RODALE INSTITUTE

COVER CROPS AND NO-TILL MANAGEMENT FOR ORGANIC SYSTEMS

This publication was supported by a U.S. Department of Agriculture Northeast Sustainable Agriculture Research and Education grant, agreement No. LNE08-268 and by a private foundation.

Why is it important to reduce tillage?

No-till practices were first introduced as a soil conservation tool and to decrease labor requirements and fuel use.[8, 26] Numerous studies have shown that soil is more protected from erosion and run-off in no-till systems[10, 18, 25, 31] and that yields in no-till systems can be as good or better than with conventional tillage.[6, 7, 16, 29] Soil carbon[2, 11, 30] and other soil quality parameters (aggregate stability, microbial activity, earthworm populations) can increase significantly after switching from conventional tillage to no-till.[16] Potential disadvantages of no-till are compaction, flooding or poor drainage, delays in planting because fields are too wet or too cold, and carryover of diseases or pests in crop residue.

In conventional ('standard') no-till systems, cover crops and weeds are usually controlled with herbicides rather than by tillage or cultivation. This increased dependence on herbicides[6] is often considered unsustainable, possibly leading to herbicide resistance in certain weeds and increased leaching of pesticides into groundwater due to higher infiltration rates in no-till systems.[15, 20, 25] In organic production systems, herbicide resistance and pesticide leaching are usually not a concern; instead, reducing tillage on an organic farm is of interest to reduce fuel and labor inputs and to improve soil and water quality.

How no-till works in an organic system

'Standard' no-till with herbicides is not an option in organic systems. In order to reduce frequency or intensity of tillage in organic systems, many farmers are exploring the option of terminating a cover crop mechanically by mowing, undercutting or rolling instead of plowing. The main crop is then seeded or transplanted into the terminated cover crop without using tillage. In this type of system, no-till planting is not continuously used for each crop but only for some of the main crops in the rotation (generally for crops that would require cultivation like corn, soybeans or vegetables). The success of this system very much depends on a well established cover crop that has dense, weed-free stands and produces large amounts of biomass for rolling or mowing. This is best achieved through timely planting of the cover crop into a clean seed bed created with tillage.

Cover crops and their many services

- prevent soil erosion by wind and/or water[12]
- increase yields, especially if legumes are used[17]
- enhance soil organic matter, aggregation and nitrogen storage[12, 23]
- reduce nitrate leaching
- conserve water resources[13, 28]
- reduce insect and pathogen damage[9, 19]
- compete with weeds
- fight compaction, soil crusting, increase aeration
- provide nutrients (for plants and microbes)

While plowing incorporates the cover crop into the soil, leaving the soil bare as a result, mowing, undercutting, and rolling all keep the cover crop on the soil surface to act as a weed suppressing and moisture conserving mulch. Flail mowing is usually the preferred method of cover crop mowing. It cuts low (right above ground level) and leaves an even layer of residue. Undercutting terminates a cover crop with sweeps or blades that travel just below the soil surface, cutting the plants below the crowns. Rolling is performed using a rolling drum with blunted blades that terminate the cover crop by rolling it into a mat without cutting the stems. Both undercutting and rolling keep the plants more or less intact and in place, thereby reducing decomposition rates and increasing the time the mulch stays on the soil surface and works to suppress weeds. Mowing chops the plant biomass into small pieces, increasing the rate at which the cover crop breaks down. In this publication we will focus on rolled cover crops.

Rolling rye and planting soybeans

Much of the interest in mechanical termination of cover crops, especially in the roller-crimper, comes from organic producers. However it can also be used in conventional systems. Some studies have shown that the roller-crimper in combination with a burndown herbicide, such as glyphosate, can both increase the effectiveness of cover crop control and reduce the rate of herbicides needed to kill the cover crop.[1, 4]

Rolling hairy vetch and planting corn

Field trials examining the effectiveness of the roller as a mechanical termination technique show promising results. Cover crop rollers can successfully terminate annual crops such as cereal grains (rye, wheat, oats, and barley) and annual legumes (hairy vetch, winter pea and crimson clover) without the use of any herbicides.[1, 21, 22] Rollers are not effective on perennials because they can't be killed by rolling and will continue to grow and compete with the main crop. In order to use the roller effectively, the annual cover crop needs to have switched from the vegetative to the reproductive stage - which means it needs to be in the flowering or anthesis stage (but before it has produced viable seed). If a cover crop is rolled too early, it will not die but continue to grow and compete with the crop that was planted into the rolled cover crop. In addition, if rolled too soon, the cover crop will most likely produce seed, turning into maybe the worst weed in the field. Recognizing the right (perfect) time for rolling may be the biggest challenge with this system, especially if it requires extra patience because you have to delay the planting date of the cash crop.

An advantage of the roller is the fairly small amount of energy and horse power required to operate it. Fuel needed for the roller is similar to a cultipacker and ten times less than the energy required for mowing.[14] The biggest energy savings, however, result from the reduced number of field operations: In a tilled organic system up to 10 field passes may be required from cover crop termination to harvesting of the main crop (plowing, disking, packing, planting, and several cultivations for weed control), whereas the no-till roller-crimper system can take as few as 2 passes (rolling+planting and harvesting).

Winter rye at anthesis, ready for rolling

Yield results and weed suppression for the roller-crimper system are also promising. In a field trial in Illinois, no-till soybeans grown after rye termination with a roller achieved similar yields to those in a chemically terminated cover crop while reducing residual weed biomass.[5] In another trial conducted in North Carolina soybeans were no-till planted into a rolled or flail mowed rye cover crop. Both treatments controlled weeds in the soybeans sufficiently (no herbicides were used) and yields were the same as in a weed-free treatment, as long as dry rye biomass was high (>9,000 lbs/a).[27]

Benefits and challenges of organic no-till systems

Benefits

- Reduces number of tractor passes over the field (saves time, fuel, and money)
- Keeps the soil covered to reduce erosion and weed growth
- Cover crop mat retains moisture and cools soil in mid-summer
- Eliminates herbicide use
- Provides a source of nitrogen to the cash crop (if leguminous cover crops are used)

Potential Challenges

- Nitrogen tie-up (when using crops with high C:N ratio, for example small grains)
- Can keep soil too cool in the spring
- Cover crop may use up a lot of water reserves
- Requires well-timed rolling and may result in later planting
- Heavy cover crop mat may pose a problem for the planter
- May provide habitat for plant-damaging pests
- Can allow weed growth if the cover crop stand is poor

Developing a rotation

For organic no-till to work, you will probably need to re-think your rotation. Cover crops are already a common feature in organic rotations, but they are even more important if that rotation includes organic no-till. You need to first identify the main reason for planting the cover crop and then determine which cover crop best fulfills that criteria and where it can fit into the rotation. Typical planting and termination dates of the chosen cover crop have to be coordinated with the planting and harvesting dates of the cash crop to ensure a wide enough growth window for both crops. As mentioned before, the success of this system very much depends on how well the cover crop is established. For example, if the cover crop is planted too late because the previous crop in the rotation is harvested late, there may not be enough time for the cover crop to produce enough biomass suitable for rolling. Trying to save time or money by either skipping steps in seed bed preparation or by reducing the cover crop seeding rate will also lead to less than ideal results.

Selection of cover crops suitable for rolling

Cover crop	Type	Hardiness °F	Seeding rate lbs/acre	Biomass range tons/acre	N fixed lbs/acre	Stage for rolling
Legumes						
Crimson clover	Winter annual	0-10	9-40	1.5-3	70-130	Flowering
Hairy vetch	Winter annual	-10	20-40	1-3	80-250	Full bloom
Fava bean	Summer annual	20	80-170	1-2.5	70-220	Flowering
Field peas	Winter annual	10-20	70-120	1-2.5	170-190	Flowering
Soybean	Summer annual	NFT	60-120	1.5-4		any time
Non-legumes						
Buckwheat	Summer annual	NFT	35-134	1-1.5	N/A	Flowering
Winter barley	Winter annual	0	70-120	1.5-5	N/A	Anthesis
Spring barley	Summer annual	15	50-125	1.5-4	N/A	Anthesis
Spring oats	Summer annual	15-20	50-100	1.5-4	N/A	Milk stage
Winter rye	Winter annual	-40	60-200	2-5	N/A	Anthesis
Winter wheat	Winter annual	-25	120-160	1.5-3.5	N/A	Anthesis

NFT= no frost tolerance

adapted from 'Managing Cover Crops Profitably', 'Northeast Cover Crop Handbook', 'Cover Crops for All Seasons'
For more details see also: Choosing the best cover crops for your organic no-till vegetable system, http://newfarm.rodaleinstitute.org/features/0104/no-till/chart.shtml

Depending on your cash crop, you can choose a winter or summer annual cover crop for organic no-till.

In northern regions, the cover crop needs to be cold tolerant to survive hard winters. Small grains (barley, oats, rye, and wheat) have good winter hardiness, grow rapidly, and seed is readily available. With their fast growth they are strong competitors against weeds, and some (such as rye) can be allelopathic, emitting chemicals that inhibit weed seed germination. Legumes, such as clovers, vetches, and peas, are less winter hardy than grasses, grow less rapidly, and are not as effective in preventing erosion or reducing leaching loss of left-over nitrogen. However, they add significant amounts of nitrogen to the soil (up to 200 lbs/acre) which is made available gradually to the following crop. The nitrogen availability pattern of these cover crops is more adapted to plant growth and needs than most mineral fertilizers.[24] To combine the advantages of both legumes and grasses, they can be planted in a mix. If the cover crop is terminated by rolling, however, the species in a mix will need to be flowering at the same time; otherwise the kill will not be successful.

Hairy vetch: Provides nitrogen and is very winter hardy

Crimson clover: Provides nitrogen and flowers early

Austrian winter peas: Provides nitrogen, less winter hardy than vetch

Winter rye: winter hardy, grows rapidly, has allelopathic properties

Choosing a winter annual has several advantages:

- The cover crop provides protection for the soil when it might otherwise be left bare
- The cover crop will flower and begin senescing in late spring, in time to plant warm season crops such as corn, soybeans, pumpkins, tomatoes or other vegetable transplants
- Summer annual weeds that germinate with the fall-planted cover crop won't survive the winter
- An established cover crop will inhibit weed germination in early spring

No-till corn into rolled vetch

No-till soybeans into rolled rye

No-till tomatoes

No-till pumpkins

No-till peanuts (photo credit: Mark Vickers, Georgia)

No-till eggplants (photo credit: Jeff Mitchell, UC Davis, California)

Sample rotations (adapted from 'Organic No-till Farming')

1. Grain/ forage rotation

This rotation is a 6-year rotation of corn, soybeans, oats and alfalfa. The alfalfa in year four, five and six provides a rest from the grain segment of the rotation, breaking pest and weed cycles and providing a significant nitrogen contribution. Since this is not a continuous no-till system, manure or compost can be incorporated in the fall before the cover crop is planted. In this example corn, soybeans and rye can all be planted without the use of primary tillage.

YEAR 1
Spring: Corn; hairy vetch (which was planted the previous fall (=Year 6) is rolled in early to mid June, and corn is planted into the rolled vetch which provides much of the nitrogen needed for the corn.

Fall: Rye - planted as soon as the corn has been harvested.

YEAR 2
Spring: Soybeans; rye is rolled in late May and soybeans are planted into the rolled rye.

Fall: Rye; this rye is strictly for winter cover if you plan to grow oats in Year 3. Alternatively, you can skip the oats, grow the rye to full maturity, and save your own seed.

YEAR 3
Spring: Oats; oats can be harvested for grain or cut for early forage. If harvested for grain, straw can be baled.

Fall: Winter wheat/alfalfa; winter wheat is planted in the fall, underseeded with alfalfa or alfalfa is frost seeded in late winter. (If there is no desire for a hay crop in the rotation, you can skip the alfalfa and proceed to Year 6 and plant hairy vetch in early fall following wheat harvest.)

YEAR 4
Summer: Winter wheat is harvested in July and the alfalfa continues to grow.

YEAR 5
Alfalfa: Alfalfa is harvested for hay (3-4 cuttings per year).

YEAR 6
Alfalfa/vetch; two to three cuttings are taken off the alfalfa during the summer. In the fall, the alfalfa is tilled under and vetch is planted as a winter cover crop for next year's corn and the rotation begins again.

2. Vegetable rotation

This rotation is an 8-year vegetable rotation based on an example in Eliot Coleman's book "The New Organic Grower". Depending on your latitude, additional crops may be squeezed in during the summer or fall. Again, this is not a continuous no-till system – tillage is performed in the fall to establish the winter cover crop, with manure or compost incorporated at that time. If desired, grains and legumes may be grown together for additional nitrogen with a carbon boost.

YEAR 1
Spring: Sweet corn; hairy vetch (which was planted the previous fall (=Year 8) is rolled in late spring and sweet corn is planted into the rolled vetch which provides much of the nitrogen needed for the corn.

Fall: Rye/vetch mix: vetch replaces some of the N lost with the sweet corn; rye provides adequate biomass for weed management.

YEAR 2
Spring: Potatoes - planted five inches deep into a raised bed. The rye/vetch cover crop is rolled two weeks later.

Fall: Rye - to be used as the cover crop for next year's summer squash.

YEAR 3
Spring: Summer squash - transplanted into rolled rye in early June.

Late summer: Buckwheat after summer squash, a quick smother crop of buckwheat is planted for additional weed suppression and phosphorus uptake.

YEAR 4
Spring: Radishes; an early planting of radishes is direct seeded into winterkilled buckwheat in April. The crop is mechanically cultivated. A mid-summer lettuce planting could follow, with supplemental nitrogen.

Fall: Rye - to be used as the cover crop for next year's beans.

YEAR 5
Spring: Snap beans; rye is rolled in early June, and beans are direct seeded into the rolled cover crop.

Fall: Vetch - to be used as cover crop for next year's tomatoes.

YEAR 6
Spring: Tomatoes; vetch is rolled in June, and tomatoes are transplanted into the rolled vetch.

Fall: Oats – to be used as cover crop for next year's peas.

YEAR 7
Spring: Peas - direct seeded into the winterkilled oat residue, mechanical cultivation is used.

Fall: Vetch - to be used as cover crop for next year's cabbage.

YEAR 8
Spring: Cabbage – vetch is rolled and cabbage is transplanted into the rolled vetch.

Equipment needed for no-till with cover crops

Roller - crimper

Rollers can vary in size and design and be modified to fit each specific operation. They can be purchased through I&J Manufacturing in Gap, Pennsylvania; free plans to build your own can also be downloaded from the Rodale Institute website. I&J rollers have standard widths of 8, 10½ and 15½ feet but they can be custom made narrower and wider (up to 40 feet wide).

I&J Roller Models

	Price	Weight
8’ Model	$2,800	1,290 lb
10 1/2’ Model	$3,200	1,680 lb
15 1/2’ Model	$4,400	2,400 lb
30’ Folding (3-point)	$18,300	
30’ Folding (trailed)	$19,800	

Source: http://www.croproller.com/

10 ½ foot roller

Raised bed roller

The Rodale roller - crimper at a glance

HOW IT WORKS:

- Crushes the cover crop
- Crimps the stems of the cover crop every 7 inches

DESIGN FEATURES

- Front mounted on the tractor
- Ground driven
- Chevron pattern maximizes downward force while keeping the tractor on a straight course
- Drum can be filled with water to increase weight
- Easy to maintain (few bearings and areas where cover crops can become jammed)

SPECIFICATIONS

- Roller diameter: 16 inches
- 10 blades: 4 inches tall, spaced evenly around the roller
- Width: 8 feet (3 row), 10.5 feet (4 row), 15.5 feet (6 row); custom made rollers are available up to 40 feet wide
- Weight (10.5 ft roller): 1,680 lbs (empty), 2,400 lbs (filled with water)
- Hitch: made to fit category I or II 3-point hitch

Source: Organic No-Till Farming

3-point front hitch and hitch mounting frame

The roller can be pulled behind a tractor but the tractor tires may leave tire depressions in the cover crop, preventing the roller from making good contact with the cover crop and resulting in less than adequate kill. Mounting the roller on the front of the tractor will circumvent that problem and also free up the rear of the tractor for a planter or transplanter, allowing a one-pass operation of rolling the cover crop and planting the main crop. A special front 3-point hitch (plus a hitch mounting frame) is needed to mount the roller on the front of the tractor (available at Laforge Systems, Buckeye Tractor Company and Double R Manufacturing). Hitches can be installed on new tractors as well as tractors built since the 1960s and need to have a lift rating that allows you to raise the roller when it is full of water.

3-point front hitch

Front mounted roller (right) results in better cover crop kill than rear mounted roller (left)

No-till planter

To work through a rolled cover crop mat, standard no-till planters will probably need to be modified by:

- Adding weights to supply downward pressure and cut through the cover crop mat
- Using cast iron closing wheels (instead of the standard plastic and rubber wheels) to press through the mulch and close the seed slot
- Adding foam markers to help determine the location of the planter passes

In addition, coulters need to be well maintained to stay sharp and avoid hairpinning.

No-till transplanter

A regular transplanter may not be able to cut through the heavy mat of rolled cover crops. The sub-surface tiller-transplanter (SSTT) developed by Ron Morse of Virginia Tech is intended to transplant vegetable plugs into cover crop mats. The SSTT has an upright, high clearance design with a double disk opener plus a sub-surface tiller that prepares a narrow strip of soil up to 8 inches deep, which enables the double disk opener to open a furrow for the transplants.

No-till Monosem planter with modifications

Sub-surface tiller transplanter (photo credit: Mark Schonbeck, Virginia Association for Biological Farming)

Tractor

The tractor size will depend on the planter size. It must be able to pick the roller off the ground for turning.

High residue cultivator

A high residue cultivator can be a very useful tool if weeds start breaking through the rolled cover crop mat (a standard cultivator will most likely not be able to work with the large amount of residue left on the surface). Research trials at the Rodale Institute have been conducted with a cultivator manufactured by the Hiniker Company that has sharp coulter discs positioned between two depth control wheels, followed by large angled sweeps. The coulter disc cuts through the cover crop mat, creating a slit opening for the sweep to pass through. The sweep travels at a soil depth of a few inches, staying under the mulch mat without disturbing it too much and severing the weeds from their roots just below the soil surface. This cultivator works best when the soil is moist, the weeds are well established and large enough to be cut (but before seed setting) and the crop is still small enough for the equipment to easily pass through the field (about 5-6 weeks after planting).


High residue cultivator in no-till soybeans- the rye mat is sliced, but intact


Coulter disc and angled sweep

Equipment Budget Example

Roller-crimper	$3,200
Front End Hitch	$2,500
No-till Planter	$20,000
Planter Modifications	$460
Total cost:	**$30,600**

Based on: 10 ½ foot roller, 4 row-planter, planter modifications at $125/row
Source: Organic No-till Farming

Penn State researchers give these tips to farmers interested in trying organic no-till (Source: http://extension.psu.edu/susag/news/2011/Sept-2011/4-org-no-till)

1. **START SMALL.** Organic no-till is a significant change for many organic farmers and conventional no-tillers alike. Try it out on a small scale to minimize risk.
2. **CHOOSE WISELY.** Select cover crops that are moderately priced, easily established, highly productive, and easy to kill.
3. **PLAN AHEAD.** Due to the central role of cover crops in this system, planning must start far in advance of a given main-season crop.
4. **DON'T SKIMP.** Get cover crops in the ground on time and at recommended seeding rates. Successful weed suppression requires a dense mat of cover crop residues. If the cover crop looks less-than-ideal in spring, be ready with a plan B.
5. **STAY SHARP.** Keep equipment in good shape. To plant through thick residue, planting equipment must be maintained in top condition.
6. **BE CREATIVE.** Organic no-till will need to be adapted to each farm's climate, soils, equipment, and resources. But with the principles in hand, many solutions are possible.

The bottom line

The following tables compare production budgets for corn and soybeans in organic and conventional tilled and no-till systems but can be applied to other crops as well.

Main expenses for organic corn production are seeds, fuel and labor, whereas the biggest portion of the budget in the conventional systems is made up of fertilizers, herbicides and seeds. Compared to the tilled organic system, total expenses in the no-till organic system are more than 20% lower due to significantly lower labor, fuel and equipment costs. The no-till conventional system, on the other hand, has higher expenses than the tilled conventional system due to higher herbicide and seed costs and only a minor savings in fuel. Note that the conventional no-till system includes a hairy vetch cover crop before corn as part of best management practices. It is assumed that nitrogen fertilizer needs for corn can be reduced by approximately half because of residual nitrogen inputs from the vetch cover crop. Individual results may vary by location and year.

Production budgets for corn

	Organic Tilled	Organic No-till	Conv Tilled	Conv No-till
	vetch+corn	vetch+corn	corn	vetch+corn
Expenses				
fertilizer	0.00	0.00	118.04	90.44
herbicide	0.00	0.00	108.19	144.56
seed	139.40	139.40	88.15	148.35
custom haul	30.00	30.00	30.00	30.00
labor	39.35	18.61	15.78	16.14
fuel	47.60	23.96	23.76	20.67
repair & maintenance	17.56	10.35	8.42	8.97
interest on op. capital	6.35	4.54	11.50	13.50
fixed expenses	52.02	30.98	27.31	27.46
Total Expenses ($/acre)	**332**	**258**	**431**	**500**
Profit ($/acre)*				
@100 bu/a yield	**504**	**578**	**-16**	**-85**
@150 bu/a yield	**922**	**996**	**191**	**122**
@200 bu/a yield	**1,340**	**1,414**	**399**	**330**
Break-even price ($/bu)				
@100 bu/a yield	**3.32**	**2.58**	**4.31**	**5.00**
@150 bu/a yield	**2.22**	**1.72**	**2.87**	**3.33**
@200 bu/a yield	**1.66**	**1.29**	**2.16**	**2.50**

These production budgets were calculated using the free on-line Mississippi State Budget Generator (MSBG), developed by the Department of Agricultural Economics at Mississippi State University, (http://www.agecon.msstate.edu/what/farm/generator/). When available, input and price data were taken directly from data collected at the Rodale Institute (2008-2010), otherwise default values from the Budget Generator were used.
* The 3-year average price for organic corn was $8.36/bu, for conventional corn $4.15/bu.

Similar to corn production, the main expenses for organic soybean systems are seeds, fuel and labor, whereas seeds and herbicides comprise the biggest portion in the conventional system expenses. Lower labor, fuel and equipment costs reduce total expenses in the no-till organic system by 30% compared to the tilled organic system. As with corn, the no-till conventional soybean system has higher expenses than the tilled conventional system due to higher herbicide and seed costs and only minor savings in fuel and labor. Note again that the conventional no-till system includes a rye cover crop before soybeans as part of best management practices.

Production budgets for soybeans

	Organic Tilled	**Organic No-till**	**Conv Tilled**	**Conv No-till**
	rye+soybeans	**rye+soybeans**	**soybeans**	**rye+soybeans**
Expenses				
fertilizer	0.00	0.00	0.00	0.00
herbicide	0.00	0.00	16.32	35.79
seed	93.02	93.02	57.34	111.34
custom haul	8.00	8.00	8.00	8.00
labor	36.87	16.13	11.36	10.93
fuel	44.03	20.38	16.00	14.10
repair & maintenance	15.62	8.41	6.25	7.04
interest on op. capital	5.06	3.43	3.45	8.08
fixed expenses	46.70	25.66	20.10	21.20
Total Expenses ($/acre)	**249**	175	139	216
Profit ($/acre)*				
@30 bu/a yield	**314**	**388**	**168**	**90**
@40 bu/a yield	**502**	**576**	**270**	**193**
@50 bu/a yield	**689**	**763**	**373**	**295**
Break-even price ($/bu)				
@30 bu/a yield	**8.31**	**5.83**	**4.63**	**7.22**
@40 bu/a yield	**6.23**	**4.38**	**3.47**	**5.41**
@50 bu/a yield	**4.99**	**3.50**	**2.78**	**4.33**

These production budgets were calculated using the free on-line Mississippi State Budget Generator (MSBG), developed by the Department of Agricultural Economics at Mississippi State University, (http://www.agecon.msstate.edu/what/farm/generator/). When available, input and price data were taken directly from data collected at the Rodale Institute (2008-2010), otherwise default values from the Budget Generator were used.

* The 3-year average price for organic soybeans was $18.77/bu, for conventional soybeans $10.23/bu.

Energy comparisons

The following tables compare energy budgets for corn and soybeans in organic and conventional tilled and no-till systems. In this comparison the conventional no-till systems include a cover crop before the main crop. It is assumed that nitrogen fertilizer needs for corn can be reduced by approximately half because of residual nitrogen inputs from the vetch cover crop.

Corn production in a no-till organic system requires close to 30% fewer energy inputs than tilled organic corn production. The main energy savings result from reduced fuel and labor inputs due to a reduced number of field operations.

Energy differences are even bigger in a comparison with conventional corn production systems. Total energy requirements in the tilled and no-till conventional systems are more than 70% higher than their respective organic counterparts. More than half of the energy requirements in the conventional systems can be attributed to synthetic nitrogen fertilizer and herbicides.

Energy budgets for corn

	Organic Tilled	Organic No-till	Conv Tilled	Conv No-till
Energy inputs	**vetch+corn**	**vetch+corn**	**corn**	**vetch+corn**
Nitrogen fertilizer	**0**	**0**	**9,875**	**4,942**
Phosphorus fertilizer	**0**	**0**	**391**	**391**
Potassium fertilizer	**102**	**102**	**118**	**118**
Lime	**203**	**203**	**243**	**243**
Seed	**2,559**	**2,559**	**1,182**	**2,468**
Herbicide	**0**	**0**	**1,055**	**1,509**
Transportation of inputs	**247**	**247**	**453**	**486**
Equipment	**639**	**615**	**619**	**509**
Diesel fuel	**5,359**	**3,046**	**2,725**	**2,201**
Labor	**1,041**	**511**	**712**	**563**
Total energy (MJ/ha*yr)	**10,150**	**7,283**	**17,372**	**13,429**

This analysis was performed using the Farm Energy Analysis Tool (FEAT),[3] a simple database model used to analyze energy use of crops and cropping systems that are grown in temperate agroecosystems. The energy requirement associated with agricultural inputs are calculated based on their embedded energy required to produce that input.
Results presented here are based on actual input data collected from the Rodale Institute Farming Systems Trial, combined with the FEAT model which is based on a comprehensive literature review.

Total energy requirements in tilled and no-till organic soybean systems are very similar to the respective organic corn systems (both at about 10,000 and 7,000 MJ/ha/year respectively). The nearly 30% energy savings in the rolled cover crop no-till system are again due to fewer fuel and labor inputs.

Conventional soybean systems do not require nitrogen fertilizer inputs, therefore total energy requirements are significantly lower than for conventional corn. The no-till conventional soybean system is actually very similar to the no-till organic system. The only difference is that lower fuel energy requirements in the conventional no-till system are offset by the energy needed to produce the required herbicides.

Conventional soybeans in a tilled system without cover crops are the most energy efficient in this comparison: Although the tilled conventional beans required higher energy inputs for fuel and equipment than the no-till conventional soybeans, the tilled system's lower seed, herbicide and transportation inputs easily counterbalance those differences.

Energy budgets for soybeans

	Organic Tilled	Organic No-till	Conv Tilled	Conv No-till
Energy inputs	**rye+soybeans**	**rye+soybeans**	**soybeans**	**rye+soybeans**
Nitrogen fertilizer	0	0	0	0
Phosphorus fertilizer	0	0	0	0
Potassium fertilizer	102	102	118	118
Lime	203	203	243	243
Seed	3,441	3,441	1,532	3,287
Herbicide	0	0	408	893
Transportation of inputs	465	465	315	497
Equipment	639	615	586	461
Diesel fuel	5,047	2,733	2,110	1,593
Labor	701	188	200	196
Total energy (MJ/ha*yr)	10,597	7,747	5,512	7,288

This analysis was performed using the Farm Energy Analysis Tool (FEAT),[3] a simple database model used to analyze energy use of crops and cropping systems that are grown in temperate agroecosystems. The energy requirement associated with agricultural inputs are calculated based on their embedded energy required to produce that input.
Results presented here are based on actual input data collected from the Rodale Institute Farming Systems Trial, combined with the FEAT model which is based on a comprehensive literature review.

Resources

BOOKS, FACT SHEETS, ON-LINE INFORMATION

Managing Cover Crops Profitably, Sustainable Agriculture Network, Handbook Series Book 3, Third Edition, 2007. www.sare.org

Northeast Cover Crop Handbook, Marianne Sarrantonio, Rodale Institute, 1994. www.rodaleinstitute.org

Cover crops for all seasons, Expanding the cover crop tool box for organic vegetable producers, Mark Schonbeck and Ron Morse, Virginia Association for Biological Farming, Number 3-06, 05/15/06. http://www.vabf.org/pubs.php

Choosing the best cover crops for your organic no-till vegetable system. A detailed guide to 29 species. Mark Schonbeck and Ron Morse. http://newfarm.rodaleinstitute.org/features/0104/no-till/chart.shtml

Organic No-till Farming, Jeff Moyer, Acres USA 2011

Organic no-till gains momentum in Pennsylvania http://extension.psu.edu/susag/news/2011/Sept-2011/4-org-no-till)

MSBG (Mississippi State Budget Generator), Department of Agricultural Economics at Mississippi State University. http://www.agecon.msstate.edu/what/farm/generator/

EQUIPMENT RESOURCES

Rodale Institute
611 Siegfriedale Road
Kutztown, PA 19530
Phone: 610-683-1400
Fax: 610-683-8548
www.rodaleinstitute.org/notill_plans

I&J Manufacturing
5302 Amish Road
Gap, PA 17527
Phone: 717-442-9451
Fax: 717-442-8305
www.croproller.com

Laforge Systems Inc.
4425-C Treat Blvd. - Suite 230
Concord, CA 94521
Phone 800-422-5636
Fax (925) 689-7198
lars@fronthitch.com
http://www.fronthitch.com/v3/pages/equipment.cfm

Buckeye Tractor Company
P.O. Box 97
11313 Slabtown Road
Columbus Grove, OH 45830
Phone 800-526-6791
Fax 419-659-2082
www.buctraco.com

Double R Manufacturing Ltd.
RR#2
Crapaud, PE C0A 1JO
Phone: 888-658-2088
Fax: 902-855-2030
http://doublermanufacturing.com/front-mount-3-point-hitch/

Ronald D. Morse
Vegetable Crops Research
Virginia Polytechnic Institute
Blacksburg, VA 24061
540-231-6724

Hiniker Company
58766 240th Street
Mankato, MN 56002
Phone 800-433-5620
http://www.hiniker.com

JOURNAL ARTICLES

1. Ashford, D.L. and D.W. Reeves. 2003. Use of a mechanical roller-crimper as an alternative kill method for cover crops. American Journal of Alternative Agriculture 18:37-45.

2. Berner, A., I. Hildermann, A. Fliessbach, L. Pfiffner, U. Niggli, and P. Mäder. 2008. Crop yield and soil fertility response to reduced tillage under organic management. Soil & Tillage Research 101: 89-96.

3. Camargo, G. G. d. T., Ryan, M. , and T. Richard. 2011. Energy usage and greenhouse gases from commodity and bioenergy crops using the farm energy analysis tool (FEAT). In preparation.

4. Curran, W., S. Mirsky, and M. Ryan. 2007. Effectiveness of a roller-crimper for control of winter annual cover crops. Proceedings of the Northeast Weed Science Society 61:29

5. Davis A.S. 2010. Cover-crop roller–crimper contributes to weed management in no-till soybean. Weed Science 58:300-309.

6. Day J.C., C.B. Hallahan, C.L. Sandretto, and W.A. Lindamood. 1999. Pesticide use in U.S. corn production: Does conservation tillage make a difference? Journal of Soil and Water Conservation 54: 477-484.

7. Dick W.A., E.L. McCoy, W.M. Edwards, and R. Lal. 1991. Continuous application of no-tillage in Ohio soils. Agronomy Journal 83:65-73.

8. Doren J.W. and D.M. Linn. 1994. Microbial ecology of conservation management systems. In: Soil Biology: Effects on Soil Quality. Advances in Soil Science, ed. J.I. Hatfield and B.A. Stewart, 1-28. Lewis Publishers: Boca Raton. FL.

9. Fritz V.A., R.R. Allmaras, F.L. Pfleger and D.W. Davis. 1995. Oat residue and soil compaction influences on common root rot (Aphanomyces euteiches) of peas in a fine-textured soil. Plant and Soil 171:235-244.

10. Gilley, J.E., J.W. Doran, D.L. Karlen. 1997. Runoff, erosion, and soil quality characteristics of a former Conservation Reserve Program site. Journal of Soil and Water Conservation 52: 189-193.

11. Halpern M.T., J.K. Whalen, and C.A. Madramootoo. 2010. Long-term tillage and residue management influences soil carbon and nitrogen dynamics. Soil Science Society of America Journal 74:1211-1217.

12. Hargrove W.L. 1991. Cover crops for clean water. Soil Water Conserv. Soc. Ankeny, IA.

13. Harper L.A., P.F. Hendrix, G.W. Langdale, and D.C. Coleman.

14. Hunt, D. 1977. Farm power and machinery management-laboratory manual and workbook. Iowa State University, Ames IA, p 46-47.

15. Isensee A.R. and A.M. Sadeghi. 1995. Long-term effects of tillage and rainfall on herbicide leaching to shallow ground water. Chemosphere 30:671-685.

16. Karlen, D.L., N.C. Wollenhaupt, D.C. Erbach, E.C. Berry, J.B. Swan, N.S. Eash, and J.L. Jordahl. 1994. Long-term tillage effects on soil quality. Soil & Tillage Research 32:313-327.

17. Kramberger B., A. Gselman. M. Janzekovic, M. Kaligaric and B. Bracko. 2009. Effects of cover crops on soil mineral nitrogen and on the yield and nitrogen content of maize. European Journal of Agronomy 31: 103-109.

18. Langdale, G.W., A.P. Barnett, R.A. Leonard, and W.G. Fleming. 1979. Reduction of soil erosion by the no-till system in the southern piedmont. Transactions of the American Society of Agricultural Engineers 22: 82-86, 92.

19. Laub C.A. and J.M. Luna. 1992. Winter cover crop suppression practices and natural enemies of armyworm (Lepidoptera Noctuidae) in no-till corn. Environmental Entomology 21:41-49.

20. Lyons D.J., S.D. Miller and G.A. Wicks. 1996. The future of herbicides in weed control systems of the great plains. Journal of Production Agriculture 9: 209-212.

21. Mirsky, S.B., W.S. Curran, D.A. Mortensen, M.R. Ryan, and D.L. Shumway. 2009. Control of cereal rye with a roller/crimper as influenced by cover crop phenology. Agronomy Journal 101:1589–1596.

22. Mischler, R.A., S.W. Duiker, W.S. Curran, and D. Wilson. 2010. Hairy vetch management for no-till organic corn production. Agronomy Journal 102: 355-362.

23. Salmeron M., J. Cavero, D. Quilez, and R. Isla. 2010. Winter cover crops affect monoculture maize yield and nitrogen leaching under irrigated Mediterranean conditions. Agronomy Journal 102:1700-1709.

24. Sarrantonio M. 2003. Soil responses to surface-applied residues of varying carbon-nitrogen ratios. Biology and Fertility of Soils 37: 175-183.

25. Shipitalo M.J. and W.M. Edwards. 1998. Runoff and erosion control with conservation tillage and reduced-input practices on cropped watersheds. Soil & Tillage Research 46: 1-12.

26. Sims G.K., D.D. Buhler and R.F. Turco. 1994. Residue management impact on the environment. In Managing Agricultural Residues, ed. P.W. Under, 77-98. Lewis Publishers, Boca Raton, FL.

27. Smith A., C. Reberg-Horton, G. Place, A. Meijer, C. Arellano and J. Mueller. 2011. Rolled Rye Mulch for Weed Suppression in Organic No-tillage Soybeans. Weed Science 59(2):224-231. 2011.

28. Stivers L.J. and C. Shennan. 1991. Meeting the nitrogen needs of processing tomatoes through winter cover cropping. Journal of Production Agriculture 4:330-335.

29. Teasdale J.R., C.B. Coffman, and R.W. Mangum. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agronomy Journal 99:1297-1305.

30. West T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. Soil Science Society of America Journal 66:1930-1946.

31. Williams J.D., H.T. Gollany, M.C. Siemens, S.B. Wuest and D.S. Long. 2009. Comparison of runoff, soil erosion, and winter wheat yields from no-till and inversion tillage production systems in northeastern Oregon. Journal of Soil and Water Conservation 64: 43-52.