A SIMPLE GUIDE FOR

CONSERVATION SYSTEMS

IN THE SOUTHEAST

USDA United States Department of Agriculture
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A Simple Guide for Conservation Systems in the Southeast

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What is a Conservation System?

Conservation systems are cropping systems that minimize surface soil disturbance and maximize plant or residue cover on the surface. Successful conservation systems maintain or increase soil organic matter content while enhancing farm profitability and sustainability. A conservation system is comprised of two components: conservation tillage and a high residue cover crop.

Traditionally, conservation tillage has been defined as anything that retains at least 30% residue cover on the surface. In the southeastern United States (US), given our warm climate and substantial annual rainfall, it is possible to achieve greater than 30% residue cover. However, the warm climate and substantial annual rainfall contributes to residue decomposition and subsequent low organic matter contents. As a result, these soils are susceptible to erosion and low productivity that affects the economic viability of the farming operation.

The best conservation systems in the Southeast minimize surface soil disruption and protect the soil with a cover crop and plant residue throughout the year.

Why adopt a conservation system?

Increased profits

- Yields are equal to or greater than traditional tillage.
- Reduced use of fuel and labor.
- Requires less time.
- Lower machinery repair and maintenance costs.
- Potential reduction in fertilizer and herbicide costs.

Improved environment

- Improved soil quality and productivity.
- Reduced erosion.
- Increased water infiltration and storage.
- Improved air and water quality.
- Provides food and shelter for wildlife.

Improving your soil with a conservation system

Reducing destructive tillage operations and increasing organic matter production has a number of beneficial impacts on soil health and productivity.

Soil erosion is a major cause of soil degradation. Erosion removes topsoil from fields, reducing organic matter contents, and lowering crop yields. Also, eroded soil particles carry adsorbed pesticides and nutrients to nearby streams or rivers. In 2012, sheet and rill erosion on US cropland was 2.66 tons/acre/year, and wind erosion was 1.94 tons/acre/year, according to the National Resources Inventory. A conservation system utilizing conservation tillage and a cover crop can reduce erosion up to 90%.

Organic matter is an important aspect of soil quality, improving soil structure and tilth. Southeastern soils typically have organic matter contents less than 1%. Tillage accelerates the oxidation of organic matter, releasing CO_2 into the atmosphere. It is nearly impossible to build organic matter in intensive tillage systems long-term. High-residue systems utilizing cover crops with minimal surface disturbance can help maintain and build organic matter.

Erosion is the detachment and movement of soil by water (rain or irrigation water), wind, or gravity. Adopting a conservation system can help reduce soil erosion.

Biological diversity increases in a conservation system. Increased organic matter and root exudates increase soil organisms that promote nutrient recycling. Soil organisms also produce organic compounds which help hold soil aggregates together. Earthworms create tunnels, improving water infiltration and root growth.

Soil structure or soil tilth will improve with a conservation system. Increased organic matter and biological activity improves soil aggregation, resulting in increased soil porosity and reduced bulk density. Residues on the soil surface also help reduce soil crusting by protecting the soil surface. Cover crop roots reduce compaction and loosen hard pans by creating root channels that subsequent cash crop roots can follow.

Adopting conservation systems helps build organic matter, increase biological activity, improve soil structure, and preserve soil moisture.

Macropores from cover crop root channels and earthworm burrows reduce runoff and improve water infiltration under conservation systems. Residue cover on the soil surface can help protect the soil from soil evaporation and raindrop impact, which contributes to soil crusting. An increase in **soil moisture** of 5% in the top 12 inches of soil under conservation tillage is equivalent to 0.6 acre-inch or 16,300 gallons of water, reducing irrigation costs by eliminating an application of water. For cotton, if similar soil moisture contents can be assumed to a depth of three feet, soils under a conservation system can fulfill the water requirement for five to seven days longer than those under conventional tillage and no cover crop.

While some studies have shown immediate yield and other improvements from a conservation system, it may take several years to realize the full benefits of this system. Management is a key factor in a profitable conservation system. It is important to plan carefully before implementation so that a successful transition can be made to a conservation system. It is recommended that you begin planning for a transition several months in advance to help work out challenges, prior to implementation. This publication will help start the planning process by looking at several aspects of a conservation system.

Conservation systems minimize surface soil disruption and protect the soil surface with a properly managed cover crop and plant residue throughout the year.

Planning the Transition to a Conservation System

Get informed

There are numerous publications and papers on conservation tillage and cover crops. The USDA-Agricultural Research Service (ARS), National Soil Dynamics Laboratory (NSDL), Conservation Systems Research (CSR) group has factsheets and special publications related to all aspects of conservation systems, as well as videos demonstrating conservation systems (http://www.ars.usda.gov/sea/nsdl). For example, background information on conservation systems is available in CSR Factsheet 04a (Cover Crops for the Southeast - Introduction).

There are a number of other organizations that provide information related to conservation systems, including USDA-Natural Resources Conservation Service (NRCS) (http://www.nrcs.usda.gov) and cooperative extension services in many states. State Cooperative Extension Services, Agricultural Experiment Stations, USDA-ARS, and USDA-NRCS sponsor field days to introduce farmers to conservation systems. Getting advice from experienced farmers utilizing conservation systems in your area is one of the best sources of practical information. Learning from the experiences of farmers who have successfully adopted conservation systems will save you time and money.

Climate effects

The Southeast has a long growing season with a wide range of climates. It is important to recognize how climate affects soil and residues. In warmer climates, soil activity is higher and crop residues break down faster than those in cooler climates. For example, in the Tennessee Valley region of Alabama (northern Alabama), some high-residue plots contain plant residues from two years prior. Rainfall variability may also affect the success of conservation systems. Proper management and timely planting of cover crops and cash crops, especially for dryland producers, is very important to the success of a conservation system.

Accumulation of plant residue protects the soil surface. This picture includes the current crimson clover cover crop, cotton residue from last fall, cereal rye residue from last spring, and corn residue from over a year ago.

Evaluate your equipment needs

It is important to evaluate how your equipment needs may change if you adopt a conservation system. Some new equipment may be required while other implements can be converted for use in a conservation system. It is also important to learn how to set up your equipment to ensure a good cover crop and cash crop stand.

Learn about federal conservation programs

There are federal conservation programs, such as the Environmental Quality Incentives Program (EQIP), available through USDA-NRCS that assist farmers with adopting conservation systems. These programs have eligibility requirements that must be met by farmers so it is important to contact your local USDA-NRCS office to learn more about these programs before implementing a conservation system.

Cash Crop Selection and Rotations

Cash crop and variety selection

Cash crop and variety selection are important management decisions within a conservation system. Varieties with early seedling vigor and disease resistance may be especially desirable in high residue systems.

Vegetable crops can also thrive under conservation systems. The development of a no-till transplanter (see *Planting in Heavy-Residue Systems*) has made adopting a conservation system a feasible option in vegetable production. Choosing varieties that will transplant well into high residue is important. Vegetable producers should consider that soils under residue tend to be cooler and wetter than those under plastic systems.

Crop rotations

Rotations are an integral part of any conservation system. Crop rotations can result in significant yield improvements and help reduce investment risk in farming by spreading it across several cropping enterprises. An important benefit of crop rotations is improved pest and disease control that helps break pest and disease cycles. A good rule of thumb is to not grow the same crop or closely related crop continuously for more than two years in the same field. However, certain crops, such as canola, may need more years between planting in a given area.

Cash crops vary in the amount of residue left after harvest. Rotating a high-residue crop (such as corn) with a lower residue crop (such as cotton) can help maintain an adequate amount of residue on the soil surface. Crop rotations can also stimulate biological activity. Crop residues with a high carbon (C) to nitrogen (N) ratio (C:N ratio), such as corn or small grains, should be rotated with crops such as legumes that have low C:N ratios. Plants with low C:N ratios tend to decompose more quickly, which can greatly affect the amount of residue on the soil surface, and potential benefits associated with the cover crop.

One popular cover crop–cash crop rotation is a clover–corn combination. This allows a nitrogen-fixing (N-fixing) legume with low biomass, low C:N ratio to be rotated with a high biomass, high C:N ratio crop.

It is important to consider pesticide selection as a factor in your rotation. Check labels for rotation and plant-back restrictions. In addition, label information can be found on the *Crop Data Management Systems* website (http://www.cdms.net/Label-Database) or on *Greenbook* (http://www.greenbook.net).

Crimson clover, an N-fixing legume, in bloom.

Cover Crops

Benefits

Pest control. Cover crops aid in weed control by physically suppressing weeds during growth and during the cash crop growing season if left on the soil surface. Most covers also release allelopathic chemicals that aid in weed suppression. Some cover crops produce biotoxins or alkaloids that have activity against soil-borne pests, including nematodes.

Soil cover and quality. Cover crops are an integral part of a conservation system, especially in fields where crop residue cover is low. It is recommended that at least 50% residue cover is present at all times. An adequate residue cover protects the soil surface from wind and water erosion. Cover crops also help build organic matter. To maximize benefits, 4,000-8,000 lb residue/acre must be left on the soil surface.

Capture nutrients/N fixation. Cover crops can utilize excess nutrients at the end of the growing season and help recycle those nutrients back into the system for the next crop. Small grains, such as wheat and cereal rye, are quick to scavenge excess N and other nutrients. Hairy vetch is a good scavenger of phosphorus (P). Legumes fix N that can be released for the next crop, potentially reducing fertilizer costs.

Challenges

Allelopathy. Cover crops may have an allelopathic effect on the subsequent crop. However, these effects are usually negligible if the cover crop is terminated at least three weeks before planting.

Terminating the cover crop. It is important to completely terminate the cover crop or soil water may be depleted by the actively-growing cover.

Spring soil temperatures are cooler. Residue on the surface slows soil warming in the spring, which can delay planting. It is important to remember that optimal soil temperature may occur later in the spring. A strip-till system that creates a wide strip will enable the soil to warm faster.

Susceptibility to early-spring diseases. Diseases may occur more often due to cool, wet soils and decaying cover crop residue. Crop rotations will help reduce the frequency of disease, and selecting resistant crop varieties will protect against disease pressure. Using fungicides or delaying planting until optimal soil temperatures are observed will also help.

Cover crop selection

Choosing a cover crop for your system is an important step in the planning process.

Several factors should be considered including:

- **Pesticide selection**. Check all labels for rotation restrictions. Some labels have a special cover crop section.
- **Nitrogen requirements**. Rotating legume covers with non-legume cash crops or vice versa could be desirable options, depending on your situation.
- **Amount of biomass**. Rotate high and low biomass cash crops and cover crops as needed to help manage the amount of residue left on the soil surface.
- **Soil/pest problems**. Certain cover crops may be better suited to help remediate particular soil/pest problems.
- **Planting/management costs**. The cost of cover crop seed, planting, fertilizer application, and termination should be taken into consideration.

Information about common cover crops has been included to serve as a guide to help start the selection process.


Wheat

Small grains, such as cereal rye, wheat, triticale, oats, and barley, are all common winter annual cereals used for cover cropping. The root systems of these covers provide erosion control and scavenge nutrients from the soil. Cereal rye typically produces the most biomass for residue cover. Wheat seeds are the most inexpensive and plentiful. *Cosaque* is a winter hardy variety of oats. While the seed of *Cosaque* is black, it is not black oats. Research is currently being conducted using *Cosaque* as a cover crop. Biomass production: 3000-7000 lb/acre.


Black Oat

Black oat is a winter annual cereal. *SoilSaver* is a variety of black oats. *SoilSaver* has shown high allelopathic activity, especially on broadleaf weeds. Greenhouse studies have shown that *SoilSaver* residues and leaf extracts inhibit radish and cotton radicle elongation. In another study, a *SoilSaver* cover crop resulted in higher cotton yields than a rye cover crop. In a study at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center, weed control in conservation tillage cotton was 34% with *SoilSaver*, 26% with cereal rye, 19% with wheat, and 16% with no cover crop. Black oats can be particularly sensitive to herbicide carryover. Check herbicide labels for more information. *SoilSaver* is not as cold-tolerant as other cover crops and should only be planted in USDA Plant Hardiness Zones 8b-10a. Biomass production: 3000-7000 lb/acre.


Turnip

Brassica species (forage rape, canola, mustards, turnip, radish) are winter annuals/biennials which have biotoxic activity against many soil-borne pathogens and pests, including insects, nematodes and weeds. Large taproots of turnips and radishes can also help break up compacted soils. Brassicas can be grown in mixtures with small grains. Biomass production: up to 8000 lb/acre.


Hairy vetch

Hairy vetch is a winter annual legume that produces a large amount of residue but decomposes relatively quickly. It tolerates a pH of 4.9 to 8.2 and prefers well-drained soils. It is a good scavenger of P and fixes N. Hairy vetch mixes well with grain cover crops, but is not recommended if nematodes are present. Biomass production: 4000-7000 lb/acre. Nitrogen fixation: 90-200 lb N/acre.


Crimson Clover

Crimson clover is a winter annual legume that has reseeding potential. Crimson clover provides a habitat for insect predators such as pirate bugs and lady beetles. It also attracts honeybees. Two popular cultivars in Alabama are AU Robin and AU Sunrise. AU Robin is more widely available. AU Sunrise may be more difficult to locate, but it flowers one to two weeks earlier than AU Robin, making it an excellent choice for a reseeding cover crop. Biomass production: 3500-5500 lb/acre. Nitrogen fixation: up to 150 lb N/acre.


Winter Pea

Austrian winter pea is a winter annual legume that grows as a vine capable of producing large amounts of residue. It decomposes quickly because of its low C:N ratio. It is intolerant of water logging or drought and prefers a clay or heavy loam soil. It makes a good forage if mixed with barley, oat, or triticale, boosting the protein content of the forage mix. Biomass production: 5000-8000 lb/acre. Nitrogen fixation: 90-150 lb N/acre.


Sunn Hemp

Sunn hemp is a summer legume that can produce large amounts of residue and N in as little as eight weeks. It may be planted after a summer crop, but will be killed by frost, so it should be planted at least nine weeks before first frost. It can make a great addition to your rotation after corn, early-season vegetables or small grains, and before a winter cover or small grain crop that would utilize N. Seed is currently expensive but supplies are expanding. Biomass production: 5000+ lb/acre in eight weeks. Nitrogen fixation: up to 120 lb N/acre.

Uses of Cover Crops

	Residue Persistence	Pest Control	Nitrogen Fixation	Weed Control	Erosion Control	Compaction Reduction	Nutrient Scavenger	Forage Quality	Attracts Beneficial Insects
Legumes									
Austrian Winter Pea	F	P	E	G	G	F	G	E	E
Cowpea	F	E	E	E	E	F	F	G	E
Crimson Clover	G	P	G	G	G	F	G	G	F
Hairy Vetch	F	P	E	G	G	F	G	G	F
Lupin	F	G	E	G	G	G	F	P	E
Medics	G	F	G	G	G	F	F	G	F
Sunn Hemp	G	E	E	G	G	G	F	P	F
Velvet Bean	F	G	E	G	G	F	F	G	F
White Clover	F	F	E	G	G	F	F	E	E
Cereals									
Barley	E	G	P	G	E	F	G	G	F
Black Oat	G	E	P	E	G	F	G	G	P
Buckwheat	P	P	P	E	F	G	F	P	E
Oat	G	G	P	E	G	F	G	G	P
Rye	E	G	P	E	E	E	E	G	G
Ryegrass	G	G	P	G	E	F	G	G	F
Sorghum-Sudangrass	G	G	P	G	E	E	G	G	F
Triticale	G	F	P	G	G	F	G	G	P
Winter Wheat	G	P	P	G	G	F	G	G	P
Other									
Brassicas	G	E	P	G	G	E	G	G	F

E=Excellent; G=Good; F=Fair; P=Poor/None

Adapted from *Managing Cover Crops Profitably Third Edition*

Cover Crop Management

Generally, cover crops are established with a no-till drill or by broadcasting. Small-seeded covers, such as clovers, may be broadcast successfully, but seeding rates will need to be increased (see the table on page 10). Traditional drills work adequately, but will not place seeds as uniformly as a no-till drill. This may cause poor germination and emergence in existing high residue systems.

No-till drill.

Aerial seeding is also an option for larger fields. This allows cover crops to be planted before the cash crop is harvested, which may be particularly beneficial when harvest is delayed. Weed control is typically not a problem in a well-established cover; however, it is advisable to control serious weed problems, prior to planting.

Fertilizing cover crops is a recommended practice to maximize biomass production. Nitrogen is the only nutrient that must be added to cover crops unless there is a severe deficiency of P or potassium. Legumes will fix their own N if inoculated with the correct N-fixing bacteria. Other covers, however, will likely need N fertilizer. Cereals, such as rye, will do best if 30-40 lbs N/acre are applied on soils with low fertility. If residual N and organic matter levels are high, N fertilizer inputs may be reduced.

Fertilized rye (left) and non-fertilized rye (right).

Research has found that earlier planting dates and later termination dates produce the greatest cover crop biomass. Correspondingly, early-season weed biomass was less in plots that had heavy cover crop biomass. Farmers in Alabama have reported saving one to two early-season herbicide applications with a heavy-residue cover crop.

A head-high cereal rye cover can be daunting. You may want to try a lower biomass cover or terminate early until you are comfortable with the system, but keep in mind that, in general, **cover crop benefits increase as biomass levels increase**.

While planting cover crops as early as possible is essential to maximizing cover crop biomass, termination timing can also influence biomass production. Cover crops should be terminated two to four weeks before planting to ensure a good kill without interfering with the subsequent crop. Typically, a non-selective herbicide such as glyphosate or paraquat is used, unless the cover has winter-killed or reached maturity. For broadleaf covers, it may be desirable to tank mix a burndown herbicide with 2,4-D to ensure an effective termination. However, be sure to check all labels for planting restrictions.

Cotton in heavy residue

Cotton in low residue

With no herbicide after burndown, cotton in heavy residue has better weed control.

Producers should evaluate soil moisture, equipment, soil temperature, N management, allelopathy, and weed suppression each year to maximize cover crop benefits, while minimizing risk to the cash crop. More information on cover crop termination is available in CSR Factsheet 11 (Termination of Cover Crops: Management Considerations for the Subsequent Cash Crop).

Establishment Guidelines for Common Cover Crops

Cover Crop	Seeding Rate	Seeding Depth	Planting Date		
	(lb/A)	(inches)	North	Central	South
Millet (Browntop, Proso, Foxtail)	D: 20 / B: 30	1/2 to 3/4	05/01–08/01	04/01–08/15	04/01–08/15
Millet (Pearl)	D: 15 / B: 30	1/2 to 1 1/2	04/20-07/01	04/15-07/01	04/01-07/15
Sorghum-Sudangrass	D: 25 / B: 35	1/2 to 1	05/01–08/01	04/15-08/01	08/01 –08/15
Sorghum, forage	D: 5 / B: 20	1	04/20–05/15	04/20–05/15	04/20–07/01
Sudangrass	D: 25 / B: 35	1/2 to 1	05/01–08/01	05/01–08/01	05/01–08/01
Ryegrass	25	0 to 1/2	08/25–10/01	09/01-10/15	09/15-11/01
Oats, Barley, Triticale	90-120	1 to 2	09/01-11/01	09/15-11/01	09/15-11/15
Black Oat	50-90	12 to 1	n/a	n/a	09/15-11/01
Rye	90-120	1 to 2	09/01-11/01	09/15–11/01	09/15–11/15
Wheat	90-120	1 to 2	09/01-11/01	09/15–11/01	09/15–11/15
Winter Pea	40	1 to 2	09/01-10/15	09/01-10/15	09/01-10/15
Clover, Ball	4	0 to 1/4	09/01-10/31	09/01-10/31	09/01-10/31
Clover, Crimson	25	0 to 1/2	08/25–10/01	09/01-10/15	09/15-11/15
Clover, Red	D: 8 / B: 15	1/4 to 1/2	09/15-11/15 02/02-04/1	09/15-11/15 02/02-04/1	09/15-11/15
Clover, subterranean	10	1/4 to 1/2	08/25–10/01	09/01–10/31	09/01–10/31
Hairy Vetch	25	1 to 2	09/01-10/15	09/01-10/15	09/15-11/01
Canola	D: 6–8 / B:12-14	1/4 to 1	08/25–10/01	09/01–10/15	09/01–10/15
Mustard	D: 5-7 / B: 12-4	1/2 to 1	08/25–10/01	09/01–10/15	09/01–10/15
Radish	D:12-14 / B:18-20	1/4 to 1/2	08/25–10/01	09/01–10/15	09/01–10/15
Turnip	D: 4-7 / B: 10-12	1/4 to 1/2	08/25–10/01	09/01–10/15	09/01–10/15
Lupin	70-120	1 to 2	08/25–10/01 04/01–04/15	09/01–10/15 04/01–04/15	09/01–10/15 04/01–04/15
Sunn Hemp	40-50	1/2 to 1	04/01–08/01	04/01–08/01	04/01–09/15

Notes:
D=Drilled, B=Broadcast
Where legumes are seeded with grasses, use the grass seeding date.
Where two or more grasses are used in mixture, reduce the seeding rate of each by about one-third.
Do not reduce the seeding rates of legumes when used in mixtures.
Seeding rates should be increased at least 30% when aerially seeded.
Seeding rates for a cost-share program should be the rate specified by the program.

Cover Crop Rollers for Termination

Researchers are studying the effectiveness of using rollers as an alternative or in addition to herbicide application for termination. Tall cover crops (such as cereal rye) may lodge in multiple directions, reducing planting efficiency. Rolling cover crops parallel to direction of planting helps reduce "hairpinning", which is caused when residues that are not cut are pushed into the soil and become trapped in the seed furrow.

Rolling cereal rye.

Flattening and crimping cover crops by mechanical rollers is widely used in South America, especially in Brazil, to successfully terminate cover crops without herbicides. Original roller designs consisted of a round drum with blunt, straight steel bars across the drum's length. The function of the bars is to crimp the cover crop stems against a firm soil surface without cutting them. When soil is too soft, crimping is ineffective. If cut (mowed), the cover crops can re-sprout, while loose residue may interfere with planting operations. When rolling is completed at the appropriate plant growth stage, such as *soft dough* or later, the roller alone can be as effective at terminating the cover crop as chemical herbicides.

Cereal rye after crimping.

The main complaint with rollers has been excessive vibration generated by rollers with straight crimping bars. The most effective method of alleviating vibration has been to reduce travel speed, but this is not desirable or economical.

Two additional roller types, the curved crimping bar roller/crimper and smooth roller with crimping bar, are being evaluated. Research with these rollers has shown reduced vibrations with adequate cover termination without the use of herbicides if the cover is terminated at soft dough three weeks, prior to cash crop planting.

If no roller is available, another implement, such as a seedbed conditioner, may be helpful to knock down a standing cover to help create the mat of residue. These options, however, would likely require the use of herbicides to successfully terminate the cover crop. More information about rollers is available in CSR Factsheet 07 (Rollers for Terminating Cover Crops) and CSR Factsheet 10 (A Roller/Crimper for Walk-Behind Tractors).

Types of roller/crimpers

Straight crimping bar roller/crimper

Curved crimping bar roller/crimper

Smooth roller with oscillating crimping bar assembly
(Kornecki et al, 2009, U.S. Patent #7,604,067 B1)

Rotary roller/crimper for elevated bed culture
(Kornecki, 2009, U.S. Patent #7,562,517 B1)

Two-stage roller/crimper
(Kornecki, 2011, U.S. Patent #7,987,917 B1)

Powered roller/crimper for walk–behind tractors
(Kornecki, 2012, U.S. Patent #8,176,991 B1)

Four-stage roller/crimper
(Kornecki, 2011, U.S. Patent #7,987,917 B1)

Two-stage roller/crimper for walk–behind tractors
(Kornecki, 2011, U.S. Patent #7,987,917 B1)

Managing Soil Compaction

Southeastern soils are prone to compaction. Hard pans have developed from heavy traffic and tillage practices, such as moldboard plowing and surface tillage. Managing soil compaction is key in a successful conservation system.

Identifying hard pans

Soil compaction can be measured with a hand-held cone penetrometer. This penetrometer registers the force needed to insert the probe into the soil. Readings at or above 300 psi (2 MPa) indicate a compaction problem that significantly inhibits root growth. (Note: For accurate readings, penetrometers should be used when the soil moisture content is near field capacity.)

Avoid compaction

Soil compaction cannot always be prevented, but good management can often keep it manageable.

- Only traffic when the soil is dry (soil moisture is less than 60% of field capacity). Vehicle traffic conducted when soil is wet can lead to excessive soil compaction that may be battled for many cropping seasons or become permanent.
- Minimize tracks across fields and try to build soil organic matter to minimize vehicle traffic effects.
- Adopt a controlled traffic system that will limit vehicle traffic to certain areas within the field, thus reducing random traffic.
- Reduce axle load by minimizing the size of the vehicle necessary for the field activity.
- Use radial tires which maximize the size of the tire footprint and reduce soil compaction, while increasing tractive effort.
- Use the lowest recommended inflation pressure for radial tires, using tire manufacturers' recommended load-inflation pressure tables.
- Consider overall benefits of tracked vehicles while recognizing that peak pressures that occur under tracks may be similar to peak pressures that occur under radial tires for similar-sized vehicles.
- Reduce contact pressure by using duals while recognizing the wider area of influence associated with dual tires.

Controlled traffic

While conservation systems may reduce overall vehicle traffic in a field, wet soils that may be found under heavy residue are still susceptible to rutting and compaction. A controlled traffic system uses traffic lanes that become compacted enough to withstand heavy traffic without rutting, while leaving row middles free from wheel compaction. Precision guidance systems that are now widely available can be used to control trafficking patterns. Row information can be saved and used year after year to help locate traffic lanes.

Side and front view of an in-row subsoiler (left) and two bent-leg subsoilers.

Cover crops

Cover crops are an important tool for managing soil compaction. Many cover crops have aggressive rooting systems, which open channels for subsequent cash crop roots. Cereal rye, sorghum-sudangrass, and Brassica species (canola, turnip, and mustards) are known to be particularly effective at breaking through hard pans. Sunn hemp and lupins also have aggressive taproots that can penetrate hard pans. The presence of cover crops also enhances earthworm activity. Earthworm channels provide a path for roots to follow.

Shallow soil compaction resulting in soil resistance to a cotton seedling's root system.

In-row subsoil to correct compaction

When soil compaction does develop, in-row subsoilers (strip tillage) can loosen compacted layers with minimal surface soil disturbance. Traditional deep subsoiling has been used with other forms of conventional tillage to disrupt the soil across the width of the implement compared to just beneath the row. Modern strip tillage implements usually: (1) maximize surface residue coverage after subsoiling, and (2) only disrupt the compacted soil beneath the row, while leaving trafficked row middles firm to support vehicle traffic.

In-row subsoiling encourages deeper root growth, allowing cash crop roots to reach deep soil moisture during the growing season. It also allows water infiltration through hard pans, resulting in increased water storage. In-row subsoiling is typically conducted in the fall before cover crop planting or in the spring, prior to cash crop planting.

It is important to know the depth of the hard pan before in-row subsoiling. In-row subsoiling beyond the hard pan results in excessive soil disturbance and higher energy costs. It may also cause a hard pan to develop below the depth of tillage that cannot be reached in later years. Insert a hand-held penetrometer or wire flag into the soil to find the depth of your hard pan.

Two main types of subsoilers are bent-leg subsoilers and in-row subsoilers. Bent-leg subsoilers can be set up for a more complete disruption of a hard pan by *lifting* the soil. In-row subsoilers have a straight shank to break through the hard pan and are typically used directly before cash crop planting.

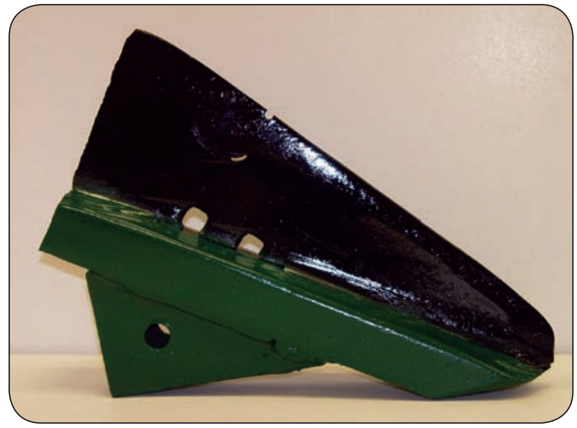
The frequency of subsoiling differs among cropping systems and soil types. A large amount of energy is required for subsoiling, so it is advantageous to perform this operation only as necessary. A study at the Tennessee Valley Research and Extension Center in Belle Mina, Alabama showed that annual subsoiling reduced bulk density compared to no-till, biennial subsoiling or triennial subsoiling. However, cotton lint yields were not statistically different among treatments. Therefore, subsoiling on these soils (Dewey silt loams) may not result in benefits that are typically realized in other areas with sandier textures.

Integrated management may prove to be the most effective tool against compaction. Using controlled trafficking patterns and cover crops can further diminish subsoiler requirements, reducing energy costs.

In-row subsoiling can loosen compacted layers with minimal surface soil disturbance.

Subsoiler Modifications

Toolbar extensions on older subsoilers can help ensure that the coulter is running on firm ground ahead of the shank to help cut residue.



Splitter points help prevent soil blow-out, especially in dry soils. Newer shanks may incorporate this design, or a piece of metal can be welded perpendicular to the center of a subsoil shank tip.

Covering sharp edges can help keep residue from building up on the shank.

Polyshields help prevent soil build-up in heavy or wet soils.

Planting in Heavy-Residue Systems

Setting up your planter correctly is vital for a good plant stand. Row cleaners should be set so that residue is moved away from the plant row without digging a trench into the soil surface. (Set the row cleaner tines to just barely touch the soil surface). Adjustments will need to be made with differences in residue amounts and among different cover crops. Soils under heavy residue are usually wetter than traditionally-tilled soils. Wet soils may result in poor slot closure, especially on heavy soils. Closing wheel adjustments can also help manage slot closure in wet or dry soils. Over time, experience will help you know how to adjust your planter to combat challenges.

It is important that terminated residue is dry and *crispy* so that coulters can cut through residue without hairpinning it in the row slot. Hairpinning results in poor seed-to-soil contact and can drastically reduce plant stands. If a roller is used to help terminate the cover crop, it is recommended that you plant parallel to the direction of rolling to avoid hairpinning and residue build up (wrapping) on row cleaners.

Soils under residue tend to be cooler in the spring compared to bare soil. Optimum soil temperatures are essential for good seed germination and seedling growth. It may be necessary to delay early planting for up to seven to ten days as opposed to fields under conventional tillage. For corn, soil temperatures should be 55–60ºF. For cotton, the minimum soil temperature recommended is 65ºF for three to four days at a four–inch depth. To get accurate readings, take soil temperature readings in the mornings.

More information about managing heavy residue is available in CSR Factsheet 3 (Modifying Equipment for High-Residue Systems) and CSR Factsheet 9 (Vegetable Transplanter for High Residue Systems).

Planters

Planters typically require some modifications to operate in high-residue systems. There are several options and modifications for planters to help manage heavy residue situations.

Most planters and drills used in conservation systems have **coulters** in front of the seed openers to help cut through heavy residue.

There are several different coulters available. Talk to a farmer with no-till experience in your area or your local equipment dealer to determine the best type for your situation.

Row cleaners help move residue away from the seedbed to prevent hairpinning, which interferes with seed placement and can cause poor seed-to-soil contact. Row-cleaners should not be set too low or they will dig a trench into the seed bed.

Double disk openers create a slot for seed placement. Notched openers can help move residue away from the seedbed to prevent hairpinning.

Seed firmers help ensure good seed-to-soil contact and keep the seed from bouncing out of the seed trench.

Spoked **closing wheels** offer a good alternative to rubber closing wheels, which can compact the soil surface and cause crusting in heavy, wet soils. Spoked closing wheels, however, can kick out seed with shallow planting.

One option is to use one spoke and one rubber closing wheel per row.

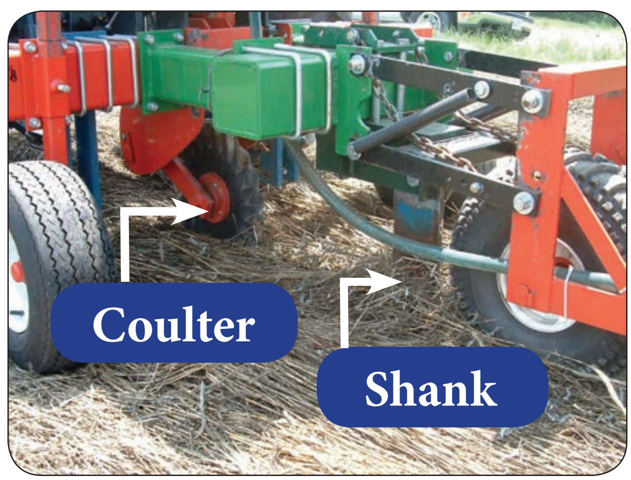
Down-pressure springs maintain the desired seeding depth in high residue or on uneven and/or firm ground.

Vegetable transplanter

For vegetable producers, a vegetable transplanter may be adapted for use in conservation systems. The modified transplanter shown here contains a coulter to cut through rolled residue. Behind the coulter, to eliminate soil compaction, a shank is mounted to shatter the compacted layer to a depth of 12-14 inches.

Depending on soil type, moisture level and degree of compaction, different shank thicknesses (from 1/2–inch to 1–inch) might be used. However, more soil disturbance may occur with a thicker shank.

For greater stability two driving wheels, one wheel on each side of the crop row (instead of the original single wheel at the center of the row), have been used. This modification also helps minimize re-compaction of the soil opening created by the shank.



This is a modified one-row RJ Canadian made transplanter with an added sub-frame assembly to accommodate subsoil shanks and/or row cleaners. Combining subsoiling and transplanting operations eliminates the need for separate equipment, thus reducing labor needs and resources, such as fuel.

Fertilizer and Lime

As with all cropping systems, soil testing is an important part of a successful conservation system. Recommendations for fertilizers and liming can be obtained from a simple soil test. However, some elements of a fertilization program will need to be altered to fit in a conservation system.

Liming

Liming takes planning in conservation systems, since it will not usually be mixed into the soil. When converting a conventionally-tilled field, incorporating lime into the upper eight inches before the transition is made may be helpful if the pH is too acidic for the desired crops. Surface applications of lime are effective at maintaining a desirable pH, but are slow to remedy pH problems below the top few inches. If a conservation system already exists, tillage to incorporate lime will not be possible.

Once a conservation system is in place, the top two to three inches of the soil should be sampled separately because higher acidity is typically found in this layer from surface N fertilizer applications. Desirable pH levels can be maintained with more frequent lime applications at lower rates. This practice helps protect against acidity problems moving deeper in the soil profile. For more detailed information, follow state extension and local soil test recommendations.

Starter fertilizers

Starter fertilizers are typically recommended for cash crops in conservation systems. Cool soil conditions that are found in high-residue systems can slow root growth. Research shows benefits from small additions of N and P at planting.

Nutrients from cover crops

Legume cover crops produce N. Some of it is immediately available to the following cash crop, while most is released later as the residue decomposes.

Some cover crops are also effective nutrient scavengers. They utilize nutrients in the soil that might not be available to the following cash crops. These scavenged nutrients become available as the residue decomposes.

Measuring N available from cover crops is difficult. Nutrients in cover crop plant tissue will be partially available to subsequent crops. Much of the N fixed by legume cover crops is released for the next crop; however, the time of release may not coincide with cash crop demand. Due to the complexity of nutrient release by various cover crops, fertilizer management decisions must be on a field-to-field basis.

Over the years, a system that consistently includes winter legumes and has accumulated organic matter may meet much of the cash crop's demand for N. Research at the *Old Rotation* in Auburn, Alabama has studied this issue. A long-term winter legume rotation with cotton or corn resulted in yields equal to yields produced by 120 lb fertilizer N/acre. However, yields increased when legumes and fertilizer were used together. Cotton and corn response to legumes *plus* 120 lb N/acre was significantly greater than the legume- or fertilizer- only treatments. Therefore, a grower may be able to cut back on fertilizer N if necessary to save input costs, but to achieve top yields, covers should be used with additional fertilizer N.

Corn sidedress N application at V6 in Central Alabama.

Integrated Pest Management

An effective IPM program will help ensure a successful transition to conservation systems. Check with other conservation tillers in your area to learn what problems you may encounter during your transition. Preventive measures are best to combat pests and diseases. Scout regularly to help stay on top of problems that do occur.

Diseases and insects

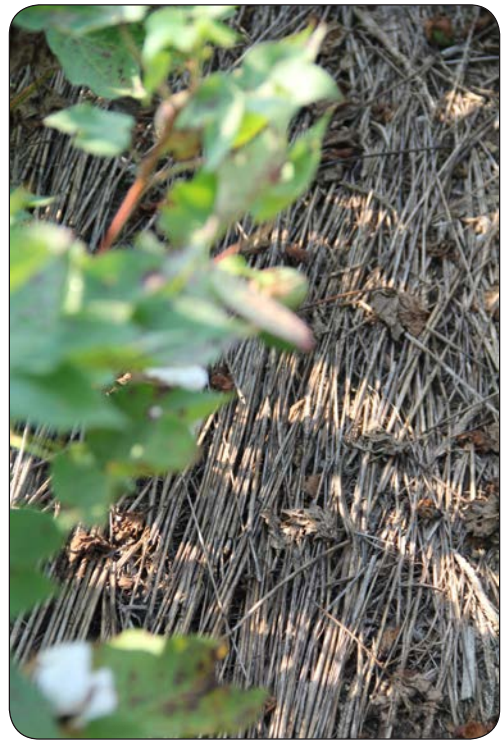
Disease and insect management can be a challenge in conservation systems. Residues on the soil surface can provide a host for insects and diseases. Also, cooler and wetter soils can amplify some seedling diseases. There are steps to avoid possible disease and insect problems.

- Rotate to a non-host cover crop or cash crop to break cycles.
- Check with seed dealers to find resistant/tolerant varieties.
- Delay planting until soil temperatures are warmer or until high risk of disease/insect infestation has passed. If planting must be delayed for a significant amount of time, check with your seed dealer to see if a shorter-season variety should be substituted.
- Consider starter fertilizers to give your crop an early season boost.

Weeds

Weed management in conservation systems can be vastly different from conventional systems. Changes in weed composition will most likely occur. Conservation systems tend to promote perennial species and small-seeded annuals. Weed challenges will change over time; therefore, an effective weed control program must change as well. Traditional cultivation will no longer be an option in conservation systems; however, several alternatives are still available. These include practices which enhance the crop's competitiveness with emerging weeds.

Row-spacing and plant population can be altered easily in some cropping systems. High plant populations and narrow row spacing promote quick canopy closure to decrease light reaching the ground, which helps inhibit weed germination. Starter fertilizers can also give crops a head start to increase their competitiveness against pests.



Thick cover prevents weed emergence and growth.

As with disease and insect control, crop rotations are very important in an integrated weed management program. Crop rotations and the use of cover crops can disrupt weed life cycles and keep any one particular species from becoming dominant. Rotations also allow the use of herbicides with different modes of action. Herbicides remain the most important aspect of weed management in most conservation systems. When soil-active preemergence herbicides are used, cover crop residue may partially intercept those applications. However, because gaps will likely occur across cover crop mulches, it's important to utilize preemergence herbicides in conservation systems to protect yield potential.

With the development of herbicide resistant crops, many weeds can be controlled more easily than before. However, to avoid developing resistant weeds, it is important to not rely completely on one herbicide system. Rotating herbicide modes of action is very important to prevent weed resistance. High-residue cover crops are being recommended to help alleviate herbicide selection pressure.

Other weed management recommendations include:

- intensive crop rotations (including pasture-based rotations);
- use of strategic inversion tillage to bury weed seed banks followed by a continuous high residue conservation system;
- integration of cultural solutions (high residue cover crops, delayed planting, minimize soil/residue disturbance, etc.);
- use of high residue cultivators; and
- intensive weed management (scouting, timely herbicide applications, etc.).

Alternative chemical management strategies for improved glyphosate-resistant Palmer amaranth control include:

- use of alternative herbicide chemistries; and
- use of fall residuals on harvested fallow fields to reduce weed seed banks.

Researchers continue to work to identify ways to improve residual herbicide performance in dry-land conservation systems and create new herbicide paradigms that are site specific for Coastal Plain/Uplands/Delta regions.

More information on integrated pest management in conservation systems is available in CSR Factsheet 2 (Valor - A Residual Herbicide for Weed Control in Conservation Tillage Cotton Systems) and CSR Special Publication 9 (Controlling Glyphosate-Resistant Pigweed in Conservation Tillage Cotton Systems).

Corn growing in cover crop and previous crop residue.

Making Conservation Systems Profitable

Including cover crops in a conservation system provides both direct and indirect costs and benefits. Cover crops offer many soil-building benefits that can be profitable in the long-run, but they can also show immediate profits if properly managed.

The main costs associated with converting to a conservation system are 1) purchase of new machinery or making modifications to existing equipment and 2) establishing and terminating the cover crop.

Equipment needs are specific to individual operations. While some producers may need to purchase additional pieces of equipment, other producers may be able to modify in-row subsoilers and/or planters for high-residue conservation systems.

Establishing and terminating a cover crop can be broken down into three sections:

- establishment, including seed and planting costs;
- fertilizer and application (if applicable); and
- termination, including chemical application, as well as other machinery such as rollers.

The costs of cover crop seed is one of the larger expenses related to cover establishment. Seed price depends on the variety, seed supply, and demand for the seed. It is also important to consider machinery and labor costs. The time it takes to manage the cover crop is not free. There are some costs that may occur regardless of cover crop use, such as spring burndown.

Aside from potential yield increases with the adoption of conservation systems, there are other agronomic benefits that increase the profitability of conservation systems. Conservation systems can reduce soil erosion, thereby reducing land repair costs associated with heavy rainfall. High-residue cover crops help to control weeds and may reduce herbicide use. Using a legume cover crop may lower N requirements for subsequent crops. Also, there may be less yield variability for crops following cover crops as part of a conservation system. For irrigated acres, the use of a conservation system may decrease the amount of water needed during the growing season, thereby reducing water and energy costs. Depending on the type of cover crop grown and goals of the operation, there may be opportunities to grow a cover crop for seed production, utilize the cover crop as part of a grazing system, and other viable options to increase economic return.

Adopting a conservation system can have a positive impact on profitability either from increasing yields and/or decreasing yield variability.

The following factsheets provide additional information related to costs associated with adopting conservation systems: CSR Factsheet 3 (Modifying Equipment for High-Residue Systems), CSR Factsheet 4o (Cover Crop Costs), and CSR Factsheet 4n (Cover Crop Sources).

Getting More Information

Federal Agencies

USDA Agricultural Research Service (ARS)

USDA-ARS, National Soil Dynamics Laboratory (NSDL),Conservation Systems Research (CSR)

USDA-ARS Coastal Plains Soil, Water, and Plant Research Center

USDA Natural Resources Conservation Service (NRCS)

USDA-NRCS Jimmy Carter Plant Materials Center

Cooperative Extension

Alabama Cooperative Extension System

University of Georgia Cooperative Extension

University of Florida (UF) Institute of Food and Agricultural Sciences (IFAS) Extension

Organizations

A National Sustainable Agriculture Assistance Program (ATTRA)

Alabama Sustainable Agriculture Network (ASAN)

Soil and Water Conservation Society (SWCS)

Southern Sustainable Agriculture Working Group (SSWAG)

Sustainable Agriculture Research and Education (SARE)

Conservation Tillage Resources

Conservation Technology Information Center (CTIC)

Georgia Conservation Tillage Alliance (GCTA)

No-Till on the Plains

Cover Crop Resources

Cover Crops and Green Manures for Hawaii

Lupins.org - Information Resource Portal for Lupins

Managing Cover Crops Profitably

Midwest Cover Crops Council

University of California-Davis Sustainable Agriculture Research and Education Program (SAREP) Cover Crops Database

USDA-ARS Northern Great Plains Research Laboratory Cover Crop Chart

USDA-NRCS Missouri Cover Crops Economics Tool

Other Conservation Tillage Information

Building Soils for Better Crops, 3rd Edition

No-Till Farmer

Pursuing Conservation Tillage Systems for Organic Crop Production

Pest and Weed Management

Crop Data Management Systems Label Database

Greenbook: Search Chemical Products Labels

Manage Insects on Your Farm: A Guide to Ecological Strategies

Collaborators

This publication is based on current and past research from USDA-ARS, NSDL, collaborators at Auburn University, and other USDA-ARS research facilities. The following people have made contributions to conservation systems research:

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Dr. Jason Bergtold

Dr. Randy Raper

Dr. Wayne Reeves

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Collaborators at Auburn University

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Dr. Clint Truman (Former USDA-ARS researcher)

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USDA

United States Department of Agriculture

Agricultural Research Service

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