html>.

PART 3 Water Management

FARMERS AND RANCHERS ARE LOOKING AT A NUMBER OF ways to improve their irrigation delivery systems, as well as crop and soil management, to become more efficient water users. Improvements to irrigation scheduling, delivery and management are better matching water supply to crop needs. Some of the most innovative farming systems re-use water to raise two products, such as fish and crops.

SMART IRRIGATION

IN COLORADO, AGRICULTURAL EDUCATORS ARE WORKING with farmers to install subsurface drip irrigation systems, which supply controlled amounts of water to crops with little waste. Drip is especially suitable for arid, hot and windy areas. Subsurface application of water to the root zone also has the potential to improve yields by reducing the incidence of disease and weeds.

Sub-surface drip irrigation is not subject to the amount of evaporation or runoff that occurs in the more common flood-furrow systems, says Jim Valliant, an irrigation specialist with Colorado State University Extension. Some of the more sophisticated systems feature computer-programmed controllers with an option to apply agri-chemicals.

“You try to fill the crop root zone profile [with water] at the early part of its growth, then add just the amount the crop needs plus a little more in case of evaporation or leaching,” he said. “You can significantly reduce the



amount of water required.”

With a SARE grant, Valliant is working with farmers to perfect their drip irrigation systems. USDA's Natural Resources Conservation Service (NRCS) is partnering on the project by offering cost-sharing incentives for drip installation, which, because it costs significantly more than furrow irrigation systems, acts as “a limiting factor in improving water delivery systems for many farmers,” Valliant said. The typical cost of \$500 to \$2000 per acre for materials, installation and monitoring controls can be prohibitive for growers of low-value crops.

Drip systems also avoid increasing salinity downstream, a serious problem with flood irrigation in arid environments. Irrigation water discharging from furrows carries dissolved solids picked up from the soil. Farmers near a river's headwaters who divert part of the water into furrows multiply the amount of solids – and salinity – for each farm that follows.

Workers lay subsurface drip irrigation lines at Colorado State University for a seedless watermelon crop. Frequent, light applications through drip are especially suitable for hot, arid areas with limited water.

– Photo by Mark Bartolo

IRRIGATION METHODS

This bulletin takes a holistic view of managing and conserving resources to improve water availability to crops. This may involve adapting irrigation systems that are more water-efficient or protect water quality. Contact your local Extension office for more information about irrigation systems, or seek resources specific to your region. (Some are listed in RESOURCES, p. 16.)

No one set of practices is universally appropriate to

manage water. Growers must evaluate their cropping and livestock systems, management constraints and water supplies to determine the right mix of irrigation practices. Some options listed in the *Colorado High Plains Irrigation Practices Guide: Water-Saving Options for Irrigators in Eastern Colorado* (RESOURCES, p. 16) provide ways to improve irrigation efficiency and conserve water.

Water Delivery Systems.

Unlined ditches lead to significant seepage losses, typically 25 to 40 percent. Lining ditches with impermeable materials can decrease water loss and improve efficiency. Consider a variety of underground or portable piping systems.

Irrigation Systems.

With proper design and installation, a center pivot sprinkler system can achieve high irrigation efficiency and uniform application.

Consider a variety of packages and operating methods.

Contact Extension or the appropriate state agency to learn about furrow irrigation strategies, such as tailwater recovery, irrigating every other row and polyacrylamide application. USDA's Natural Resources Conservation Service offers many cost-share programs to encourage water-saving systems, such as its Agricultural Management

Assistance Program. (RESOURCES, p. 16)

Irrigation Management.

Determining the amount and timing of irrigation for efficient water use can play a huge role in conservation. Monitoring water application for crop needs and soil moisture content remains a key strategy. Consider a variety of low-cost, user-friendly electronic devices.

CATTLE RANCHER IMPROVES WATER DELIVERY ON NAVAJO NATION LAND



Milford Denetclaw
Beef producer
Shiprock, New Mexico

— Photo by Lindsay Pierce

For generations, members of the Navajo Nation in northwest New Mexico have shared 23,000 acres of rangeland on which they live and raise crops. Milford Denetclaw’s family was one of a fortunate few to inherit a permit to raise livestock. While it’s a privilege, it’s also been a challenge for Denetclaw, who raises certified Beefmaster cattle that need to be segregated to maintain their bloodlines.

“Most of the Navajo Nation is open range with no real way of managing it,”

Denetclaw said. “Watering holes are a common gathering area for livestock, and your livestock co-mingle with others.”

Preserving the breed was a main motivator for Denetclaw to apply for a SARE grant. To segregate his herd, he needed to create nutritious forage on his recently acquired 28-acre slice of the Navajo rangeland, and to do that, he needed to improve both his irrigation system and his grass species. Two years later, he is happy to report the project was a success.

Previously, Denetclaw accessed water from a 1920s-era canal that siphoned water from the San Juan River. However, he had to send water across his neighbor’s field, and the sandy soil absorbed much of it before it reached his pasture.

“I was so close to the main canal, I thought, ‘Why can’t I get my own head gate and bring water directly onto my farm?’” Denetclaw said.

With help from his local Extension agent, Denetclaw built a head gate, then regulated its flow with gated pipe. Gated pipe contains

holes covered by slide gates that limit water flow.

His new irrigation system enabled Denetclaw to plant four varieties of cool- and warm-season grasses. In the first year, he was pleased to harvest two cuttings of hay. By the second, he ran his cattle on the pasture through the winter.

“I wanted a place where I could have my cattle for 60 days on pasture – that is not something too many people do,” he said. “I want to let the cattle harvest the grass, convert that weight and market my cattle and get my return rather than the traditional way of cutting hay and baling it, with all of those other expenses and time. What I grow will eventually go back into my cattle.”

Denetclaw demonstrated his renovations to other Navajo ranchers and presented a slide show during the annual conference of the Navajo Nation Soil and Water Conservation District. “As far as water delivery goes, I couldn’t ask for anything more,” Denetclaw said.

Improving irrigation efficiency was also a goal of The New Entry Sustainable Farming Project, a Massachusetts-based nonprofit organization that works with immigrant farmers, primarily Hmong and Cambodians, to access land and hone their vegetable-growing and marketing skills. With a SARE grant, New Entry staff tested a combination of trickle irrigation systems and plastic mulch to improve water delivery and reduce labor. They emphasized irrigation scheduling to counter the farmers’ traditional daily watering practices.

The farmers, who grow and sell ethnic vegetables popular with Boston-area Asian Americans, used to plant in bare soil, then weed and hand-water their crops from a farm pond. They lost moisture to evaporation, drew down the pond and spent up to three hours a day irrigating vegetables.

“Due to their experience in tropical climates, where during the growing season it rains each day, they continue to be convinced that certain plants will die without daily water,” said Jennifer Hashley, project coordinator with The New Entry Project. “They tend to produce fast-growing

greens that their customers want to be succulent and tender, requiring more irrigation than other crops.”

Working with New Entry staff, about 16 vegetable farmers installed drip irrigation tape under black plastic. Since the work occurred as a demonstration, their work was shown to at least 15 other active immigrant farmers.

Most of their crops, such as bitter melon, okra, tomatoes and eggplant, grew faster and fruit matured earlier with the trickle irrigation/mulch system. They realized reduced weed pressure thanks to the plastic mulch and decreased the time they spent weeding and irrigating. While there were upfront costs for drip tape and plastic, those costs were offset by savings in labor and increased sales from earlier and larger yields.

In New Mexico, many farmers irrigate from ditches called *acequia*, named by the Spanish settlers who dug them. When an area was settled, new residents dug acequia first and built homes later. Today, many farmers in central New Mexico rely on old rock-and-brush dams that divert water onto their crop fields and pastures. Like

WESTERN WATER LAWS

Water rights laws in the West are complex and vary by state. All Western states strongly support water conservation, and many recently passed laws that fully protect the water rights of those who conserve. If you want to expand acreage or permanently reduce water use through conservation, contact the appropriate state water resources agency beforehand.

RUNOFF CAPTURE SYSTEM RECYCLES PRECIPITATION ON DIVERSE MINNESOTA FARM



Tim Gieseke
Diversified crop, livestock
and tree producer
New Ulm, Minnesota

— Photo by Ruth Klossner

Tim Gieseke had more than one goal when he decided to diversify his central Minnesota farm. For his young sons, he wanted long-term profits, should they choose to be the fifth generation of growers on the family's land. For him and his wife, he sought crop diversity to achieve continuous short-term profits. And for the land ecology, he hoped to plant a crop that would perform well on a 10- to 15-percent slope and find a way to capture runoff.

To achieve that, Gieseke planted black walnut trees, started a flock of sheep and

planted hay, all integrated in an agroforestry system designed to maximize water use.

"We have a steep piece of land that won't grow row crops," said Gieseke, who with his wife owns 50 farm acres and rents another 30 from his parents. Elsewhere on the two parcels, they grow corn, soybeans and wine grapes. "We were making a few dollars from hay production. I wanted to continue that, but also look at the potential long term."

With just a few acres, Gieseke decided on high-value black walnut trees. Walnut trees need 35 inches of water a year to thrive, but Gieseke's farm in southern Minnesota averages 30 inches a year. To make up the difference, Gieseke, with help from a SARE farmer grant, constructed an innovative contour system featuring irrigation holes that trap hillside runoff and convey it to the tree roots.

He planted seedlings in rows 20 feet apart, created earthen curbs on the contour and augured 9-inch-wide, 30-inch-deep holes filled with pea rock between every other tree. The infiltration system absorbs water from even torrential downpours with

minimal runoff. Gieseke had a front-row seat to what his system could handle when a heavy rain dropped half an inch in 15 minutes while he was building the system. On the side where he had finished installing the curb/weir system, he did not see runoff or water pooling. On the unfinished half, he saw water pour down the hillside.

Moreover, the grove was resilient even during the sensitive first few months of seedling growth despite a short drought. "We had very dry conditions the first season, with a few heavy rainfalls that I think the contour curbs caught nicely," he said. In fact, in the first three seasons, he has not had to irrigate the saplings.

Gieseke built the system using available equipment, such as his chisel plow, and his own manpower. What equipment he lacked, such as a grader, he rented on the cheap. "Part of conservation is understanding what you have and using it accordingly," said Gieseke, a former conservation planner for the Carver Soil and Water Conservation District in Waconia, Minn. "Whatever I do I want to be applicable to nearly every farm."

the old name for ditches, water laws are based on history and state who has water rights (usually, the oldest systems) and who can lose them (those who don't irrigate regularly for three years).

The widely used ditch/dam method, however, directs water unimpeded onto fields and pastures, with an estimated 60 percent lost to seepage and evaporation. Members of the Tierra y Montes Soil and Water Conservation District, with a SARE grant, sought to help farmers do better.

Stephen Reichert, project facilitator with the conservation district, demonstrated conservation-oriented irrigation methods, including drip irrigation, corrugated pipe and above-ground gated pipes. Gated pipes, favored by many because they are less expensive and easy to use, contain holes covered by slide gates that control water flow.

"The more farmers hear about this and see how a better distribution system makes it easier, the more they're interested," Reichert said. However, while

"irrigators are sold on these improvements, in many cases they require financial assistance to change."

Gil Gallegos was among a handful of farmers to test the gated pipe system after siphoning water from a ditch dam for years.

"It wasn't working because if you don't have a constant, sustainable supply of water, the tubes will go dry," said Gallegos, who grows alfalfa, oats and sorghum and runs 120 head of cattle on three parcels near the Pecos River. "Now, I conserve water, I'm more precise, and I can move it as I need."

Similarly, across the state, Milford Denetclaw used to flood-irrigate his 28-acre pasture from a San Juan River canal. Yet, his soil is so sandy that the practice was wasteful. "I could irrigate the whole day and, once I shut it off, within a day it would be like I never had the water on," said Denetclaw, a member of the Navajo Nation who raises certified "Beefmaster" beef and received a farmer-rancher grant from SARE to improve his pasture and conserve water. (See profile, p.13.)

With help from his local Extension agent, Denetclaw built a head gate that brought water from a San Juan River canal, then regulated its flow with gated pipe.

Along with his improved irrigation system, Denetclaw planted four varieties of cool- and warm-season grasses in his pasture and was able to graze his cattle there through the winter. He demonstrated his renovations to other Navajo ranchers and presented a slide show during the annual conference of the Navajo Nation Soil and Water Conservation District. "As far as water delivery goes, I couldn't ask for anything more," Denetclaw said.

WATER CYCLING/AQUACULTURE

SOME FARMERS AND RANCHERS SEEKING TO MAXIMIZE EVERY drop of precipitation are creating systems that double the benefits of a water source by applying it to two enterprises. Many of them pair crops with aquaculture, which not only recycles water but also provides nutrients from fish waste. Worldwide, aquaculture is expected to grow at about 7.3 percent annually, from \$66 billion in 2003 to more than \$93 billion in 2008 in response to market demand.

University of Arizona researchers funded by SARE integrated shrimp ponds with olive trees on a Gila Bend, Ariz., farm to test the benefits of running irrigation water through two systems. Researchers designed a plot of 120 trees, irrigated them from the shrimp pond, and compared canopy height and trunk circumference to a set of trees watered from a well. Watering trees from the shrimp ponds also supplied saplings with 1.6 to 5.6 kilograms of nitrogen per row from the shrimp waste. In the second year, they met the full nitrogen recommendation for olive trees.

"We wanted to show how to pair crops with aquaculture, running water through fish or shrimp first, then putting it on their crops," said project leader Kevin Fitzsimmons, a soil, water and environmental researcher. "The trees grew significantly better with the effluent than the trees that were on well water."

Fitzsimmons also tested shrimp pond sludge – shrimp waste that settles to the bottom – on tomato plots at the university's Environmental Research Lab. The tomatoes amended with sludge in Fitzsimmons' project produced significantly more fruit than the tomatoes in the control plot with unamended soil: 141 grams of fruit per plant compared to 39 grams in the control plants. "A major point is that we're using the N and P in the waste from the shrimp to replace the N and P fertilizers that farmers would otherwise have to buy," Fitzsimmons said.

Through field days, Fitzsimmons' team publicized their results and, since then, close to a dozen Arizona



crop farmers are trying to integrate fish and shrimp farming into their systems.

The climate on the U.S. Virgin Islands is also semi-arid, and Islanders view water as a valuable resource. To help the small, high-value market crop farmers on St. John, researchers at the University of the Virgin Islands explored ways to use tank-grown tilapia to add fertility and recycle water.

Project leader Don Bailey hopes to raise the standard of living by introducing a marketable new product in a territory that imports more than 80 percent of its seafood and 90 percent of its fruit and vegetables.

"Fish is an alternative crop for farmers to diversify their income beyond field crops," said Bailey, who tested tank-raised fish on a St. John farm growing organic greens, using dried fish sludge as a soil amendment. Tilapia can bring up to \$3 a pound and costs just \$1.25 a pound to produce.

As part of a SARE-funded project at the University of Arizona, grower Craig Collins raised olive trees irrigated from his shrimp pond.

– Photo by Kevin Fitzsimmons

WHAT YOU CAN DO...

For more information on conservation-oriented irrigation methods and water recycling, consider:

- Cost-share assistance to conserve water on farms and ranches through USDA-NRCS. See [RESOURCES](#), p. 16.
- The irrigation series of publications by University of California. anrcatalog.ucdavis.edu/; Click on "soils & water" then "irrigation."
- For information, links and discussion groups related to irrigation, visit www.wcc.nrcs.usda.gov/nrcsirrig/.

Resources

GENERAL INFORMATION

Sustainable Agriculture Research and Education (SARE) program. (301) 504-5230; sare_comm@sare.org; www.sare.org. Studies and spreads information about sustainable agriculture via a nationwide grants program. See research findings at www.sare.org/projects.

Alternative Farming Systems Information Center (AFSIC). Free assistance and resources to farmers and agricultural professionals, including information on water use and water quality. (301) 504-6559; www.nal.usda.gov/afsic.

ATTRA. National information service offers 200+ free publications. Click on “water management” for information on irrigation and water use. (800) 346-9140; Spanish (800) 411-3222; http://attra.ncat.org.

Water Quality Information Center. Links to drought and weather information: www.nal.usda.gov/wqic/drought.html and water conservation: www.nal.usda.gov/wqic/cons.html

SOIL MANAGEMENT RESOURCES

Building Soils for Better Crops by the Sustainable Agriculture Network. How ecological soil management can raise fertility and yields and improve water-holding capacity. 240 pp; \$19.95 + \$5.95 s/h. (301) 374-9696; sanpubs@sare.org; www.sare.org/WebStore

Drought Resistant Soil by ATTRA. Pamphlet on how texture, aggregation and organic matter affects water-holding capacity. Free. (800) 346-9140; http://attra.ncat.org/attra-pub/summaries/drought.html.

Field Guide for Compost Use by the U.S. Composting Council. Technically based compost use guidelines. \$30. (631) 737-4931; www.compostingcouncil.org/article.cfm?id=64

Managing Cover Crops Profitably. Comprehensive look at the use of cover crops to improve soil, slow erosion and capture precipitation. \$19 + \$5.95 s/h. (301) 374-9696; sanpubs@sare.org; www.sare.org/WebStore

Stubble Over the Soil by Carlos Crovetto Lamarca. In-depth look at no-till applications, which renovated soils and brought higher wheat and corn yields to this Chilean farmer. 247 pp; \$40. (608) 273-8080; https://secure.societystore.org/index.php

PLANT MANAGEMENT RESOURCES

PLANTS Database, Natural Resources Conservation Service (NRCS). Click on “Advanced Search” for detailed characteristics. http://plants.usda.gov.

Texas Tech University Department of Plant and Soil Science Forage Research Program, which focuses on water conservation. www.orgs.ttu.edu/forageresearch/sustainable.htm

WATER MANAGEMENT RESOURCES

Colorado High Plains Irrigation Practices Guide: Water-Saving Options for Irrigators in Eastern Colorado, 80 pp.; free. Colorado Water Resources Research Institute, Fort Collins, Colo. (970) 491-6308; cwrrri@colostate.edu; http://cwrrri.colostate.edu.

Crop Residue and Irrigation Water Management by Nebraska Cooperative Extension. http://ianpubs.unl.edu/irrigation/g1154.htm



Photo by Jerry DeWitt

Drip Irrigation for Vegetable Production by Penn State University Extension. http://agalternatives.aers.psu.edu/crops/Irrigation/DripIrrigation.pdf

Drought Preparedness and Response by University of Wisconsin Extension. www.cft.uwex.edu/ces/news/info/drought.pdf. 22 pp.

Natural Resources Conservation Service (NRCS) irrigation cost-share assistance:

- The Agricultural Management Assistance Program (AMA). www.nrcs.usda.gov/programs/ama.
- The Ground and Surface Water Conservation program, part of the Environmental Quality Incentives Program (EQIP). Available in selected states only. www.nrcs.usda.gov/programs/eqip/eqip_gswc_fs101305.pdf
- For state water management cost-share programs, go to your state NRCS home page (locate that at www.nrcs.usda.gov/about/organization/regions.html#state) and select “programs.”

Water Conservation and Irrigation. Selected linked publications compiled by North Carolina State University. www.ces.ncsu.edu/depts/hort/consumer/hortinternet/water_conservation.html

Water Conservation Publications such as “Livestock Water Management During a Drought” and “Estimating Water Flow Rates.” Oregon State University Extension. http://eesc.orst.edu/waterwise.

SARE works in partnership with Cooperative Extension and Experiment Stations at land grant universities to deliver practical information to the agricultural community. Contact your local Extension office for more information.

This bulletin was written by Valerie Berton. Thanks to SAN's team of technical reviewers. This publication was funded by USDA-CSREES under Cooperative Agreement 2003-47001-01565 for the Sustainable Agriculture Network.