

Farming for Success in the 21st Century: Increasing Biodiversity

Scientists predict that climate change impacts on California agriculture will include less available water, drier and hotter conditions, more unpredictable and extreme weather events, and new pest and disease pressures. Increasing biodiversity can help growers cope with a changing climate and more extreme weather events by providing “insurance” against unpredictable conditions and by restoring the ecosystem services that support crop productivity.

For centuries, farm systems were diverse mixes of grazing land, cropland, orchards, wetlands, and managed forests, which could support a wide array of biological diversity. However, farmscapes over the past fifty years have become increasingly uniform. Average field sizes have increased while areas of non-crop vegetation and native landscapes have decreased. As a result, biodiversity has diminished and farm systems have become more vulnerable to extreme and unpredictable circumstances.

Ecosystem services such as clean drinking water, crop pollination, nutrient cycling, biological pest control and climate regulation all rely on biodiversity. On-farm biological diversity

can be increased in farm products (crop varieties and rotations, use of perennial crops and trees, integration of livestock) and in the landscape (e.g., soil microbes, birds, insects, riparian corridors, hedgerows). Growers can diversify farming systems at different scales through a variety of practices that minimize the loss of productivity and provide economic benefits. In California, pollinator-dependent crops comprise one-third of agricultural products and represent a net value of \$11.7 billion a year. A recent UC Berkeley study estimates that wild pollinators provide more than one-third of all pollination services, worth up to \$2.4 billion to farmers.

Implementing management changes can take time and often require short-term investments. Economic and ecosystem benefits will accrue over time. For example, increasing crop diversity needs new approaches to planning and management. Enhancing wildlife habitat requires time and equipment for weed control and irrigation. Incremental, phased changes and combinations of investments, rather than any single project, will restore long-lasting diversity to farm systems.

Increased Biodiversity Yields Multiple Benefits:

- Enhances resilience to unpredictable and extreme events such as drought, heavy rainfall, pest infestations
- Regenerates the ecosystem services that provide critical agricultural inputs, increase yields and reduce costs
- Reduces reliance on off-farm inputs
- Enhances biological control of pests
- Reduces need for pesticides, lowers input costs and reduces farmworker and consumer chemical exposure
- Improves water quality; reduces downstream costs associated with sedimentation
- Provides additional business opportunities: beekeeping, cut flowers, fish farming
- Enhances aesthetic appeal; increases natural beauty for residents
- Increases acceptance of farming practices by public



photo: Bonterra Vineyards

“Increasing biodiversity not only helps control pests and reduces pesticide use, it creates wildlife habitat and contributes to the terroir that makes high quality grapes and wines.”

— David Koball, *Director of Vineyards*,
Bonterra & Fetzer Vineyards

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This project was funded by a grant from Western Sustainable Agriculture Research and Education and produced by these partners:



Crop Diversity – Manage with crop rotations, intercropping, fallowing, leguminous crops, insectary strips, agroforestry; different crop varieties (e.g. multiple cultivars, native forages)

Benefits

- Higher organic matter in surface soils increases abundance, diversity & activity of organisms responsible for nutrient cycling; can improve yield
- Plants requiring less water reduce water consumption, costs for water & irrigation
- New crops can provide a market advantage
- Insectary strip crops support predatory & parasitic insects; host pollinators, reducing need for honeybee rentals

Case Studies

- Strip-cutting alfalfa increased yields 15% and beneficial arthropods 400% per acre compared to full-cut alfalfa (*UC Davis, Entomology*).
- In an extreme drought year, corn yields were 137% higher in a legume/manure-based organic system than in a conventional system (*Rodale Institute*).
- Long-term crop rotations (3-4 yrs) have 200x less toxic runoff than short-term rotations (1-2 yrs) (*Iowa State University*).

Considerations

- Intercropping may affect harvesting strategy
- Limited by types of crops that can be grown in an area
- Time commitment for additional planning & management



photo: Full Belly Farm

Landscape Diversity – Re-vegetate farm edges (hedgerows, border plantings, grass strips, areas of native plants); Integrate strips of vegetated land in between fields; Add farm ponds, riparian buffers, woodlots, pastures

Benefits

- Habitats boost biodiversity while reducing pesticide use
- Cost-effective alternative to herbicides, disking, mowing
- Hedgerows serve as fences & windbreaks, slow runoff & trap sediment
- Perennial plants & grasses sequester carbon
- Perennials can out-compete invasive annual weeds

Case Studies

- Including sweet alyssum, baby's breath, common coriander, or Persian clover in the margins of lettuce fields attracts aphid predators (*UC IPM Program*).
- Riparian buffers mitigate N & P runoff into waterways (*UC Davis, LAWR*).
- Costs for establishing a hedgerow can range from \$1-4 per linear foot (*UC Cooperative Extension Santa Cruz*).

Considerations

- Can risk attracting pest insects or diseases
- Some annuals can become invasive
- Perennials can be difficult to establish; may require irrigation



photo: Sam Earnshaw

Species Diversity – Integrate livestock or fish; Add bird or bat boxes, raptor perches; Plant or conserve native trees

Benefits

- Diversity improves disease resistance
- Natives can be cultivated under unfavorable crop conditions (e.g., drought, salinity, poor soils)
- Expands product line and consumer market
- Nesting raptors, owls help with gopher control; song birds help with insect control
- Livestock produce manure for on-farm fertility

Case Studies

- Using sheep to graze alfalfa crop residue reduced adult alfalfa weevils by 35-100% and larvae by 40-70%, without impacting crop yields or quality (*SARE-funded project, Montana State University*).
- Herbivore suppression, enemy enhancement & crop damage suppression were significantly stronger on diversified crops than on crops grown in less diverse systems (*UC Santa Cruz*).

Considerations

- Availability of crop cultivars are dependent on breeding programs & may vary by region
- Requires restructuring of farm system & expertise in livestock management; possible to rent grazing animals

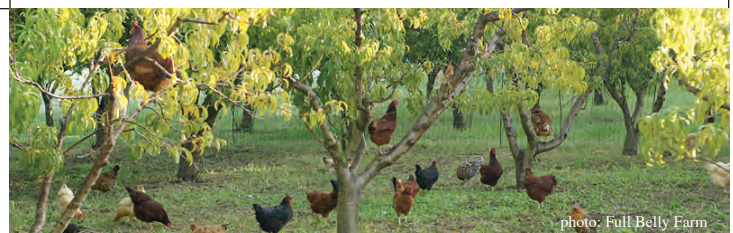


photo: Full Belly Farm

Farming for Success in the 21st Century: Water Stewardship

Scientists predict that climate change impacts on California agriculture will include less available water, drier and hotter conditions, more unpredictable and extreme weather events, and new pest and disease pressures. Growers can cope with a changing climate and extreme weather events more effectively by employing water stewardship strategies such as increasing water use efficiency (WUE), maximizing yields, and reducing soil erosion — all important for enhancing the resilience of farm operations and controlling costs.

Agriculture uses about 80% of California's developed water in order to irrigate roughly 9.6 million acres. Other competing uses of water include:

1. Urban (residential, commercial, municipal) — California's steadily increasing population increases water demand even as water conservation measures are implemented.
2. Environmental — Fresh water allocation for conserving fish and other wildlife.
3. Hydroelectric — As California transitions to cleaner energy sources to meet growing demand, more water is needed for hydroelectric power.

4. Salt-water intrusion prevention — Rising ocean levels will require more fresh water for saltwater displacement, particularly in the Delta.

The predicted impacts of climate change will continue to exacerbate California's chronic issues with water scarcity by altering the pattern, variability, amount, and temperature of precipitation. Deeper and more frequent droughts are expected. In addition, the Sierra snowpack is predicted to store less water and melt earlier and faster, effectively diminishing the volume of water stored in the state's most important reservoir. More rapid snowmelts may lead to flooding in some areas in the spring and water scarcity and drought in the summer.

Growers can prepare for greater water scarcity in California by improving water and soil management, reducing overall consumption of water, and storing water on farms and ranches. Building soil organic matter and improving soil structure are key drought and flood management strategies (see "Soil Building" fact sheet on this topic). What follows is a list of practices to help farmers bank more water in soils and catchments and improve WUE on-farm, thereby increasing the water independence and resilience of farming systems when water is scarce and increasingly costly.

Water stewardship benefits:

- Save money, maximize yields
- Reduce water and energy use
- Lower carbon footprint
- Improve water quality
- Reduce soil erosion, tail water runoff
- Store water for drought periods
- Recharge groundwater



Practices that capture, conserve, and recycle water:

- **Farm ponds:** *On-site collection of water for storage, irrigation, or filtration*
- **Recycling water:** *Capturing, cleaning & purifying wastewater via on-site constructed wetlands*
- **Rainwater catchment:** *Collection & use of rainwater from rooftops*
- **Swales:** *Contour ditches that increase water infiltration, reduce runoff & soil erosion*
- **Keyline system/Yeomans plow:** *Soil management method that slows water flow & maximizes absorption*
- **Vegetative filter strips/buffers:** *Strips of perennial vegetation that slow overland runoff & trap sediment*
- **Irrigation efficiency:** *Combining furrow & sprinkler; pressurized system; fine tuning the timing & amount of irrigation*
- **Soil moisture monitoring:** *Augmenting evapotranspiration data with soil moisture conditions to increase WUE*

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Water Stewardship Techniques

Water Catchment Systems – *Farm ponds; Tailwater ponds & return systems; Constructed wetlands; Rainwater catchment; Recycling water*

Benefits

- Offset reliance on purchased or well water
- Maximize seasonal water availability
- Ponds recycle nutrients & prevent erosion
- Trap, filter & store water; return sediment to fields
- Ponds provide water for livestock & habitat for wildlife

Case Studies

- Parducci Wine Cellars & Fetzer Vineyards reclaim 100% of their winery water via on-site constructed wetlands for reuse in vineyards.
- Tailwater recovery & recirculation system at Suncrest Nurseries cut water use by 50% (*EcoFarm Water Stewardship Project*).

Considerations

- Water storage capacity is limited by catchment size
- Permits can be costly, restrictive
- Cost of construction, maintenance & permitting
- Farm ponds remove land from production
- Ponds function best on clay versus porous soils



Soil Surface Management Practices – *Keyline system/yeoman's plow, swales, contour farming*

Benefits

- Keyline systems help control flooding & erosion
- Yeoman's plow effective on highly compacted soils
- Swales trap & settle suspended solids, increase water infiltration, reduce nutrient & pesticide losses in runoff

Case Studies

- For every 1% increase in soil organic matter, 16,500 gallons of water per acre can be held in soil up to one foot deep (*Arkansas Water Resources Research Center*).

Considerations

- Must be suited to farm topography
- Swales are ideal for runoff from roadways, parking lots or equipment yards
- Long slope length, mild gradient provide best filtration



Plant Management Practices – *Vegetative filter strips, cover crops*

Benefits

- Vegetative filter strips can reduce herbicide applications near susceptible water sources, cool watercourses
- Easy to incorporate into landscape; aesthetically pleasing
- Cover crops reduce winter runoff & nitrate leaching

Case Studies

- Higher irrigation tail water quality from winter cover crop vs. winter fallow field — significantly lower concentrations of nitrate, ammonium, and total dissolved nitrogen (*UC Davis/Sustainable Agriculture Farming Systems Project*).

Considerations

- Short-term time & resources involved in establishing filter strips, weed control & irrigation
- Timing cover crop kill & incorporation is important for conserving soil moisture for subsequent crop



photo: Hedgerow Farms

Reduction of applied water – *Soil moisture monitoring; Irrigation scheduling & efficient technology; Dry farming*

Benefits

- Reduces water, energy use & improves yield
- Alternate furrow reduces soil salinity, nitrate leaching
- Automated systems save on labor costs
- Pressurized systems increase distribution uniformity
- Drip reduces greenhouse gas emissions

Case Studies

- WUE is 90% for drip, 83% for center pivot, 68% for furrow (*CAWSI*).
- Alternate furrow used 25% less water than every furrow with no yield decrease (*UC Davis, LAWR*).
- Nitrous oxide emissions from drip fertigated tomatoes were 60% less than furrow irrigated (*UC Davis, Plant Sciences*).
- Frog's Leap Vineyard saves about 16,000 gallons/acre with dry farming compared to lightly irrigated vineyards (*CAWSI*).

Considerations

- Availability, cost & maintenance of moisture monitors
- Deficit irrigation may only work for certain crops
- High initial cost of drip; center pivot cheaper
- Increased energy use for pumping & pressurizing
- Dry farming needs soil with good water holding capacity



photo: USDA NRCS

Farming for Success in the 21st Century: Soil Building

Scientists predict that climate change impacts on California agriculture will include less available water, drier and hotter conditions, more unpredictable and extreme weather events, and new pest and disease pressures. Building healthier soils can help growers enhance the resilience of farm operations and cope with a changing climate while improving crop yields, increasing soil water holding capacity and water infiltration rate, increasing soil fertility, and decreasing input costs.

Keeping nutrients such as carbon (C) and nitrogen (N) in balance is important for not only for healthy soils, but also for environmental protection. Microorganisms can convert C into carbon dioxide (CO₂), a greenhouse gas. Excess N can become nitrous oxide (N₂O), an even more potent greenhouse gas, or nitrate that can leach into groundwater. The presence of excess nutrients can be

an indication of inefficiency in the farm system and an opportunity to reduce input costs.

Maintaining high levels of soil organic matter (SOM) is also essential for soil health. SOM consists of: (1) living microorganisms; (2) fresh and partially decomposed plant roots and residues; and (3) humus, well-decomposed and highly stable organic material.

Synthetic fertilizers deplete SOM and are linked to N₂O emissions and nitrate groundwater contamination (as is raw manure application). Alternatively, SOM levels can be increased by adding plant material (from compost, cover crops, dry manure, etc.) and/or by reducing soil disturbance to slow down the rate of SOM decomposition. Growers interested in these practices can get technical and financial support from the California Natural Resource Conservation Service.

Benefits of Soil Organic Matter (SOM)

The ability to cycle nutrients and provide ‘free’ fertilizer is a major benefit of building healthy soil. When microbes consume SOM they give off nutrients that are available for plant use.

Increasing SOM can:

- Increase the ability of soil to store and supply nutrients to crops
- Increase nutrient cycling and the availability of soil N to plants
- Improve water infiltration and reduce surface crusts
- Stabilize soil against erosion and reduce runoff
- Minimize soil temperature fluctuations
- Provide habitat for beneficial soil microorganisms
- Sustain or enhance soil fertility and crop productivity
- Store (or “sequester”) C that could otherwise accumulate in the atmosphere as CO₂



“If I use cover crops to provide nitrogen, I don’t have to buy any fertilizer. That’s money in the bank.”

— John Teixeira, Lone Willow Ranch,
Firebaugh, CA

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Soil Building Techniques

The following practices increase the amount of SOM in the soil.

Cover & Green Manure Crops – *Grasses or legumes grown in same year as cash crop, during fallow period*

Benefits

- Reduce nutrient losses, winter runoff, surface compaction
- Can suppress some weed growth
- Leguminous cover crops can substitute for some synthetic N fertilizer
- Maintain &/or increase soil C, N levels
- Cover crops can scavenge excess N & reduce N₂O emissions, nitrate leaching

Case Studies – (from SARE’s “Saving Soil Nutrients and Money with Cover Crops”)

- Well-established buckwheat stand eliminated 98% of summer weeds
- Vetch cover crop replaced 110 lbs feather meal/acre on broccoli crop, saving \$500/acre
- Cover crops & no-till in Ohio corn-soybean rotation eliminated most runoff of N & P
- Forage radish can capture & hold up to 150 lbs. N/acre that stays in soil after fall harvest.

Considerations

- May need extra irrigation; can compete for moisture
- May need more tractor work to incorporate
- Could delay field entry
- Timing of incorporation is important for nutrient availability to crops
- Non-leguminous cover crops may require supplemental N after incorporation



Compost & Animal Manures

Benefits

- Increase SOM levels over a longer time period
- Higher levels of lignin & humus increase soil aggregation & help with slow release of nutrients
- Compost has relatively low levels of N in a stable form
- Manure provides readily available & slow-release N

Case Studies – (from SARE’s “Building Soils for Better Crops”)

- Over 70% of the N, 60% of the P, and 80% of the K in animal feed may end up in manure
- Soil in long-term study plots receiving manures were better aggregated, less dense & had more pore space than fields receiving no manure
- Severity of root rots and leaf diseases can be reduced with composts that have low levels of available N but still have some active organic matter

Considerations

- Manure typically provides more readily available nutrients than compost which is more decomposed
- Raw manure can cause nitrate groundwater contamination & high N₂O emissions
- Over time, high manure use can cause P & K buildup & salt damage if insufficient leaching by rainfall or irrigation



Conservation Tillage – *Practices that minimize or eliminate tillage operations (e.g., disking, plowing, ripping)*

Benefits

- Conserve SOM & improve soil structure
- Reduce soil compaction and erosion
- Reduce fuel use, labor, wear on machinery
- Good match for subsurface drip irrigation & overhead sprinklers
- Lower CO₂, dust, particulate emissions from reduced tractor use
- Combined with cover crops, can reduce N₂O emissions & sequester C in soil

Case Studies

From UC Conservation Agriculture Systems Innovation:

- Conservation tillage in Central Valley tomatoes led to profit increase of \$736/acre

From the Conservation Technology Innovation Center:

- Fuel savings = average 3.5 gallons/acre
- Machinery wear & maintenance savings = estimated \$5/acre
- Soil erosion can be reduced by up to 90%

Considerations

- Residues may interfere with furrow irrigation
- Higher rates of N may be required initially
- Placing fertilizer below surface residue can help avoid immobilization of N by soil microbes
- Effect of no-till on N₂O emissions over time varies depending on soil, moisture conditions



Farming for Success in the 21st Century: Resources for Soil Building, Biodiversity and Water Stewardship

Soil Building

California's Resource Conservation Districts (RCDs) — Leaders in on-the-ground conservation efforts, working with landowners on practical, hands-on conservation projects: <http://www.carcd.org/home0.aspx>

Natural Resource Conservation Service (NRCS) — Works with landowners through conservation planning to ensure productive lands and healthy ecosystems. Publications and practical guides available at: <http://soils.usda.gov/sqi/publications/publications.html>. Guide to soil quality, including a glossary of terms and how to test for and manage soil quality: http://soils.usda.gov/sqi/publications/files/th_bk_body.pdf. *Unlock the Secrets in the Soil* has videos, fact sheets and checklists: <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health>

UC Cooperative Extension — Provides research-based knowledge and educational programs via county offices throughout California in the areas of farm management and more. <http://ucanr.edu/>

National Sustainable Agriculture Information Service (NCAT/ATTRA) — “Ask an expert” resource and extensive publications covering organic production, livestock, horticultural crops, business and marketing, farm energy, water and pest management and more: <https://attra.ncat.org/>.

COMET-VR 2.0 is a computer-based tool to estimate soil carbon changes from various practices. www.comet2.colostate.edu/

Nutrient Management

Whole-Farm Nutrient Management Planning for Organic Farms — Guide to interpreting soil tests and using organic nutrient sources: <http://www.sare.org/Learning-Center/Project-Products/Northeast-SARE-Project-Products/Whole-Farm-Nutrient-Planning-for-Organic-Farms>.

Building Soils for Better Crops: Sustainable Soil Management — Practical guide to ecological soil management: <http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition>.

Cover Crops

UC Davis Agriculture Sustainability Institute — Has an extensive list of practical guides for cover crop management in different cropping systems: <http://www.sarep.ucdavis.edu/covercrop/res/cover-crop-publications/>

Sustainable Production of Fresh-Market Tomatoes and Other Vegetables with Cover Crop Mulches — A practical guide to selecting, establishing, and mulching cover crops in vegetable cropping systems: www.ars.usda.gov/is/np/SustainableTomatoes2007/TomatoPub.pdf

Managing Cover Crops in Conservation Tillage Systems — An overview of the benefits derived from combining CT management and cover crops: <http://www.westernsare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Managing-Cover-Crops-in-Conservation-Tillage-Systems>

Cover Cropping for Vegetable Production — Handbook describing cover crops with specific recommendations for the Central Valley, desert, and coastal regions of California: <http://anrcatalog.ucdavis.edu/Items/3517.aspx>

Crop Rotation on Organic Farms: A Planning Manual — Practical guide to applications of crop rotation including improving soil quality and health, and managing pests, diseases, and weeds: <http://www.sare.org/Learning-Center/Books/Crop-Rotation-on-Organic-Farms>

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Conservation Tillage

Conservation Agriculture Systems Innovation — Six-part video series on the benefits of CT in different cropping systems and with overhead irrigation systems, including farmer interviews and demonstration projects in California:

http://casi.ucanr.edu/Video_library_636/CASI_documentary/

Conservation Agriculture Systems Alliance — Network for farmers and advisors to share information, respond to questions, find out about relevant opportunities and events:

<http://www.ctic.purdue.edu/Conservation%20Agriculture%20Systems%20Alliance/>

Financial Support

A number of cost share programs that support soil building practices are available through the NRCS.

Conservation Stewardship Program (CSP) — On an annual basis, farmers can receive land-use payments for environmental benefits produced on-farm. Soil building practices selected by farmers that received compensation in 2009 and 2010 included: cover crop mixtures, crop rotations, and continuous no-till:

<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp>

Farmers Guide: <http://sustainableagriculture.net/wp-content/uploads/2011/09/NSAC-Farmers-Guide-to-CSP-2011.pdf>

Environmental Quality Incentive Programs (EQIP) — EQIP contracts provide financial, technical and cost sharing assistance for conservation farming practices that improve environmental quality:

<http://www.ca.nrcs.usda.gov/programs/eqip/2012/index.html>. An online tool is available for limited resource and beginning farmers to see if they qualify for up to 90% cost share payment rates: <http://www.lrftool.sc.egov.usda.gov/>

Water Stewardship

Fish Friendly Farming — Environmental certification program offering expertise on erosion and soil loss, stream bank failure, and water quality degradation. Operates in Mendocino, Sonoma, Napa, Solano, and El Dorado counties:

<http://www.fishfriendlyfarming.org/>

California Agricultural Water Stewardship Initiative — Resource center for growers, ranchers, and others interested in sound farm water management: <http://agwaterstewards.org/>

Department for Environment: Food and Rural Affairs — Practical tools to enhance resource conservation. *Catchment Sensitive Farming: Practical Tips* has information on constructed wetlands, buffer strips, recycling water, swales and more:

<http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HCIIG33ALM59DZ>

Smart Water Use on Your Farm or Ranch — Covers compost, conservation tillage, cover crops, crop rotation, water-conserving plants, rangeland drought mitigation, low-volume irrigation, water recycling: <http://www.sare.org/Learning-Center/Bulletins/Smart-Water-Use-on-Your-Farm-or-Ranch>

Vegetative Filter Strips for Improved Surface Water Quality — A practical guide to designing, installing and maintaining vegetative filter strips: www.extension.iastate.edu/Publications/PM1507.pdf

Increasing Biodiversity

Dietrick Institute for Applied Insect Ecology — Offers training on practical strategies that benefit biodiversity. *Biological Control of Insect Pests Using Pest Break Strips* available at: <http://dietrick.org/projects/naturfarm.html>.

Wild Farm Alliance — *Biodiversity Conservation Guides* describe methods to maintain and enhance on-farm biodiversity: www.wildfarmalliance.org/resources/BD%20Guide%20Organic%20Farmers%20.pdf. Practical guide for hedgerow installation and maintenance: http://caff.org/wp-content/uploads/2010/07/Hedgerow_manual.pdf

Sheep Grazing to Manage Crop Residues, Insects & Weeds in Northern Plains Grain & Alfalfa Systems —

<http://www.sare.org/Learning-Center/Fact-Sheets/National-SARE-Fact-Sheets/Sheep-Grazing-to-Manage-Crop-Residues-Insects-and-Weeds-in-Northern-Plains-Grain-and-Alfalfa-Systems>

Steel in the Field: A Farmer's Guide to Weed Management Tools — Practical guide to the implements and techniques that can control weeds while reducing, or eliminating, herbicides through improved cultivation tools, cover crops and new cropping rotations: <http://www.sare.org/Learning-Center/Books/Steel-in-the-Field>