Smart Water Use on Your Farm or Ranch

Idaho farmer Pat Purdy is able to deliver more water to the soil with a low-elevation spray application system (the pivot span on the right) than a standard spray system (the pivot span on the left) because of reduced wind drift. His adoption of this technology, along with soil health practices, has improved water management on his farm. *Photo by Pat Purdy*

CONTENTS

WHEN PAT PURDY RETURNED HOME TO JOIN HIS FATHER Nick at Picabo Livestock Company near Picabo, Idaho, in 2008, his desire was to beef up the farm's environmental efforts with a fresh perspective. The farm has been in the family since the 1880s with the goal of living in harmony with Silver Creek, which runs alongside the property. Silver Creek is a major trout stream.

And while Silver Creek is close by, the farm itself is on a flat, arid span amid a higher mountain altitude. That makes irrigation mandatory for the malt barley grown on contract for Anheuser-Busch and Coors. The Purdys also raise alfalfa hay and mustard seed, and have a cow-calf enterprise.

"We get 12–14 inches per year of precipitation from mostly snowpack and little to no summer rain," Purdy says. "Water availability is always a concern, so we are efficient in how we use it."

In 2017, Purdy used a SARE grant to see if he could save water using a low-elevation spray application system (LESA) with cover crops, no-till and managed intensive grazing. The plan was to follow intensive grazing of cover crops with a malt barley crop the next season. He hoped to get a positive income stream the first year from cattle grazing followed by improved barley yields in year two.

LESA systems are attractive options compared to traditional center pivot irrigation because, with low-to-the-ground sprinkler heads, water is applied at lower pressures, which reduces pump power consumption and increases efficiencies. (The exact potential of a LESA system to improve efficiency will depend on the region, soil type, crops being grown and management practices.)

According to soil moisture sensors, the LESA system delivered 3.1 inches of additional water into the soil over the course of the season compared to using the conventional center pivot with no cover crops. In addition, soil water infiltration reached 32 inches under the LESA system with cover crops versus 12 inches under the center pivot control. The extra water represented a chance to save 15–20 percent of pumped water.

Also available at www.sare.org/water-bulletin, or order a free hard copy at (301) 779-1007.

SARE Sustainable Agriculture Research & Education

Photo by Lance Cheung, USDA

Water Management in a Changing Climate

The importance of sustainable water management will continue to grow as the impact of climate change intensifies. Temperature and moisture extremes are projected to increase in frequency and intensity over the next 30 years throughout the country. Heavy rainfall interferes with field operations, causes labor issues, degrades soil health, threatens crops and livestock, and damages infrastructure. Drought is challenging even with irrigation, if access to water becomes limited.

As one example, University of Vermont graduate student Alissa White surveyed vegetable and berry farmers in New England to identify the adaptive strategies they're beginning to use to meet climate-related challenges. Her project, funded through a SARE grant in 2017, found that growers were most concerned about projected increases in heavy precipitation and drought.

To adapt to these challenges, White concluded, farmers should start by using a whole-systems perspective for farm planning, and they need to understand the flow of water on their land. Strategies that farmers are using to cope with too much precipitation include the use of raised beds, investments in stormwater management, adjusted crop locations based on site and soil characteristics, new high tunnels, perennial plants and reduced tillage. Management strategies for drought include water harvesting, efficient irrigation systems, mulch, reduced tillage, cover crops and crop planning.

The strategies for managing water outlined in this bulletin are part of a holistic approach to conserving water and reducing the climate risk your farm or ranch faces. Learn more about how sustainable farming and ranching practices provide climate risk management in SARE's bulletin *Cultivating Climate Resilience on Farms and Ranches* (www.sare.org/climate-resilience).

Water conservation was not the only benefit. Purdy wanted to reduce wind erosion and enhance wildlife habitat by eliminating the bare soil that comes with fall tillage and winter fallow, so he planted cover crops. He no-till seeded a cool-season mix of forage barley, oats, peas, common vetch and purple top turnips in the spring. Cattle grazed the area separated into paddocks, moving once or twice a day. Following the first grazing of the cool-season mix, Purdy planted a warm-season mix for late summer forage. He was able to get four grazing cycles per season.

"Regenerative agriculture will benefit any farm," states Purdy. "We now have an organic matter layer on the soil surface that absorbs moisture and reduces puddling. We also reduced fuel use and wear and tear on our equipment. We saw a 10–15 bushel per acre bump in barley yields that was a direct result of the soil health improvements from intensive grazing the prior year. To me, that showed us the effort was all worthwhile."

A Systems Approach to Water Management

Water is fundamental to food production. In fact, agriculture accounts for 85 percent of U.S water consumption, according to the USDA Economic Research Service. Yet, farmers nationwide face water-related challenges, whether it's too little, too much or both. And some practices have contributed to declining water quantity and quality.

For example, in the West, urban and suburban communities compete with each other and with farmers and ranchers over water withdrawals from the Colorado River. In the Northeast, farmers face water challenges with annual, short-term droughts. And coastal farmers deal with increasingly more dramatic wet and dry spells, as well as saltwater intrusion that requires unique management strategies.

Many farmers around the country like Purdy are using a whole-farm approach to tackle their water problems. Rather than relying on changes to individual areas of their operation, they are adopting farm-wide practices that build soil, improve crop and livestock management, and efficiently use water across the farm. Farmers are simultaneously changing up crop rotations, incorporating cover crops, reducing tillage, integrating crops and livestock where feasible, improving their irrigation systems, and more.

This bulletin 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 that are often used in conjunction to improve overall water management:

» **Part 1: Soil Management.** Apply practices that build soil health, which results in a porous, well-structured soil that allows water to infiltrate and holds it there for plants to use.

» **Part 2: Plant and Livestock Management.** Select plants, such as drought-tolerant species and native varieties, that maximize water availability in crop rotations or pastures; practice other rangeland management strategies.

» **Part 3: Water Management.** Improve the efficiency of irrigation systems; refine application schedules and volumes to meet crop needs without over-watering.

Part One
Soil Management

Adding organic matter to the soil, reducing disturbance and maximizing living roots (a rye cover crop is pictured here) are key strategies for improving water management.
Photo by Edwin Remsberg

THINK OF THE SOIL AS A SPONGE: IT ABSORBS AND HOLDS water, and it reaches a point where it's full and cannot hold any more. Unlike a real sponge, though, you can change the amount of water that soil can hold through the way you manage your soil. However, you are somewhat limited by your soil's texture. Keep in mind, finer soils that have a high percentage of silt and clay particles tend to hold more water than coarse, sandy soils.

Otherwise, practices that add organic matter and improve soil structure, such as adding compost or cover cropping, will increase water infiltration and waterholding capacity while decreasing runoff and erosion. Such soils are porous and allow water to enter easily, rather than running off to streams and rivers. With poor tilth, soil aggregates break down, compaction increases, and aeration and infiltration drop.

Most soil-improving strategies work slowly over several years. In contrast, management practices that degrade soil are often immediately apparent. Working soil when it is too wet will quickly compact it and degrade its structure. Degraded soils do not absorb precipitation as quickly or hold as much, which leads to increased ponding and runoff of excess water when it rains.

Organic matter also plays a vital role in soil health and water availability. Organic materials like cover crop residue or straw mulch applied to soils and maintained on the soil surface protect the soil from erosion (Figure 1). Vegetative cover deflects rain drops, while living roots and the exudates they produce hold soil together. Additionally, surface residues and mulches reduce evaporation and smother weeds, so plants have more water.

FIGURE 1. RAINDROP ENERGY AND SOIL MOVEMENT

Falling on water | **Falling on soil** | **With surface residue**

During a rainfall millions of drops fall at speeds up to 30 feet per second. Without raindrops, little soil erosion would be caused by water.

Raindrops explode like tiny bombs, splashing water and soil particles as high as 3 feet and as far to the side as 5 feet, and breaking soil aggregates where the soil surface is not protected.

Small aggregates and soil particles can be carried down slopes and off fields where the soil surface is not protected. Crop residue on the surface can prevent most soil loss.

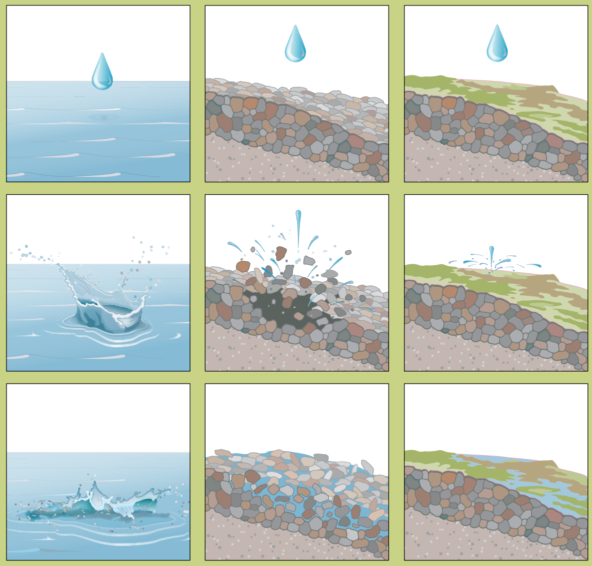


Illustration by Vic Kulihin

This multi-species cover crop is being grown on a farm in eastern Oregon to evaluate whether it can conserve moisture in a dryland system. *Photo by Garrett Duyck, USDA NRCS*

As organic matter increases, soil particles clump together and form aggregates. The spaces between aggregates are called macropores and are important for soil water dynamics. These larger pores contain open spaces that facilitate drainage and aeration. Smaller micropores fill with water and contribute to the total waterholding capacity of the soil. Plant residues and other organic amendments decompose and help bind soil particles together.

Strategies to increase organic matter content include:

» Spreading manure or letting livestock deposit manure in well-managed pastures.

» Applying composts from a variety of materials ranging from poultry litter to leaves.

» Rotating crops and using cover crops, which provide nutrient-rich residue after they die.

» Reducing tillage. Plowing breaks down soil aggregation and hastens organic matter loss.

Cover Crops

Cover crops, seeded between or amid cash crops, contribute a variety of conservation benefits for water and soil. For water, they offer a triple bonus. A living cover crop traps surface water. When killed and left on the surface, cover crop residue bumps up water infiltration and lessens both erosion and evaporation. When incorporated into soil, residue adds organic matter that boosts infiltration to the root zone.

Before choosing to test any cover crop species, first identify your needs and consider factors like your cropping system, climate, tillage options, planting window, soil type and more. Where water conservation is the goal, adding a grass into the rotation, either as a hay crop or forage, can

Rotational grazing increases both organic matter and the waterholding capacity of pastures. *Photo by Lance Cheung, USDA*

Profile: Wicking Hills and Cover Crop Valleys

Like many farmers in the Northeast, Louis Lego, Jr. has increasingly faced flooding and drought troubles while he grows certified organic fruits and vegetables at Elderberry Pond Country Foods in Auburn, N.Y. In 30 years of farming, Lego has never seen a greater climate challenge. But through trial and error, he has finally found an effective way to manage his soil for the extremes.

"The last three years, every spring has gotten worse with heavy rains and flooding. The water was not getting absorbed," he states. "We have a nice loam soil, but the fine particles were coming to the top in our flat fields, creating a layer that made it difficult for water to filter down."

As an organic farmer, Lego is required to plant cover crops every three years. But they were no match for the impact of heavy precipitation on the soil. Lego first tried adding more drainage tiles. His neighbors did as well, and the result was more water draining into streams and causing flooding. They expanded their pond to catch more water and tried hybrid mulching techniques. Neither of those strategies worked well either. So, Lego turned to "wicking hills," a type of raised bed system that contains natural wicking/drainage materials in the form of straw or plant stalks. In his case, Lego used sunflower stalks.

"Wicking hills have been by far the best solution for keeping water on the farm—higher soil moisture and no flooding. It is a natural irrigation and flood protection system," he says. "But it takes some time and effort up front to put the hills in place. It is a multi-step, multi-year process."

Supported by a SARE grant, Lego designed his wicking hill system for vegetable production, and he notes that root crops do very well in the raised rows, including carrots, onions, garlic and potatoes. The only equipment requirements were a rotary plow and a seed spreader. He planted sunflowers in the rows of hills he created during the first year. The leftover sunflower stalks become the wicking fiber for new wicked hills in subsequent years. The sunflowers also provide value-added cut flowers and chicken feed.

The second year, the raised rows use the high-carbon sunflower residue to stabilize the hills. They also drain excess moisture when it is wet and draw up water to keep soils moist when it is dry, through capillary action.

In between the hilled rows, Lego plants a cover crop of medium red clover. The clover absorbs excess water during storms and improves soil health. Soil quality tests confirm higher nutrient availability, more neutral soil pH and higher organic matter content.

Lego is still evaluating the long-term results of the SARE-funded trial. For example, the clover cover begins to deteriorate after a couple of seasons and may need to be periodically reseeded.

"It is a lot of work to put the hills in, but we believe it has been worth it," he affirms. "We have no weed issues, no water runoff and no replanting. Our pickers have better conditions standing in clover rather than in mud, and our crop yield and vegetable quality surpassed our expectations."

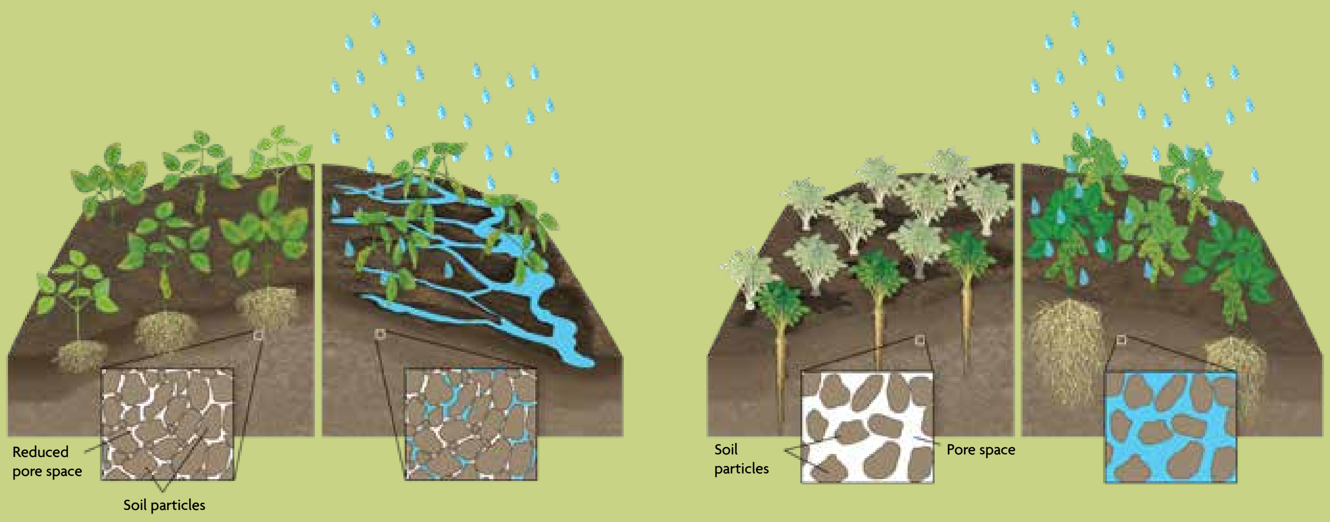
Elderberry Pond supplies vegetables, fruits and meat to its on-farm retail store, farmers' markets and its own restaurant, promoting small-scale sustainable farming and demonstrating the quality and nutrition of local food production. Lego also makes presentations to farm groups about the wicking hills system and invites visitors to the farm to see how it works first hand.

"We have converted the whole 25-acre production area to this system," says Lego. "It is very sustainable, good for small farms and easy to adapt for home gardens."

Learn more: https://projects.sare.org/sare_project/fne18-903

"Wicking hills" are a raised bed system that contains natural wicking or drainage materials, such as sunflower stalks, and acts as a natural irrigation and flood protection system. Raised vegetable beds are prepared (top) after sunflowers are grown and harvested (bottom), and cover crops grow between rows. *Photos by Louis Lego*

FIGURE 2. THE EFFECT OF COMPACTION ON WATER STORAGE



Left: Compacted soil had reduced pore space between soil particles, which reduced the ability of the soil to absorb moisture. This increases erosion and results in poor crop health. Right: A tillage radish cover crop can break up compaction and increase pore space between soil particles, which allows the soil to hold more water for crops to use (see the photo on this page). *Illustration by Carlyn Iverson*

improve soil aggregation, since the complex root system of grasses loosens soil.

Grasses like rye, wheat and sorghum-sudangrass produce biomass that, when terminated, provides soil coverage to reduce evaporation rates and supply organic matter. Tillage radish and its deep taproot are useful for breaking up compacted soils and improving water infiltration (Figure 2).

This hole was created by the large taproot of a tillage radish cover crop. *Photo by Edwin Remsberg*

Learn more about selecting and managing cover crops in *Managing Cover Crops Profitably* (www.sare.org/mccp).

The conservation benefits of cover crops usually translate into higher yields, cost savings or both, especially when water is scarce. During the severe drought of 2012, some Midwestern and Western farmers who had planted cover crops found that corn yields were an average 9.6 percent higher than on fields where cover crops had not been planted. Soybean yields were 11.6 percent higher, as reported by farmers who participated in the six-year National Cover Crop Survey conducted by SARE, the Conservation Technology Information Center and other partners (view survey results at www.sare.org/covercrop-survey). Better yields were most likely due to cover crops providing ground cover, reducing evaporation and increasing available soil water for the crop.

In drought conditions, corn and soybean farmers can expect to recoup the cost of cover crops in a single year, according to an economic analysis of the National Cover Crop Survey found in the SARE report, *Cover Crop Economics: Opportunities to Improve Your Bottom Line in Row Crops* (www.sare.org/cover-crop-economics). Depending on how many years the farmer was using cover crops for before the onset of a drought (from one to five years), they can expect an average return on corn of

Profile: Coastal Modification for No-Till Success

In the coastal region of South Carolina where Mary Connor runs Three Sisters Farm with her two sisters, practices that improve soil health and water management are critical but complicated. Because of tropical weather conditions that often bring extreme rains, they need to grow their vegetable crops on raised beds on their 90-acre farm. This makes it difficult to practice no-till, even though conservation tillage and cover crops are needed both to improve organic matter in their sandy soils and to conserve moisture during periods of drought.

"Our high annual rainfalls typically occur in concentrated time intervals. We can get eight inches of rain over a 48-hour timeframe," says Connor. "Raised beds help prevent complete water saturation of plants. But converting to no-till in the beds has many obstacles in the coastal plain."

To begin with, most no-till equipment is not designed for raised beds. And sandy soils in the coastal plains are susceptible to losing nutrients and carbon in the soil structure. To enhance moisture retention, humus in the soil must be retained through something like cover crops.

With funding from a SARE grant, Connor tested a no-till roller-crimper that was modified to work on the raised beds of her Bluffton, S.C., farm. Her aim was to manage the impacts of frequent flooding and drought, as well as to enhance and improve soil health, using the combination of no-till, cover crops and tarping. Her approach to improving water management and soil health combined an Austrian winter pea cover crop with surface mulch to lower water loss via evapotranspiration.

Using a roller crimper in no-till, raised-bed applications is a relatively new way to terminate cover crops. It is designed to kill cover crops by crimping but must be timed properly to prevent cover crops from regrowing. Once the family terminates their Austrian winter pea cover crop, they tarp for a month to ensure die down. This allows clean transplants. The cover crop mulch provides weed suppression and moisture retention for vegetable crops.

"The water retention of our soil has noticeably improved since we started this process," Connor says. "This is a small farm, so we do not have any water meters. But I can tell you from walking the farm a couple of times a day, there is a visual difference. You can feel the moisture when you handle the soil even during those periods when we may go two or three weeks without rain."

In addition to cover crops, Connor uses tarping to retain soil moisture and to manage problematic, often herbicide-resistant, weeds like nutsedge. Tarps reduce the time spent weeding by hand by about 250 labor hours, which represents a savings of $4,000–$6,000. Additionally, she puts silage tarps on raised rows until planting, keeping topsoil in place and weed seeds out. Connor has observed higher yields with these tactics as well as reduced labor for weeding.

Other soil and water conservation efforts include getting double-ground leaf and grass mulch from a large residential resort development on nearby Hilton Head Island, and using drip irrigation and micro-irrigation as needed for lettuce and carrots. The water comes from an onsite well.

Soils are tested every five years. Connor has been able to reduce fertilizer use with a documented increase in organic matter and Cation Exchange Capacity (CEC). CEC is used as a measure of soil fertility. A higher CEC reflects well-humified organic matter and clay minerals.

"By building organic matter, soil characteristics like waterholding content and water infiltration have improved," states Connor. "CEC was raised to 9, where typically we would have only a range of 3–6 on most areas. That is as dramatic as if we added high-quality compost to our soil."

Temperature variations that happen more frequently are another concern for the coastal farm. Connor has moved frost-sensitive crops like lettuce into the farm's hoop house for production and has switched to more weather-hardy plantings outside, such as bok choy, spinach, broccoli, collards and carrots.

And while Connor says other farmers can replicate her work, she cautions not to expect overnight results. "You have to be willing to adapt to your conditions," she says. "This is a unique area, so what works elsewhere may not work here, and what works here may not work in other regions."

Learn more: https://projects.sare.org/sare_project/fs16-288

Mary Connor tested this roller crimper that has been modified to work on raised beds at her South Carolina farm, where she has to manage with regular periods of both drought and flooding. *Photo by Mary Connor*

No-till soybeans emerge through corn stubble on a Pennsylvania farm. *Photo by Edwin Remsberg*

$27.34–$110.45 per acre. The average return on soybeans is $41.69–$84.54 per acre.

In 2008, no-till farmer Keith Berns began experimenting with cover crops in dryland rotations of corn, soybeans and wheat on his Bladen, Neb., farm. This SARE-funded project revealed that some multi-species cover crop mixes conserved water as well as wheat stubble alone, and they resulted in higher yields of the following corn crop than stubble.

"Results of this project made us firm believers in cover crops," Berns says. Today, Berns and his brother Brian continue using diverse cover crop species on their 2,000-acre farm to increase organic matter and manage soil fertility. They also operate a thriving cover crop seed business. Moisture management remains both a focus and a challenge each spring as they make decisions about when to terminate cover crops and plant cash crops based on available moisture in the soil.

Compost and Amendments

Some farmers, particularly organic farmers, have long applied manure and compost to meet fertility needs. Most non-organic vegetable producers rely on the quicker fix of annual applications of commercial fertilizer. In either case, nutrient applications should be based on the crop's needs and on results from soil testing if they are to enhance soil health and water management.

Animal manures are high in important crop nutrients and help build and maintain soil organic matter. Analyze manures first to accurately determine application rates. Keep in mind potential limitations like pathogen contamination of crops intended for direct human consumption and accumulations of potentially toxic metals if application rates exceed crop needs.

Composting organic residues before applying them to soil can, if done correctly, eliminate plant disease organisms, weed seeds and many potentially noxious chemicals. Compost provides extra organic matter that improves the soil's waterholding capacity and provides a slow release of nitrogen. Good composting requires plentiful, decomposable carbon- and nitrogen-containing materials, good aeration, moist conditions and enough pile size to allow high temperatures to develop for microbial activity.

Conservation Tillage

Conservation tillage leaves at least 30 percent of the soil surface covered by residue after planting. No-till planters leave even more than that by placing seeds or transplants in narrow slots, the only area where farmers disturb the soil. No-till also consistently improves water infiltration, with reports of up to three times the infiltration compared to moldboard-plowed soil.

Soil porosity and infiltration are likely to continue to increase the longer the soil is under no-till and is accumulating organic matter. Other benefits of reducing soil disturbance include increased biological activity by arthropods and soil microbes, deeper rooting depth for crops, and the surface residue that protects the soil from temperature extremes.

Composted dairy manure is an excellent soil amendment that improves organic matter, infiltration and waterholding capacity. *Photo by Rob Myers, North Central SARE*

More on Farm-Scale Composting

A SARE-funded project at Oregon State University led to development of an agricultural composting and water quality bulletin. It provides detailed, step-by-step guidelines on how to develop a composting enterprise on the farm, regulatory considerations and impacts on water quality.

Learn more:
https://catalog.extension.oregonstate.edu/em9053
https://projects.sare.org/sare_project/ow10-329

Part Two

Plant Management

White Sonora wheat (left) and Chapalote flint corn (right) are examples of drought-tolerant crops that can be used to diversify crop rotations in arid and semi-arid regions. *Photos by Native Seeds/SEARCH*

SELECTING PLANTS ADAPTED TO INDIVIDUAL FARM AND ranch conditions is an important part of a water management strategy. Consider drought-tolerant varieties for water efficiency. Plants with deep root systems, such as buffalo grass, can stretch to the water table. Rangeland species—cool-season grasses ideal for cool-climate pastures or warm-season plants for hotter zones—can thrive in dry conditions.

Crop Rotation

Crop rotation is one of the most effective ways to manage water resources nationwide. Since farmers began growing grain, particularly in the Great Plains, they've used long periods of fallow to conserve water for wheat and other cash crops. The fallow system leaves the land bare over a year or more and allows water to accumulate in the soil.

More recently, farmers and researchers turned to crop rotation as an alternative. They find that rotations improve soil health, conserve water and achieve better profits.

Crop rotation using cover crops is one way to enhance soil health and subsequent crops while also helping to maintain cleaner surface and groundwater. Cover crops prevent erosion, improve soil physical and biological properties, and supply nutrients to the next crop. They also suppress weeds, improve soil water availability and break pest cycles. Individual benefits will vary by species, crop productivity and how long a cover crop grows before soil is prepped for the next crop. Learn more about selecting and managing cover crops in *Managing Cover Crops Profitably* (www.sare.org/mccp).

Water-Conserving Plants

Certain varieties of grain crops can perform well in dry conditions and can help conserve moisture. Likewise, certain cover crops help farmers and ranchers conserve soil moisture. Look for crops that work in your specific climate and that might provide a market advantage.

For example, cotton is a significant water user. Texas accounts for 45 percent of the total U.S. cotton supply, with most of that concentrated in the state's High Plains region. Water levels are declining at an alarming rate in the Ogallala aquifer, the main water source for Texas cotton.

Long-term research led by the Texas Alliance for Water Conservation and funded in part by SARE has shown that rotating cotton with perennial forages that are adapted to dry conditions uses 24 percent less water than a cotton monoculture. What's more, such a diversified system opens a door to profitable beef marketing opportunities.

When plant residue is left on the soil surface, water infiltration increases and evaporation decreases, so there is less moisture stress during drought. Lightly incorporated cover crops can trap surface water and add organic matter to increase infiltration to the root zone.

Especially effective at covering the soil surface are grass-type cover crops, such as rye, wheat and a sorghum-sudangrass hybrid. Some water-efficient legumes, such as medic and Indianhead lentils, provide cover crop benefits in dryland areas while conserving more moisture than fallow.

Profile: From Fallow to Field Peas

As farmers in western Nebraska face higher cash rents and property taxes, many want a more profitable, sustainable alternative to fallow for crop rotation. Strahinja Stepanovic, a University of Nebraska Lincoln Extension educator, received a SARE grant to find suitable crops for the mix.

"Farmers in the semi-arid regions of western Nebraska (14–19 inches of annual precipitation) who have no irrigation often conserve soil water by rotating cereal crops, such as corn or wheat, with a period of summer fallow," says Stepanovic. "Unfortunately, fallow expenses are increasing due to development of herbicide-resistant weeds, record-low wheat prices and low protein levels. Farmers are slowly abandoning the fallow concept and are searching for alternative crop rotations. We have shown that pulse crops like field peas and chickpeas are a solid alternative to fallow."

Stepanovic notes that before 2013, only 10,000–20,000 acres of field peas were grown in the Nebraska panhandle. Between 2014 and 2018, as farmers became familiar with peas through research and outreach efforts by Stepanovic and others, acreage grew to 70,000 and spread into central and eastern Nebraska. Production is slated to continue to expand.

A research site in Nebraska includes field peas (left) as an alternative to summer fallow (right). Diversifying rotations with field peas is helping many farmers in this semi-arid region conserve water, improve soil health and adapt to market fluctuations. *Photo by Strahinja Stepanovic, University of Nebraska Lincoln Extension*

"Replacing fallow with field peas has helped many farmers intensify and diversify crop rotations, improve soil health and better cope with herbicide-resistant weeds and weather- and market-related fluctuations," asserts Stepanovic. "Adding field peas to crop rotations helps conserve moisture."

Stepanovic says that in 2018, precipitation was above average at 22 inches from March to September. On fallow ground with 60% residue cover, 19 of those inches were lost to percolation into the aquifer (11 inches) and evaporation (8 inches), with 3 inches stored in the soil profile for fall-planted wheat.

"Water is way too valuable to lose," Stepanovic states. "We can 'harvest' 11 inches of water as a 30-bushel-per-acre pea crop and still not lose as much water as during fallow." Field peas are a short-season crop (March to July), and if the soil water profile regenerates between field pea harvest and wheat planting in September, the yield impact on the next year's wheat crop may be negligible, he adds.

Depending on the year, farmers may report gains of $50 per acre. That is a significant improvement compared to $40–$90 per-acre expenses associated with spraying herbicides to control weeds in fallow. Additionally, three pea processors are now located in Nebraska along with about eight seed companies, so getting good quality seed and marketing are much easier now.

New research conducted since the SARE-funded project also is positive for pea farmers. Stepanovic notes one farmer planted field peas under pivot irrigation on sandy hills where irrigated corn yields were not attractive. In the dryland corners, field peas produced a 15-bushel yield while the same variety under pivot made a 65-bushel yield by supplementing only 1.5 inches of water applied at the right time.

"We learned if you irrigate properly, you can get 50–60 bushels of peas by applying only two or three inches of irrigation water, and then double-crop forage sorghum with no additional fertilizer or chemical inputs. That adds three to five inches of irrigation water between July and October to turn a pretty good profit," Stepanovic says. Contrast that to a high-input crop like corn that requires more than 13 inches of water on sandy ground to make 180 bushels per acre, he adds. "This is how to save water with crop rotation. This is the most fundamental way to manage water."

Learn more: https://projects.sare.org/sare_project/onc16-021

Early Weaning Options

In a SARE-funded project that began in 2018, University of California rangeland specialists partnered with local ranchers to assess early weaning of beef calves as a drought management strategy. In a producer survey conducted prior to and following the conclusion of California's 2012–2015 drought, project coordinators learned that while early weaning is done by significant numbers of ranchers, very little research has been conducted in annual rangeland systems to determine whether such a strategy is economically or ecologically beneficial.

While the project is ongoing, researchers learned during the first season that, as expected, early weaned calves were significantly lighter than traditionally weaned calves and did not gain as rapidly post weaning. Early weaned cows recovered their body condition score more rapidly than traditionally weaned cows, which may have bearing on conception rates in years following drought. The project team aims to develop guidelines that help individual ranchers decide when and how early weaning might work as a drought management strategy.

Photo courtesy Dan Macon, University of California Extension

Heritage Grains

Native Seeds/SEARCH, an organization in Arizona that promotes arid-adapted crop diversity, worked with a team of farmers and researchers to successfully reintroduce two heritage grains to the arid Southwest. Supported by a SARE grant, the team evaluated Chapalote flint corn and White Sonora wheat for their capacity to reduce water use and enhance both soil fertility and moisture-holding capacity. They chose Chapalote corn for its reputation of performing well during dry years with little supplemental irrigation. White Sonora wheat was similarly selected for its drought tolerance. Using these heritage varieties, they reduced their seed, water and nitrogen inputs by up to 50% compared to conventionally grown varieties. Native Seeds/SEARCH restored local production of this heritage grain and helped support the community by enlisting members to produce value-added products from the grain.

Regional Crops

Researchers and farmers in different states have evaluated such water-conserving species as hulless barley, quinoa and pearl millet. Washington State University researchers in the Palouse region of Idaho and Washington tested **hulless barley** and **quinoa** on dryland, no-till farms for seeding rate, nitrogen supply and yield. Evaluation of quinoa revealed farmer enthusiasm, but continued research is needed on combining agronomic practices with varieties that can tolerate drought conditions. Results with food-grade barley were much more favorable. Barley yielded reliably across three years of research on participating farms, and the team identified optimum seeding and fertility rates. They released a new cultivar of hulless barley with nutritional characteristics that are attractive to the health-food market.

Pearl millet is one of the most drought-resistant commercial grains. It can grow in areas that experience frequent dry weather during the plant's vegetative or reproductive phases. This warm-season annual grass has a high protein content and a short maturing season that allows it to fill a midsummer, double-crop production niche. Pearl millet appears to be more tolerant of sandy and acidic soils than other summer crops, is deep rooted, and takes up residual nitrogen, phosphorus and potassium. The grain is used in poultry and livestock rations, and is a good option for wildlife plantings and birds. Opportunities also exist in health-food outlets and in beer brewing.

Other drought-tolerant crop alternatives, especially in the South, include **sesame** and **cowpeas**.

Rangeland Drought Management

Ranchers must prepare for the ever-present challenges posed by drought. They need practical ranch management options during drought to sustain soil health, plant diversity and livestock production while supporting rural economies in the western United States.

Rangeland livestock producers are often the first to feel the impacts of drought, especially in California, where the majority of precipitation and forage growth occurs in fall, winter and spring. Ranchers report lost grazing capacity and profits, as well as reduced calf weaning weights during dry years. And many are not prepared for frequent drought events.

Ken Tate, University of California Davis Extension specialist, advises ranchers to keep hay on hand to avoid paying a premium for it during a drought. Here, hay is fed to cattle during the 2015 drought in California. *Photo by Tracy Schohr, University of California Cooperative Extension*

Profile: Adapt-or-Perish Approach

In 2013–14, University of California Davis Extension Specialist Ken Tate interviewed ranchers and asked if their current management strategies would be sufficient to deal with more frequent drought events (5–8 drought years in a 10-year period). Most (82%) did not think so, and more than half said they would reduce their base herd size as a result.

Better options exist, however, according to Tate, whose effort to help ranchers adapt to more persistent drought was funded by SARE. "We can place management strategies into two bins: proactive in case of drought and reactive when there is drought. The best adaptive capacity is to have a good mix of both of these strategies as part of an actual drought management plan."

Proactive strategies for cow-calf ranchers, particularly:

- Stock the herd at a moderate level with a safe number of animals should drought occur. Tate advises ranchers to protect their herd's genetics and not to impulsively add or sell cows from their basic herds at random in response to adverse weather.
- In good years, scale up the number of short-term tenants on pastures to use up forage. Consider buying 500–600 pound stockers and putting them on grass.
- Keep 10 percent of a ranch's forage in a resting state, or stockpile for emergencies.
- Keep hay on hand so you don't have to buy it during a drought.
- Be aware of specific financial risks and evaluate drought insurance.
- Be aware of federal and state programs for drought aid. Track the federal drought monitor and provide input for your region so it is accounted for in aid packages.

Reactive strategies for cow-calf producers:

- Determine which cows you would cull first during the drought and why. Cull open cows, old cows or bad-temperament cows first.
- Have price triggers in your drought plan. Watch the market as drought begins to have an impact and sell if you can get a good price.
- Replace feed with hay and realize you can't feed your way out of a drought. Decide how long you are willing to invest in feeding cows before culling a second or third group.

"Water management is another priority. Producers need a strategy to handle water availability," Tate notes. "It is a pain to haul water to cattle, but if you do not have enough stock tanks, ponds or creeks then you need to have a plan to improve water distribution so cows can access forage that may be farther away from existing water sources. That makes more forage available."

For example, keep a water truck that you can take to the cattle full during a drought. Explore USDA cost-share dollars to put in equipment for improved water management. Tate adds that either option can be labor intensive but should be analyzed for long-term opportunities.

"No one thing will get you through. Successful ranchers are those who are willing to be risk takers and try new things," says Tate. "Ranches on the same ground for generations have people who know what works locally. They are good resources for other ranchers."

For the long term, Tate encourages ranchers concerned about climate change or more frequent periods of dryness to weigh other options, including genetic selection to reduce cow size, adding or switching cattle breeds, or exploring opportunities with other ruminants.

"Take an adapt-or-perish strategy," he states. "Switching breeds is not easy, but maybe it is a consideration. Sheep offer greater flexibility in forage and crop residue consumption and can be transported closer to urban areas for grazing than cattle can. Just don't rush into a new enterprise. Match livestock to the environment and anticipate it not to be a good year every year."

Other rangeland management specialists have found that adding small ruminants, such as goats and sheep, to a cattle operation can deflect the effects of drought. Large and small ruminants have different forage requirements. In addition, when drought strikes, common advice is to make the most of forage. Send the herd to graze drought-stricken crops to salvage the value of those crops, but monitor residues from drought-stressed crops for prussic acid and high nitrate levels.

Learn more: https://projects.sare.org/sare_project/sw10-073

Part Three

Water Management

In areas with frequent droughts or limited water availability, many producers are conserving water by adopting more efficient irrigation systems combined with improved soil management practices.
Photo by Lance Cheung, USDA

FARMERS AND RANCHERS IN MANY PARTS OF THE COUNTRY are taking steps to make irrigation systems more efficient and cost effective. Regardless of which irrigation system you use, there are common ways to improve your management of irrigation water.

Improve soil health. The soil management practices described in this bulletin increase organic matter, aggregation, infiltration, waterholding capacity and rooting volume. They reduce crusting, erosion and surface evaporation. All of this maximizes a crop's ability to use the irrigation water you apply.

Use water conservatively. Schedule irrigation times and amounts based on data from soil moisture sensors and weather forecasts, and based on the needs of the crop at different growth stages. Work with local specialists to determine the best ways to integrate sensor technologies on your farm. There may be other ways to modify your irrigation system to make it more efficient or opportunities to replace one system for another. Careful water management can also help manage salinity issues.

Harvest and reuse water. Water storage systems can be used to catch and store rainwater to supplement your needs, depending on your state and farming circumstances. If available, explore options for using good-quality recycled wastewater. EPA's *Guidelines for Water Reuse* may help you find out your state's regulations.

Contact an NRCS technical service specialist to develop an irrigation management plan that will control volume, frequency and flow rate to promote desired crop response, optimize water use, improve water quality, minimize irrigation-induced soil erosion, manage salts in the root zone and reduce energy consumption.

An irrigation audit may help determine what goals or outcomes are best for your individual farm. The Texas Water Conservation Implementation Task Force uses an audit with three phases:

» **Data collection.** Key information may include sketches or maps of fields, locations of water supply networks, meters or measuring points, and inventories of pumping plants. Crop types, field slope, soil types and textures, and infiltration rates are also important. Irrigation scheduling method, previous water use data and prior audit results can also be significant, along with well construction information and well testing records.

» **Onsite audit.** A physical irrigation audit should verify water use by assessing water and energy use efficiency across the farm.

» **Audit report.** Data gathering and onsite audit phases should provide enough information to generate a report about current equipment, recent irrigation schedules and identified water uses throughout the operation. The irrigation audit report generally provides practical options for scheduling maintenance to improve irrigation systems and serves as a guidance tool for making innovative management changes.

Typical irrigation systems, which can have varying degrees of efficiency and cost, include (from top left): surface flooding, standard center pivot, center pivot with low-elevation application nozzles, drip, and mobile drip (a combination of drip tubes and low-elevation center pivot). *Photos by (from top left): New Mexico State University Extension; Lance Cheung, USDA (second, third and fourth); and Kansas State University.*

Irrigation Systems

Many irrigation packages and operating methods are available. For example, with proper design and installation, a center pivot sprinkler system can achieve high irrigation efficiency and uniform application. Furrow irrigation strategies, such as tailwater recovery, irrigating every other row and polyacrylamide application, also provide ways to lower water use. Other water delivery systems include lined on-farm irrigation ditches or pipelines, drip/micro and subsurface irrigation, gated and flexible pipes for field water distribution systems and surge flows.

Types of Irrigation Systems

Surface irrigation supplies water to the soil surface by gravity. Surface irrigation systems can vary. Water flows over the ground and through the crop, with levees and gates used to control water depth, furrows or borders. Cascade flood irrigation involves water entering the field at the highest elevation and cascading down through a series of levee gates. Side-inlet flood irrigation involves a lay-flat pipe placed across levees with holes in it to simultaneously deliver water to each zone of the field. Surface irrigation systems are the cheapest to install and use, but water application rates are not exact and distribution across the field is typically uneven. They are most associated with salinization concerns because they may easily raise groundwater tables depending on the depth of the water table and how effective your drainage systems are. Flood irrigation is often less efficient than other systems due to the likelihood, depending on your circumstances, of experiencing higher rates of evaporation, deep infiltration or surface runoff. Techniques like land leveling, surge flooding, and capturing and reusing runoff can improve the efficiency of flood-irrigated systems.

Sprinkler irrigation applies water to crops via nozzles. Sprinkler systems use a water pump, or gravity in some cases, to build pressure and deliver water to crops through fixed or continuously moving nozzles that can be programmed to start and stop, such as with center pivot irrigation. Sprinkler irrigation works well on medium and coarse soils that have naturally higher infiltration rates. Sprinkler systems may be adapted to use on heavier soils by combining with practices like land leveling, tillage or diked furrows to help hold water while it infiltrates. Water can be applied at low rates with fertigation and chemigation, but frequent applications may be needed to recharge soils. Sprinkler irrigation improves efficiency compared to flooding systems by allowing for more precise water application rates. It does require a larger up-front investment and more energy use. Adaptations to center pivot and linear sprinkler irrigation systems can reduce water loss to evaporation and drift. These systems include:

- **MESA**, or **mid elevation spray application**, is a center pivot system where nozzles are spaced farther apart (10 feet) and the nozzles are higher (approximately 5–15 feet) off the ground. In MESA systems, water is delivered above the crop canopy. MESA can be less efficient than other systems because water applied above the crop canopy can be lost both to wind drift and to evaporation from the crop and soil surface. Use nozzle weights and flexible drop hoses to reduce water loss and improve water distribution.
- **LESA**, or **low elevation spray application**, is a modified center pivot system where the sprinkler nozzles are spaced closer together (less than 5 feet apart) and are suspended closer to the soil surface (1–1.5 feet). LESA systems deliver water under the crop canopy and closer to the soil surface, so less water is lost to evaporation and wind drift. LESA irrigation systems run at low pressure, so they use less energy to pump water than MESA systems.
- **LEPA**, or **low energy precision application**, is a modification to typical center pivot systems that uses suspended nozzles to deliver water directly to furrows at lower pressures. Nozzles are typically spaced 60–80 inches apart, and water is delivered directly to the soil up to about 18 inches from the ground. The crop canopy stays dry since water is delivered close to the soil. Drag socks can be installed to minimize furrow erosion. LEPA irrigation systems work well with low-growing crops. They minimize water loss to wind drift and evaporation, and also optimize energy use since water is run at lower pressure.

Drip irrigation delivers water to crop roots; it is supplied under low pressure through plastic tubing with emitters to regulate flow rate. Tubing can be placed on the ground or buried beneath the soil surface. Drip irrigation is efficient with water by minimizing evaporation loss. It also reduces nutrient losses from leaching. More maintenance may be required for drip irrigation, but it offers a high level of control. Drip irrigation systems may be expensive to install, but reduced water and energy use, as well as potential yield increases, makes drip irrigation systems a good investment.

Mobile drip irrigation combines features of drip irrigation with the flexibility of center pivot irrigation. Mobile drip systems consist of trickle tape attached to a center pivot system that delivers water directly to the soil surface. Water loss to wind drift and evaporation are minimal under mobile drip systems. Energy savings may be significantly improved due to the low pressure needed to run these systems.

Sub-surface irrigation delivers water beneath the soil surface through drip lines installed underground. The system is used to raise and maintain the water table near

Photo by Lance Cheung, USDA

Profile: New Techniques Tweak Efficiencies

Furrow irrigation supplies water to crops through shallow, evenly spaced furrows. University of Missouri Extension describes it as, "parallel beds usually spaced 30–38 inches apart. Water flows from a pump in lay-flat plastic pipes with holes in them to obtain desired flow rate."

Though furrow irrigation is not very efficient on its own, the economics of it are attractive to farmers given little capital investment other than possible land grading. About two-thirds of Mississippi's crop acres are irrigated, and more than 80 percent of them use furrow irrigation. During the last few years, Mississippi farmers have upgraded to technology tied to smartphones and computers.

Soil moisture sensors that signal when to start and stop irrigation are installed in this soybean field at depths of 6, 12, 24 and 36 inches. *Photo by Drew Gholson, Mississippi State University Extension*

"We have demonstrated in the Delta region that combining furrow irrigation with technological advances, such as computerized hole size selection, irrigation timing using a soil water balance, and sensors for real-time feedback of plant and soil moisture conditions, can produce significant water savings," says Curt Lacy, Mississippi State's Delta Region Extension coordinator.

Lacy and other Mississippi State Extension staff used a SARE grant to educate farmers on how to reduce water use through adoption of improved furrow irrigation management. On-farm demonstrations of the three tools validated practices, improved efficiency and uniformity, and saved water:

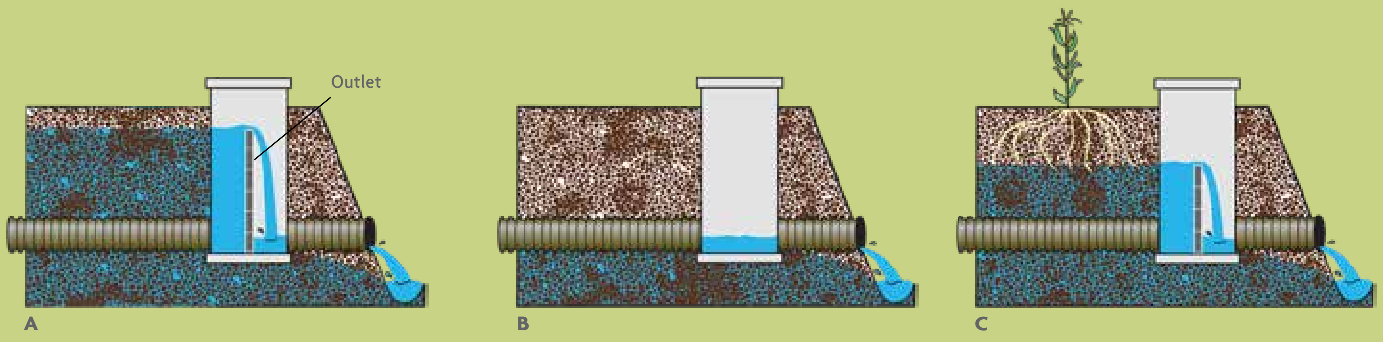
- Right-size holes are created by putting information regarding elevation and flow rates into a computer program. Holes are punched into pipes for uniform water distribution.
- Soil moisture sensors signal when to start and stop irrigation, and reduce water use.
- Surge irrigation valves are used to increase application efficiency.

Research shows that utilizing soil moisture sensors, computerized hole selection and surge irrigation in corn decrease total water applied by 39.5 percent while increasing corn grain yield by 6.5 bushels per acre and irrigation water use efficiency by 51.3 percent. Net returns above irrigation costs rose from $25 to $40 per acre, according to Drew Gholson, a Mississippi State Extension irrigation specialist. Soybean returns and yield were unchanged as water use was reduced by 21 percent and water use efficiency increased 36 percent.

"More than 18 trials showed statistically significant improvement in water use efficiency," says Gholson. "Soil moisture sensors allowed farmers to prolong irrigation as long as possible without affecting crop development. Farmers should work with local Extension specialists on trigger thresholds best for their areas and on crop growth stages vulnerable to timely water application."

Learn more: https://projects.sare.org/sare_project/es16-127

FIGURE 3. EXAMPLES OF HOW A CONTROL STRUCTURE IS USED TO MANAGE FIELD DRAINAGE



A: The outlet is raised after harvest to reduce nitrate delivery to ditches and streams in the off season. B: The outlet is lowered a few weeks before planting (and again before harvest) to allow the field to drain more fully before machinery is operated. C: The outlet is raised after planting and spring operations to increase water storage for crops during the summer. From *Drainage Water Management for the Midwest: Questions and Answers about Drainage Water Management for the Midwest* (WQ-44), Purdue Extension.

the root line. This system is less labor intensive and is good for soils with low water retention capacity and smooth, level topography; it also can double as a drainage system. Tubing and emitters must be placed close to plant roots to be effective, and lateral water flow from the trickle line through the soil is limited.

Drain Water Management

Tile drainage systems are widely used to manage excess water in regions that receive a lot of precipitation. But when crop production practices that diminish soil health, such as excessive tillage and no crop rotation, are also used, then tile drainage systems do not operate as efficiently as they can because of poor water infiltration. This is why practices that improve soil structure, like conservation tillage and planting cover crops, and that result in increased water infiltration, are important for getting the most out of a drainage system. Excess water will flow more easily through the soil profile and into drain pipes instead of ponding or running off the surface.

In addition, fitting a drainage system with water control structures allows you to control the timing and amount of water leaving the field each year. Drainage water management, or controlled drainage, is a conservation drainage practice that focuses on managing the timing and flow of water leaving your drainage systems. Adjustable water-level-control structures allow you to raise and lower the water table (Figure 3). This gives farmers some flexibility and opportunity to manage their soil water table throughout the year, especially during excessively wet or dry periods.

Water levels are typically managed at key times during the growing season. Raise the water table after harvest in order to keep water and nutrients in your fields. Two weeks before planting or before any scheduled field activities, lower the water table to allow the field to fully drain so you can safely operate equipment without impacting the soil. Raise the water table near your crop root zone after planting. Effective management of drainage water can provide benefits, such as reducing the nitrogen lost as nitrate from fields by up to 40% and reducing annual

Drainage water management reduces the flow of nitrates to water ways and can make more water available to crops. *Photo by Curt McDaniel, USDA*

Manage Salinity with Cover Crops

In the Northern Plains, extensive wet periods lead to salinity problems on an estimated 15–35% of cropland. Creating cropping systems that use more water and that drive salts deeper into the soil profile is one recommended strategy for addressing this challenge. Funded by two SARE grants, North Dakota State University Extension specialists partnered with area farmers to demonstrate how crop rotations involving cover crops can manage salinity while providing other soil-health-related benefits.

The team worked with four farmers to implement rotations on salt-affected fields. They were able to extend the amount of time a crop was growing in those fields by up to four months by combining cover crops with an early season, salt-tolerant crop, such as a small grain. Along with better management of excess moisture, these rotations that extended the length of the growing season also improved soil health and developed more sustainable agronomic systems. The cover crops used on each farm were mixes that included cereal rye, radishes and turnips, plus additional species in some treatments.

Learn more:
https://projects.sare.org/sare_project/ONC15-012
https://projects.sare.org/sare_project/ONC17-036

water discharge by 20–40%. In drier years, crop yield may increase by up to 10%. Further environmental benefits of controlled drainage are improved wildlife habitat, reduced erosion and cleaner water.

Controlled drainage systems may be retrofitted onto older systems. Newer systems offer automatic controls, cellular data collection and weather monitoring. Work with your local technical service providers and Extension agents to develop a drainage water management plan that works for you. Cost-share programs are available through NRCS and your state's department of agriculture to help manage the costs of improving your system.

Managing Salinity

As salt accumulates in the soil, crops have more difficulty taking up the water that's available. High salinity in the root zone also causes nutrient imbalances and affects plant growth and yield. High concentration of specific ions can be toxic to crops.

Salinization occurs when irrigation water evaporates, which leaves salts behind. It is especially prevalent with flood irrigation systems, which tend to over apply water and can raise saline groundwater tables. Once the water table gets close to the surface, capillary water movement transports soil water to the surface, where it evaporates and leaves salts behind. When improperly managed, this can render soils unproductive within a matter of years.

The adverse effect of salinity can be reduced through proper irrigation and crop management practices, such as leaching, selecting plants like barley or alfalfa that can tolerate salinity or specific ions, and soil/water amendments. Testing for salinity and sodicity in irrigation water and soils can help you develop irrigation and crop

The rainwater harvesting system that Cherry Flowers and Tim Page added to one of the high tunnels at their urban farm in Minnesota. *Photo by Marie Flanagan, North Central SARE*

Water Harvesting

Farmers with greenhouses, high tunnels and other structures with significant roof area can consider installing systems to capture and store rainwater for irrigation. Capturing, storing and pumping the water that falls on such rooftops can be an attractive way to supplement other sources of irrigation water.

Cherry Flowers and Tim Page operate an urban farm in the Twin Cities area of Minnesota, and they saw many positives to adding a rainwater harvest system to their high tunnel, which they did with support from a SARE grant. It consists of gutters lining both sides of the structure, which drain into rain barrels. The barrels are connected to the drip irrigation system inside the tunnel, and water is pushed through by a solar-powered pump. The system can capture 600 gallons of water in a 1-inch rainfall, and in the first year of use, there were only four rain events that exceeded the capacity of the system.

Along with using rainfall to irrigate the crops inside the tunnel, Flowers and Page have found other benefits of the system: it allows them to avoid chemicals that are found in municipal water and are potentially harmful to crops, such as flouride and chlorine; it eliminates erosion and ponding around the inner and outer edges of the high tunnel, which used to occur during heavy rainfalls; and it reduces the amount of stormwater their operation contributes to the municipal sewer system.

management practices that will sustain crop yields, maintain or improve soil physical properties, and minimize adverse environmental impacts.

One option is to keep soils moist. Drip irrigation with low-salt water plus a surface mulch does not allow salt content to get as high as it would if allowed to concentrate when the soil dries. Another option is to grow saline-tolerant crops like barley or Bermuda grass.

The only way to get rid of salt is to add sufficient water to wash it below the root zone, which requires significant amounts of water and time. If the subsoil does not drain well, drainage tiles might be needed to get rid of salt water. In arid regions, where shallow groundwater tables and less precipitation is common, irrigation management systems should be designed to both supply and drain water to avoid the issues that contribute to salinity accumulation in soil.

Smart Irrigation

Unlike traditional irrigation controllers that operate on a preset schedule to deliver a uniform amount of water across a field, variable rate irrigation systems allow you to change the water rate either from one irrigation event to the next, or to apply different rates in various zones of a field during a single event. These systems use data from sensors monitoring soil moisture, weather conditions and crop plants, combined with analysis software and irrigation system controls, to automatically adjust irrigation schedules based on actual conditions. These systems are becoming more sophisticated in their ability to determine the precise needs of individual crops and to account for variability across fields in terms of both soil type and moisture level.

Basic systems can start with soil moisture sensors that are placed at varying depths and in multiple field locations. These sensors can be connected to smartphones and can help you recognize when soil-moisture levels are adequate to reduce a scheduled application of water, or to skip it entirely.

Contact local specialists with NRCS, Extension or irrigation suppliers to explore strategies for adopting sensor technology on your farm or ranch.

Regularly test soil to avoid over-application of nutrients. *Photo by Jason Johnson, Iowa NRCS*

Apply Nitrogen and Phosphorus with Care to Protect Water Quality

Managing soil phosphorus is a concern for farmers and environmental regulators. Over-applying phosphorus in composted or uncomposted animal waste may contribute to surface water pollution. Although nitrogen and phosphorus are essential for plant nutrition, excessive amounts can wash and leach into waterways.

The first step for keeping nitrogen and phosphorus in fields and out of surface waters is to rely on regular soil testing and to maintain soil nutrient levels that support plant growth but do not accumulate beyond optimal levels. NRCS recommends soil testing fields every three to five years. Any nitrogen and phosphorus added through bio-solid or manure applications should be accounted for when determining how much plant-available nitrogen and phosphorus is required to reach the levels recommended by a soil test.

Experts suggest analyzing the phosphorus and nitrogen contents of compost as part of nutrient management planning. Routine testing is both recommended and widely available. Test soil—as well as organic amendments such as compost—for nitrogen and phosphorus levels, and test compost for moisture content. Each state's soil testing lab, typically located at land grant universities, can also provide information about the phosphorus index (PI) to measure phosphorus concentration.

The NRCS recommends using one of three phosphorus application options when manure or other organic byproducts are land applied:

- PI rating: nitrogen-based manure application on low- or medium-risk sites, phosphorus-based or no manure application on high- or very-high-risk sites
- Soil phosphorus threshold values: nitrogen-based manure application on sites where the soil test phosphorus levels are below a threshold value, phosphorus-based or no manure application on sites that equal or exceed threshold values
- Soil test recommendation: nitrogen-based manure application on sites where there is a soil test recommendation to apply phosphorus, phosphorus-based or no manure application on sites where there is no soil test recommendation to apply phosphorus

Profile: Low-Cost Irrigation Technology Ideas

Efficient irrigation management is important for all farms regardless of their size, but some small-scale growers find that the cost of commercial technology puts it out of their reach. This motivated Christian Flickinger of Renegade Acres in Howell, Mich., to create a low-cost, automated irrigation system using a mix of commercial- and professional-grade components. The system, which Flickinger developed through a SARE-funded project, is controlled with open source technology, meaning other farmers can easily adopt a similar approach and modify it based on their irrigation needs.

The web-based controller in Flickinger's system includes flexible programming options with the capability of reducing irrigation schedules based on real-time weather patterns, which is helpful when managing the water requirements across his diversified, 7-acre operation. He used consumer-grade solenoid valves and professional-grade drip tape to complete the system. In 2017, his first year using the new system, he reduced his water use by 58%, or by more than 58,000 gallons, compared to 2016. Both years had similar weather patterns. The savings were a result of irrigating less frequently and for shorter periods of time because his schedules took weather conditions into account.

The low-cost irrigation system set up by Michigan farmer Christian Flickinger includes a mix of commercial and professional components (top) that is controlled by web-based, open source technology (bottom). *Photos by Christian Flickinger*

Resources

To further explore sustainable water management, read this bulletin online at www.sare.org/water-bulletin, where you will find links to additional resources that were developed by SARE and by SARE grantees. General resources that are free to access online:

Cost-Share Resources

USDA's Conservation Stewardship Program provides financial and technical assistance to eligible producers to conserve and enhance soil, water, air and related resources on their land.

The **NRCS Environmental Quality Incentives Program (EQIP)** provides producers with financial resources and one-on-one help to plan and implement conservation practices that lead to cleaner water and air, healthier soil and better wildlife habitat, all while improving agricultural operations.

The **USDA's Agricultural Management Assistance program** is available in 16 states to help producers implement conservation practices that reduce financial risk and that can be used to construct and improve water management and irrigation structures.

Soil and Plant Management

Building Soils for Better Crops
www.sare.org/bsbc

Cover Crops for Sustainable Crop Rotations
www.sare.org/cover-crops

Crop Rotation on Organic Farms
www.sare.org/crop-rotation-on-organic-farms

Cultivating Climate Resilience on Farms and Ranches
www.sare.org/climate-resilience

Managing Cover Crops Profitably
www.sare.org/mccp

Rangeland Management Strategies
www.sare.org/rangeland

Water Management

USDA Natural Resources Conservation Service (NRCS) irrigation page
http://go.usa.gov/Kow

Contact your local Extension or NRCS office for site-specific irrigation information.

USDA United States Department of Agriculture | National Institute of Food and Agriculture

SARE Sustainable Agriculture Research & Education

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