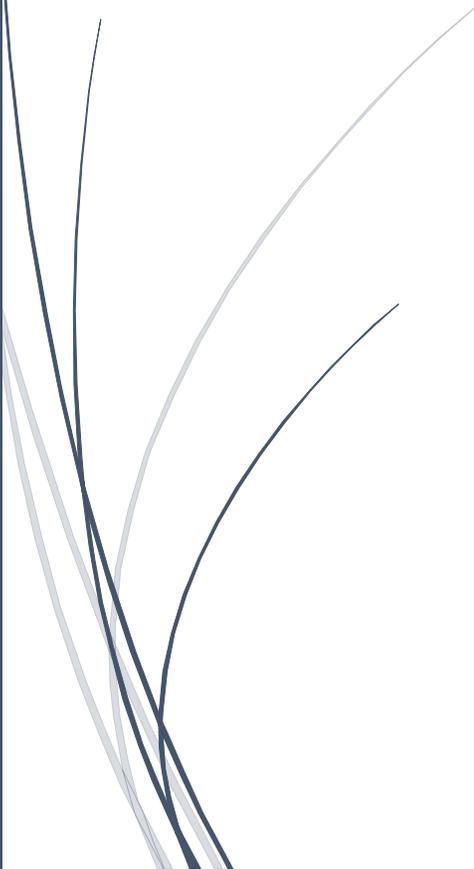




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# Soil Management Choices

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## Overview

The subject of tillage equipment selection cannot be simplified enough to be effective and accurately used in an app-based calculator because the interpretations at the producer level are varied and complex. The subject is complicated by the number of implement choices, range of adjustments and settings, available options, limited understanding of performance, conflicting marketing messages from equipment manufacturers, equipment dealers and a diverse range of opinions advanced by advocates of their favorite soil management practices. Accordingly, this document has been prepared to present unbiased information in a consistent format to help with equipment selection choices.

This document is a summary of soil management tool performance and experience gathered from across the Great Lakes Basin states and provinces. The document identifies tools and their functions addressing the top seven soil management challenges facing farmers.

Soil management challenges addressed using equipment include:

1. Soil erosion
2. Soil texture management
3. Moisture and temperature management
4. Residue management
5. Pest management
6. Treatment of shallow and deep density generally known as compaction
7. Surface levelling

In each discussion throughout the document, the co-authors have provided the reader with an effectiveness rating with respect to the challenges on a scale of 1 to 10, with 10 being the best outcome possible. We hope these will be helpful in sorting through equipment choices. Residue management has always been a challenge to find the balance of leaving enough residue on the surface to protect the soil and managing residue through sizing, uniform distribution and conditioning to allow for optimum planting conditions. Our target for residue coverage varies with soil type and texture, species of plant residue, planting equipment capabilities and topography. In general, the ideal residue coverage ranges from 30% to 40%. The residue scoring considers this range, scoring a surface finish with 35% residue cover a “10” and scoring a surface finish with no cover a “0”. The addition of a cover crop accelerates residue digestion, and this is considered.

This is an example of a typical scoring box:

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	10	3	3	4	5	5	0
No Cover Crop	4	1	2	0	0	3	0

The word “tillage” conjures up a variety of images and understandings or misunderstandings depending on your experience and the source of your training. Without an adjective the word tillage is like the word water. For example, are we discussing heavy water, hot water, cold water, polluted water, fresh water, colored water, salt water or bottled water? We could fill the page with the variants of water if we wanted to. Categorizing water is simple as there are two main

branches of water: salt water and fresh water. There are five main branches of tillage: primary tillage, secondary tillage, vertical tillage, strip till and no-till.

Just as we have altered water for our use, (e.g. converting fresh water to heavy water) we have adjusted secondary tillage tools and how we use them for other purposes namely residue management and seeding. We have created hybrids that perform across the entire soil and residue management spectrum. We have created tools that confine tillage to row crop bands and tools that perform tillage with the seeding unit. The words “tillage” and “no-till” have become limiting factors and it is helpful to step back and consider that we are addressing the management of limiting factors that affect our profit and sustainability.

## Definitions

**Vertical Tillage** – All ground-engaging parts are mounted vertically with no angles causing sideways soil movement.

**Conditioning** – The crushing and pressing of plant material into the soil surface to speed up residue digestion, evaporation of excess moisture and speed up soil warming.

**Residue Management** – The crushing or conditioning of plant residue and the uniform distribution of plant residue.

**Residue Relocation** – Residues are moved to the side, but not incorporated or conditioned.

**Soil Management Practices** – Include all forms of soil disturbance including no-till, strip till and minimum till.

**Warm Moist Soil** – Soil temperatures 40° F / 4.4° C or warmer and will not form a ball when compressed in your hand.

**Sizing** – Used in crop residue management and refers to the reduction of biomass stubble length to assist with digestion.

## Basic Soil Management Rules for Optimum Results and Sustainability

1. Perform soil management (tillage) operations when soils are warm and dry or slightly moist (40° F / 4.4° C or warmer). Never disturb cold, wet soil. If you can form a ball of soil in your hand that holds its shape, this soil is most likely too wet to disturb without causing damage to soil sustainability and productivity.
2. There is little downside to operations on cold and dry soil other than the difficulty or inability to germinate and grow a crop.
3. Time soil management operations when it is possible to immediately establish a crop or ground cover. This may require the selection of earlier maturing varieties allowing for a longer cover crop growing season.
4. When it is necessary to incorporate nutrients during less than ideal soil conditions, choose tools that offer the least amount of soil disturbance. The true vertical tillage tools are a good choice especially when the soil has some residue cover.
5. Disturb your soil as little as possible, but as much as necessary for optimum crop profitability. Weeds and other pests never develop a resistance to steel and diesel fuel. There are situations where it is more practical and profitable to engage steel than herbicides, fungicides and pesticides.
6. Never operate soil management or crop management tools closer than 10 ft. from an open drain, ditch or stream.
7. Never operate soil management tools in a manner that destroys a grass waterway protecting against erosion.
8. Never leave soil bare and exposed especially over the winter.
9. Rotate aggressive soil management tools with cover crops, minimal tillage and zero tillage crop production.

10. Operate within the range of the manufacturer's recommendations.
11. Get down on your hands and knees with garden tools, thermometer and a density probe and analyze soil conditions before taking machinery to the field.

## Thoughts on Sustainability

One acre of soil covered with green growing plants sequesters 3 tonne of CO<sub>2</sub> per year. Our current crop production practices only sequester 1.5 tonne / year. OMAFRA has recently made available a soil loss calculator at [www.omafra.gov.on.ca/english/landuse/gis/portal](http://www.omafra.gov.on.ca/english/landuse/gis/portal).

If we made the maximum use of our natural resources: soil, light, air, water and managed run off and erosion, we could reduce the amount of agricultural sediments and nutrients ending up in our lakes by 90%. The key to sustainability is photosynthesis, which **requires living plants throughout the year.**

## Soil Management Practices

Tillage is a soil management activity that we can group into five main categories and one new category, terraforming.

1. **No-Till or Zero Till** – Planting into previous crop residue with or without attachments providing residue management and soil disturbance.
2. **Strip Till** – Narrow bands of soil disturbance resulting in a seedbed.
3. **Vertical Till** – Primary purposes include residue management with very little incorporation, very low soil disturbance, influence moisture, temperature and seed zone density.
4. **Conservation Till** – Soil disturbance that results in more than 30% residue cover.
5. **Conventional Till** – Soil disturbance that results in less than 30% residue cover and requires secondary treatments for seedbed preparation.
6. **Terraforming** – a recognized method that will fall into the soil management toolbox. This management practice is used to direct surface water to grassed waterways or collection areas. Terraforming requires loose soil with little or no residue in the top two inches to facilitate the best equipment performance.

Tillage summaries are presented in three sections: no tillage, primary tillage and secondary tillage.

## No-Tillage

**No-Till or Zero-Till** is the practice of planting or seeding directly into previous crop residue using single or double-disc openers. It results in very minimal soil disturbance and leaves the residue at the surface.

The double disc planting unit is sometimes led by a coulter and or a residue manager. The single disc opener is normally used as a stand-alone unit but is sometimes preceded by a coulter cart or vertical tillage tool.

The planter or drill frame can be equipped with nutrient application equipment for the purpose of applying starter fertilizers in row or in surface bands beside the row. The equipment presses the nutrients into the soil surface.

These tools achieve a satisfactory level of texture management, temperature and moisture management and residue management. They have no influence on deep density reduction or pest management.

**Best Management Practices:**

These implements perform best in warm and moist-to-dry soil conditions across a wide range of soil types.

Field operations can be minimized with nutrient attachments that incorporate which will also protect against nutrient losses.

No-Till tools can be used to plant “green” that is planting or seeding into a growing cover crop or companion crop or plant into bio-strips. They may require some density reduction assistance in low organic matter soils that have dried out and have greater resistance than the down pressure and frame weight can overcome. Where the cover crop has created large amounts of biomass, farmers can rely on burndown at or prior to seeding. An alternative biomass management technique can rely on use of crimpers.

There may be residue cover limitations that require a vertical tillage pass to obtain best planting performance.

**Cautions:**

While it is important for all soil and residue management equipment to be well maintained, it is critically important for no-till planting equipment to have all ground engaging parts maintained to their highest level for best performance.

Planting into cold, wet soil will result in disappointment or failure.

Don’t be afraid to leave the seat and check planting performance. If you are not creating an optimum seedbed, then figure out how to do so.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	10	9	4	10	3	5	0
No Cover Crop	7	6	7	8	1	1	0

**No-Till Notes:**

Recently there have been several innovations added to the no-till toolbox. Practices like inter-planting, relay cropping, green planting and bio-strip planting show great promise in improving soil health, reducing input costs, improving yield, extending the planting season and stopping soil erosion in its tracks. These innovations are not complex and will be described and supported in a separate document.

## Primary Tillage

**Purpose:**

To satisfy a traditional habit, deep density reduction, pest management, surface levelling, residue management and soil texture management.

A primary step in seedbed preparation and occasionally one-pass seedbed preparation to establish cover crops.

### Primary Operation Parameters:

Operating Depth	4" – 12"
Soil Disturbance	25% to 100%
Residue Incorporation	25% to 100%

### Primary Implement Type and Soil Management Effect

*Described in sequence from least aggressive to most aggressive*

#### 1. Deep Rippers

This class of tool is available as In Line, Offset or V tool bar configurations. These tools can be equipped with residue management and soil levelling tools.

Effective operating depth range:	8" to 14"
Standard shank spacings:	30", 20", 15" (40" requested occasionally)
Residue mixing / incorporation:	Very little
Weed or pest management:	Very little

#### Best Management Practices:

Deep rippers are effective in the treatment of compacted soils that no longer drain or absorb moisture in a timely fashion. Excessive surface run off and ponding resulting in crop loss or yield reduction is an indication that deep ripping may provide significant benefits. In very heavy, severely compacted soils shank spacings of 30" and 40" are generally used and effective. The lighter or looser the soil texture the closer the shank spacing needs to be for best performance. In low to very low organic sands 15" shank spacing may be necessary to obtain a satisfactory result. Use these tools when soils are dry, preferably in late summer or early fall to allow time for a deep rooted and fibrous rooted cover crop blend to establish. Establishment of living root systems are required to anchor the soil surface and prevent sub surface soils from reforming into the pre-treatment structure.

In severely compacted heavy clays, post treatment tillage may be necessary due to the emergence of large blocks of soil brought to the surface. The ripping up of large blocks of compacted soil can be minimized and even avoided with a pre-ripping pass with vertical tillage tools, discs or compact discs. The disc style tools can reduce traction; however, the vertical tillage pre-rip treatment does not affect traction. The pre-ripping treatment also reduces fuel use, labor costs and wear parts costs. The post ripping tillage (soil management) should be kept to a minimum number of passes and can be used to establish the cover crop. Deep ripping tools should never be used in cold wet soils. They can be effective when the soil surface is frozen lightly enough to support the tractor, but frozen shallow enough to allow the shanks to penetrate easily. The frost ripping method should only be used in soils where a previously established cover crop has gone dormant.

Consider establishing a cover crop before ripping to reduce operating costs. Fuel, horsepower requirements and wear parts costs will be reduced. The acres per hour output will be increased and depreciation and labor costs will also be reduced.

### Cautions:

There is very little and often no benefit derived from deep ripping wet soil. There may be some truth to the argument that rainwater and snow melt water can filter down the shank channel and freeze the soil open, however in most cases that does not occur. Deep ripping followed by several tillage and levelling passes late in the fall rarely results in benefit and will most often earn a negative result.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	10	6	6	0	0	8	0
No Cover Crop	8	1	4	0	0	4	0

## 2. Strip Till

This tool creates 100% soil disturbance and residue relocation in narrow bands ranging from 8" to 12" in width. Strip till tools are frequently used to incorporate nutrients at various depths. These tools can be used very effectively in organic cropping operations.

Effective operating depth range:	2" strip freshening to 8" when equipped with shanks
Row crop spacing options:	30", 22" and 20". Most common spacing is 30".
Residue mixing / incorporation:	n/a
Weed or pest management:	Poor

### Best Management Practices:

Soil health and organic matter levels influence the recommendations.

For heavier soil types, strip till operations should be performed in the fall. On lighter and healthier soils, especially on soils susceptible to erosion, the strip till operation is best performed just ahead of planting.

A strip till toolbar can be easily combined with commodity delivery systems for incorporation of fertilizer and a cover crop. The equipment exists to perform these operations and the argument against this is the added time and cost. In the writer's opinion, the purchase of a strip till tool without the commodity tanks is as foolish as purchasing a dairy cow without an udder.

Strip till operations should always be performed on moist to dry soils.

In some soil conditions it is advantageous to operate a vertical tillage tool ahead of the stripping operation to manage moisture levels and residue to ensure high-quality seedbeds.

This additional operation has the added benefit of reducing horsepower and fuel required for the stripping operation.

The vertical tillage pass can also double as the cover crop establishment pass. Strip till tools have a lot of economic upside as they can be and should be used to incorporate crop nutrients and at the same time, seed cover crops in bio-strips.

### Cautions:

Strip till tools are intended to be used as one-pass seedbed preparation tools. In medium to heavy soils they are most often used following fall harvest.

When harvest is late and soils are cold and wet, it is very difficult to create a zone that will over-winter into a seedbed.

Strip fresheners may be required to improve or create optimum seedbed conditions. In loamy soils or even clay soils high in organic matter, waiting until spring may be the better management practice.

Over time and with the use of cover crops these limitations can be reduced.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	10	10	7	10	0
No Cover Crop	6	7	7	7	4	8	0

### 3. Aerators

There are two basic aerator models, single rank and dual rank. These tools providing density reduction from 40% to 80% soil displacement. Some models offer soil finishing and residue management attachments as standard and some brands offer the finishing attachments as options.

These tools offer poor weed management ability, however when equipped with finishing systems they are very good at uniform germination of weed seeds which increases the efficacy of herbicide application.

This class of tool is often used in pre and post application of liquid manure or mounted directly to application hoses or tankers. The aerator pokes holes in the surface of the hay field and pasture to enable liquid infiltration with minimal damage to the sod.

Effective operating depth range:	8" of vertical soil penetration
Standard shank spacings:	7 1/2" or 5"
Residue mixing / incorporation:	25% to 50% of residues are incorporated with some conditioning
Weed or pest management:	Poor – see comment above on equipping with a finishing system

#### Best Management Practices:

When equipped with finishing harrow systems, this tool can be used for one pass soil density management in highly erodible soils.

In extremely heavy dense clay soils these tools struggle to penetrate to their full operating depth. A vertical tillage pass prior to the aerator pass helps to achieve full penetration and results in a finer finish that can often be no tilled in the spring.

This class of tool is best used in the late summer and fall. They can be operated in higher soil moisture conditions than other primary tillage tools with the tractor weight and finishing roller harrow being the most limiting factors.

When equipped with finishing systems, they are excellent tools for establishing a cover crop and there are cover crop and fertilizing attachments available for this purpose.

#### Cautions:

These tools can operate in wet to very wet conditions, which can result in severe soil damage from the weight of the tool and the weight of the tractor. Because there is a lot of surface residue to carry the rollers and the rollers are operating at very high rpm, they are not as subject to plugging in wet soil. This means that roller plugging, as an indicator of soils being too wet to operate in, is **not** reliable.

Some of these tool designs offer an angle mounted spike rolling harrow which does a great job of finishing; however, they can result in windrowing of soil and residue if not properly adjusted for conditions.

You can expect heavy seedling weed germination in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	10	8	10	9	3	10	4
No Cover Crop	8	6	7	7	1	7	4

#### 4. Vertical Tillage with Hydraulic Shanks

These tools are basically innovative high clearance disc chisel plows with finishing systems that can be hydraulically converted to a secondary soil and residue management tool from the tractor cab. The shanks on these implements are capable of injecting liquid or dry nutrients. They provide excellent obstacle protection for operations up to 9 mph. These implements are almost always equipped with soil finishing and residue conditioning equipment. They offer very good weed management performance. Often being used as one-pass stale seedbed preparation tools. Adjustments enable these tools to be capable of performing primary tillage, secondary tillage and residue management.

Effective operating depth range:	4" to 8"
Standard shank spacings:	30", 20" or 15" options
Residue mixing / incorporation:	15% to 50% depending on post-harvest residue levels and type of residue
Soil disturbance:	25% to 50% soil disturbance depending on adjustment
Weed or pest management:	Very good

#### Best Management Practices:

These tools can be effectively used to manage soil density while managing heavy residue. They can operate in higher soil moisture conditions than a standard chisel plow. The limiting factor being tractor weight, traction and plugging of the rolling harrow. This class of tool can operate across the full range of soil types. When soils are extremely dry, penetration to the desired depth becomes a limiting factor.

While somewhat variable, depending on soil moisture and soil type, the spring-loaded coulter mount sends vibrations into the soil far below the operating depth. These vibrations create fissures for air and moisture migration.

Warm moist soils result in the best overall performance.

These are exceptional tools for establishing and managing cover crops.

They are often used to improve deep ripping and strip till performance, improve seedbed conditions after planting, break crusted soil more effectively than a rotary hoe to improve seedling emergence and to reduce the volume of cover crop residue in the fall without killing the crop.

#### Cautions:

These tools can operate in wet to very wet and cold conditions, which can result in severe soil damage from the weight of the tool and the weight of the tractor.

Because there is a lot of surface residue to carry the rollers and the rollers are operating at very high rpm they are not as subject to plugging in wet soil. This means that roller plugging, as an indicator of soils being too wet to operate in, is **not** reliable.

You can expect heavy seedling weed germination in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	10	9	10	10	6	10	9
No Cover Crop	7	8	8	8	4	8	9

## 5. Hybrid Vertical Tillage

Hybrid vertical tillage tools are constructed using shallow compound angle discs that are individually mounted at 12 - 13 degrees on the front half of the machine while the rear half is equipped with individually mounted straight coulters. This group of tools has excellent obstacle protection required for high-speed operations up to 9 mph. These implements are always equipped with soil finishing and residue conditioning equipment. They are often used as one-pass stale seedbed preparation tools. Adjustments enable these tools to be capable of performing primary tillage, secondary tillage and residue management.

Blade spacing options:	5" and 7.5"
Disc blade diameter range:	20" to 22"
Weight per blade:	250 lbs. to 350 lbs.
<b>Nutrient Placement Shank Option:</b>	
Shank spacing:	30"
Operating depth range:	8"
Residue mixing / incorporation:	35% to 80% depending on post-harvest residue levels and type
Soil disturbance:	75% to 100% in depths ranging from 3" to 4"
Weed or pest management:	Very good

#### Best Management Practices:

These tools are a combination of compact discs and vertical tillage elements and finishing systems. This design allows them to be utilized as primary soil management and secondary soil management. They can be effectively used to manage shallow soil density and residue. They have roughly the same soil moisture limits as a standard chisel plow. The limiting factors being tractor weight, traction and plugging.

These tools operate across the full range of soil types however in compacted low organic matter soils, penetration becomes a limiting factor.

Warm moist soils result in the best performance. These tools are less likely to create secondary density layers than gang mounted discs or C-shank field cultivators as the individually and compound angle mounted discs send vibrations into the soil below operating depth. The compound angle discs lift the soil rather than scrape the soil sideways.

These tools are exceptional tools for establishing cover crops and are reasonably effective in managing cover crop residue.

**Cautions:**

These tools can operate in wet to very wet conditions, which can result in severe soil damage from the weight of the tool and the weight of the tractor. Because there is a lot of surface residue to carry the rollers and the rollers are operating at very high rpm they are not as subject to plugging in wet soil. This means that roller plugging as an indicator of soils being too wet to operate in – is not reliable.

You can expect heavy seedling weed germination in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	9	10	8	8	8	9
No Cover Crop	5	7	9	7	7	6	9

**6. Tandem Disc Harrows**

There are two frame options in this class, the adjustable gang angle and the fixed gang angle. While both frame choices feature gang axle mounted discs, the adjustable model is constructed to operate on angles from 0 degrees to 10 degrees. Fixed gang angle models range from 18 degree to 21 degree angles and some have less angle on the front gang when compared to the rear gang angle.

Some models feature serrated blade options and on models that feature adjustable angles, the gang angle can be set to operate effectively as vertical tillage tools, as well as a more traditional disc harrow. These adjustable gang angle tools can be operated at speeds of up to 9 mph in healthy soils.

Ground speed for this implement is limited by soil type and moisture conditions, but it is rarely used at speeds over 5.5 to 6 mph. The high-speed versions are equipped with residue conditioning and soil finishing attachments. These attachments are optional on the fixed gang tandem models.

	<b>Adjustable Gang Angle Model</b>	<b>Fixed Gang Angle Model</b>
Effective operating depth range:	2" to 4"	3" to 5"
Soil disturbance:	20% to 50% combined with some surface levelling and good residue management	100%

Weed or pest management:	Limited - when set at shallow angles	Good
Residue mixing and incorporation	75% to 100% - soybean residue 40% to 60% - heavy corn residue *If adjusted to the high angle setting.	75 to 100% - soybean residue 40 to 60% - heavy corn residue
Weight per blade:	140 lbs. to 200 lbs.	

#### Best Management Practices:

These tools are improved versions of traditional disc harrows and are now capable of being combined with finishing systems. They can be effectively used to manage shallow soil density and residue. They have and roughly the same soil moisture limits as a standard chisel plow. The limiting factors being tractor weight, traction and plugging.

Tandem disc harrows are effective across a wide range of soil types but are best used in the fall as they quickly release soil moisture, therefore caution must be used in the spring prior to planting.

When heavy, low organic matter soils are extremely dry; soil penetration and the creation of large lumps of soil become limiting factors. Warm, moist, healthy soils result in the best performance.

These tools can be adjusted for establishing and managing cover crops when equipped with their soil finishing attachments. These tools should be used rotationally with other soil management tools as they can set up secondary density layers.

#### Cautions:

These tools should never be used in cold and or wet soils or when you can form a ball of soil in your hand. They are best used in soils with few stones as they are subject to mechanical damage. As well, they bring stones to the soil surface, which can become planting and harvest hazards.

When operated at high speeds and shallow depths, they can mask irregularities in the seedbed, which places higher demands on planting equipment and puts more onus on the operator to recognize and adapt to the seedbed quality. Disc harrows can ridge and make your soil uneven if not properly adjusted or if operated at high speeds.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	7	8	9	7	7
No Cover Crop	0	7	5	6	9	5	7

## 7. Heavy Duty Compact Discs

These tools consist of two ranks of individually mounted, compound angle mounted disc blades providing very good obstacle protection at high speeds. Discs are mounted on compound angles ranging from 10 degrees to 13 degrees. These discs are capable of very high speeds. They are equipped standard with residue conditioning and soil finishing attachments.

Blade spacing options:	5"
Disc blade diameter range:	22" to 28"
Weight per blade:	330 lbs. to 500 lbs.
Operating depth range:	3" to 6" or 7"

Residue mixing / incorporation:	75% to 100%
Soil disturbance:	100%
Weed or pest management:	Very good

#### Best Management Practices:

These tools are improved versions of traditional discs on steroids, combined with finishing systems. They can be effectively used to manage soil density up to 7" deep and incorporate heavy residue. This class of tool can be utilized for deep primary and secondary soil management.

They have a lower tolerance for operating in high soil moisture than tandem discs. The limiting factors being tractor weight, traction and plugging of the harrow finishing system. The heavy-duty compact disc design operates across a wide range of soil types in spring and fall, however when compacted low organic matter soils are dry, penetration into the soil becomes a limiting factor. They should be used rotationally with other tools as they can set up secondary density layers. These tools are less likely to create secondary density layers than gang mounted discs or C-shank field cultivators as the individually and compound angle mounted discs send vibrations into the soil below operating depth. The compound angles lift the soil rather than scrape the soil sideways.

When used on heavy residue (e.g. wheat stubble with no straw removed or high yielding corn) they can create a residue layer at and just below seeding depth, which if not disturbed prior to planting, will result in poor germination and uneven emergence. Warm moist soils result in the best performance.

These tools can be adjusted for establishing cover crops when equipped with the soil finishing attachments.

#### Cautions:

This class of tool uses the rear mounted finishing bar style roller or solid consolidator to determine the operating depth. There are two main types of finishing systems. One is a solid rubber or steel wheel. The other option is a round or flat bar roller.

The solid rubber or roller systems are less likely to roll up with wet soil; however, they press oxygen out of the soil, which may slow down residue digestion especially when operated at a shallow depth and / or in residue with high carbon to nitrogen ratios (e.g. wheat and corn).

The round and flat bar rollers are more likely to plug in wet soil. When they are plugging, this is a good indication that you are damaging your soil. The bar roller options are less likely to reduce the amount of oxygen in the soil and therefore can be operated at shallower depths in high residue with less risk of slowing residue digestion.

If you select the round or flat bar depth control system you can expect heavy seedling weed germination in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control. When used in high moisture conditions, the steel and rubber roller systems will compress the soil and discourage germination as well as slow residue digestion.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	7	8	7	7	8	7	8
No Cover Crop	0	7	6	6	7	6	8

## 8. Chisel Plows

Chisel plows are high clearance, deep penetrating tools designed to mix enough crop residue to allow field cultivators to perform secondary tillage. They can be equipped with residue conditioning and soil finishing tools.

Effective operating depth range:	6" to 12"
Standard shank spacings:	15" 20" or 30"
Residue mixing / incorporation:	35% to 75%.
Soil disturbance:	50% - 70%
Weed or pest management:	Fair

### Best Management Practices:

Chisel plows should be used in warm moist soils in late summer or early fall. Match the chisel point options to the soil and residue conditions.

Chisel plows can be used across a wide range of soil types but are best suited to high organic soils and loam soils. They can leave the soil surface extremely rough requiring additional secondary tillage passes.

The tandem disc harrow secondary tool is best suited as partner for levelling soil surfaces and refining soil texture in preparation for a field cultivator pass to create a high-quality seedbed. Another alternative is one to two passes using a compact disc.

Use chisel plows in rotation with other soil management practices.

Avoid operations in cold wet conditions. Equip with soil finishing systems to reduce the number of secondary tillage passes to prepare a quality seedbed.

If possible, make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

### Cautions:

It is generally believed that chisel plows disturb 100% of the soil to the full operating depth.

This can happen in light and loamy soils with good organic matter and optimum moisture conditions. Most often, especially on 30" shank spacing these tools only disturb 50% of the soil. This creates high- and low-density zones that can result in widely variable soil moisture, temperature and density environments.

The variability in soil environment requires a higher level of management and high-quality secondary management tools to ensure high-quality seedbeds.

In heavy corn residue chisel plows are not able to incorporate enough residue to enable the use of field cultivators in the first pass. In high residue and heavier soil, a disc harrow, compact disc or vertical tillage tool is needed for the first spring pass. When possible, make this pass in the fall to set the field up for one pass spring seedbed preparation.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	6	7	6	6	7	4
No Cover Crop	4	4	6	5	5	5	4

## 9. Moldboard Plows

This implement inverts 100% of the soil and results in total soil displacement. Soil displacement is different than soil disturbance. The displaced soil is rolled or inverted in narrow bands rather than being shattered and stirred as they are with chisel shanks and disc blades. Plant root systems are inverted but remain attached to the soil and are often intact in the band.

Crop residue is not mixed or conditioned unlike all other primary tillage tools, which mix residues into the fractured zones. 80% to 100% of the residues are buried. Density reduction is less than disc chisel disc or disc ripper disc operations.

This implement is frequently and wrongly accused of creating a plow pan. A plow layer or pan is created when a moldboard plow is operated at the same depth repeatedly, towed by a tractor with over inflated tires or bias tires, improperly adjusted, and operated with worn-out parts or combinations of the above. A properly set moldboard plow, when used correctly, will never create a plow pan.

Moldboard plows are tools that are often overused and misused which has resulted in all sorts of undeserved criticism and misunderstanding. Residue decomposition is quite slow and the conversion of residue to carbon dioxide is quite slow when compared to most of the other tools in the primary tillage tool classification.

Effective operating depth range:	6" to 10"
Residue mixing / incorporation:	None
Soil displacement:	100%
Weed or pest management:	Excellent

### Best Management Practices:

Moldboard plows should be used in warm moist soils in late summer or early fall. If using a moldboard plow in the spring on highly erodible sandy loam and silt loam soils, secondary tillage and a seeding or planting tool should immediately follow this operation.

Moldboard plows can be used across a wider range of soil types and soil moisture conditions than most other primary tillage tools, but like all other primary tools, the soil should ideally be warm and moist, or dry. It is very important with this tool to change the ground engaging wear parts before they are completely worn out.

A poorly set and poorly operated plow can leave the soil surface extremely rough requiring additional secondary tillage passes. When used to break up tightly compressed low organic soils in dry conditions it is advantageous to deep rip or vertical till these soils first. Moldboard plows should be used strategically in rotation with other soil management practices.

This implement should not be used as a habit, but as a tool to manage specific problems such as resistant pests or in situations where complete incorporation of crop residues is required because the following crop has a zero or very low tolerance for the previous crop residue left at harvest.

When possible make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

**Cautions:**

An unbreakable rule is – never set a plow to operate below topsoil depth. A general rule of thumb is to set the width of cut no more than two times the plow working depth. Avoid plowing in cold, wet conditions. Moldboard plows can be used on frozen ground up to 1” of frost but should never be used if the soil below the frost layer is saturated. Avoid using moldboard plows on consecutive years if possible. Always vary the working depth from one use to the next. Low pressure properly inflated radial tractor tires should always be used especially when operating a semi mount plow or mounted plow with the tractor wheel operating in the furrow. The idea that you can mix subsoil with topsoil and increase your topsoil depth is incorrect and will result in reduced soil quality and profitability. It is important to maintain wear parts, adjust for minimum draft and employ well-trained operators. This is not a tool that can be operated by untrained or careless drivers.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	10	7	10	10	6
No Cover Crop	6	7	8	*0	8	8	6

\* 0% -3% surface residue cover

**10.Disc Chisels**

These tools are chisel plows equipped with a leading rank of curved or straight discs followed by chisel shanks on 15” or 30” spacing. With 100% disturbance you can expect reasonably good weed management performance. The wide spaced 30” shank options result in less soil disturbance and a reduction in weed management performance. Residue conditioning and soil finishing tools are optional.

Effective operating depth range:	6” to 12”
Standard shank spacings:	15” or 30”
Residue mixing / incorporation:	45% - 80%
Soil disturbance:	50% to 100% when equipped with concave front disc blades mounted on angles

**Best Management Practices:**

Disc chisel tools should be used in warm moist soils in late summer or early fall.

Match the chisel point options to the soil and residue conditions. Disc chisel plows can be used across a wide range of soil types but are best suited to high organic soils and loam soils.

In compacted dry soils their use can leave the soil surface extremely rough requiring additional secondary tillage passes.

The tandem disc harrows, compact discs, hybrid vertical tillage, C shank field cultivators and soil finishers are the range of secondary soil management tools used to prepare high-quality seedbeds following disc chisel use.

Use disc chisels in rotation with other soil management practices. Avoid operations in cold wet conditions. Equip with soil finishing systems to reduce the number of secondary tillage passes to

prepare a quality seedbed. If possible, make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

**Cautions:**

Like the chisel plow, it is generally believed that disc chisels disturb 100% of the soil to the full operating depth. This can happen in light and loamy soils with good organic matter and optimum moisture conditions. Most often, especially on 30” shank spacing, these tools only disturb 50% of the soil. This limitation creates high- and low-density zones that can result in widely variable soil moisture, temperature and density environments.

This variability in environment requires a higher level of management and high-quality secondary management tools to ensure high-quality seedbeds.

With disc chisels, you can expect more uniform soil temperature and moisture conditions at planting depth in the spring than you can expect from a chisel plow.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	7	7	7	7	7	6
No Cover Crop	4	6	6	6	6	5	5

**11.Disc Chisel Disc and Tandem Disc Chisel Disc**

This class of tool is a more aggressive and heavier version of the disc chisel. It consists of curved or straight discs sometimes in tandem followed by chisel shanks on 15” or 30” spacing which are followed by curved discs. Residue conditioning and soil finishing tools are optional but normally these implements are sold as complete systems.

Effective operating depth range:	6” to 12”
Standard shank spacings:	15” or 30”
Residue mixing / incorporation:	70% to 100%
Soil disturbance:	100%
Weed or pest management:	Good to very good

**Best Management Practices:**

Disc chisel disc tools should be used in warm moist soils in late summer or early fall. Match the chisel point options to the soil and residue conditions.

This design can be used across a wide range of soil types and performs better than disc chisels in heavy soil and in compacted low organic matter soils.

Tandem disc harrows, compact discs, hybrid vertical tillage, C shank field cultivators and soil finishers are the range of secondary soil management tools used to prepare high-quality seedbeds following disc chisel disc use.

Use this tool in rotation with other soil management practices. Avoid operations in cold wet conditions.

Equip with soil finishing systems to reduce the number of secondary tillage passes to prepare a quality seedbed. If possible, make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

### Cautions:

This implement can leave the soil surface very level with very light residue cover. The soil subsurface is also fine textured, setting up ideal conditions for serious wind and water erosion.

Disc chisel disc tools are normally used in late fall in high moisture conditions to incorporate corn residue so it is highly unlikely that cover crops can be established to adequately protect the soil from wind and water erosion.

When operating the models equipped with tandem discs, pay close attention to adjustments including operating speed as this tool can create extreme ridging which will require several secondary passes and perhaps more than one year to re-level the field.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	8	8	8	8	8
No Cover Crop	2	7	7	7	7	6	8

### 12. Heavy Discs and Heavy High-Speed Discs

This class of tool has three frame designs and two blade mount designs. The original designs use a solid axle mounted on tandem or offset frames. Newer innovative designs utilize individually mounted compound angle disc blades on 5" to 9" spacing.

Residue conditioning and soil finishing systems are optional. 100% of the high-speed versions are sold with residue conditioning and soil finishing systems.

The heavy-duty, high-speed models with individually mounted blades are occasionally capable of one pass stale seedbed preparation in healthy, high organic soils and loam soils. These are very aggressive soil management tools.

Weight per blade range:	350 lbs. to 580 lbs.
Operating depth range:	4" to 8"
Residue mixing / incorporation:	80% to 100% residue mixing and incorporation
Soil disturbance:	100% soil disturbance to the full operating depth
Weed or pest management:	Good to very good

### Best Management Practices:

As with all other tools using disc elements, these tools should never be used in cold, wet soil conditions.

These designs are effective across the full range of soil types. In extremely dry soil conditions in low organic matter soils, the surface finish can be quite rough requiring several passes with finishing tools to properly prepare the seedbed.

Use this class of tool in rotation with other soil management practices. Avoid operations in cold wet conditions. Equip with soil finishing systems to reduce the number of secondary tillage passes to prepare a quality seedbed.

When possible, and if the soil surface is uneven and lumpy after operation, make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

### Cautions:

The gang style heavy disc can layer residue when operated at speeds less than 4.5 mph. These layers can be a detriment to uniform germination and emergence.

The gang style is prone to bringing up stones on soils where stones are an issue.

These implements can leave the soil surface very level with very light residue cover. Pay attention to adjustments including operating speed as this tool can create extreme ridging which will require several secondary passes and perhaps more than one year to re-level the field.

The individually mounted blade designs have excellent obstacle protection and if properly set, will not cause ridging at high speeds in most soil conditions.

Residues are uniformly mixed and there is no risk of affecting germination and emergence in the following planting season.

The high-speed operation with the harrow finishing system may result in fine textured surface and subsurface soils, which are ideal conditions for wind and water erosion.

This class of tool is often used in late fall in high moisture conditions to incorporate corn residue so it is highly unlikely that cover crops can be established to adequately protect the soil from wind and water erosion.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	9	7	8	7	8
No Cover Crop	2	7	7	6	7	6	8

### 13.Disc Ripper Discs

This primary tillage tool design is the most aggressive of all the soil management tools available when you take into consideration their operating depth range, the aggressiveness and the number of disking elements. The disc elements consist of curved disc blades (sometimes in tandem) followed by ripper shanks on 30" or 38" spacing which are often split by chisel shanks on 15" or 19" spacing. The shanks are followed by levelling discs and finishing harrows.

Residue conditioning and soil finishing tools are optional but normally these implements are sold as complete systems.

As previously mentioned, these are the most aggressive soil management tools available to crop producers and like all primary tillage tools they should never be used as a habit, but strategically incorporated into a soil management system that is rotational by design.

Operating depth range:	8" to 14"
Residue mixing / incorporation:	80% to 100%
Soil disturbance:	100%
Weed or pest management:	Good to very good

### Best Management Practices:

Disc ripper disc designs should be used in warm moist soils in late summer or early fall. Match the chisel and ripper point options to the soil and residue conditions.

Disc ripper discs are used across the widest range of soil types and perform better than disc chisel discs in heavy soil and compacted low organic matter soils.

Tandem disc harrows, compact discs, hybrid vertical tillage, C shank field cultivators, S-tine cultivators and soil finishers are the range of secondary soil management tools used to prepare high-quality seedbeds following disc ripper disc use.

They are exceptionally effective at managing high residue crops in compacted soils.

Disc ripper discs are meant to be used in rotation with other soil management practices.

Avoid operations in cold wet conditions. Equip with soil finishing systems to reduce the number of secondary tillage passes to prepare a quality seedbed. If possible, make one secondary finishing pass in the fall while incorporating nutrients and cover crop seed.

**Cautions:**

This implement can leave the soil surface very level with no or minimal residue cover. The soil subsurface is also fine textured setting up ideal conditions for serious wind and water erosion.

This tool is normally used in late fall in high moisture conditions to incorporate corn residue so it is highly unlikely that cover crops can be established to adequately protect the soil from wind and water erosion.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	8	8	9	7	8	10	10
No Cover Crop	0	7	8	5	7	8	10

**14. Rotary Tillers**

This tool is a combined primary tillage and seedbed preparation tool. This tool is not ideal as a one-pass tool because the prepared surface is most often too loose for planting equipment to operate effectively even when equipped with soil firming attachments.

They generally require more fuel and power per acre and are not capable of high acre per hour output compared to other tools in the primary tillage category.

Operating depth range:	3" to 6"
Residue mixing / incorporation:	100%
Soil disturbance:	100%
Weed or pest management:	Excellent

**Best Management Practices:**

These tools are best suited to vegetable operations where there are very few to no stones. They should only be used when soils are slightly moist to dry and perform best in sandy or lighter silt and clay loam soils.

Rotary tools completely reorganize soil structure to the full operating depth, pulverize and incorporate residues leaving the soil texture very fine with little residue protection and therefore highly susceptible to wind and water erosion.

A crop should be immediately planted following a rotary tiller operation.

Cautions:

Never use these tools in wet soil. These tools are not meant to be used in stony soils.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Cover Crops	7	10	9	7	10	10	8
No Cover Crop	0	10	7	*0	10	8	8

\*0% residue cover

## Secondary Tillage

### Purpose:

Secondary tillage provides a seedbed finish following spring or fall primary tillage. It provides shallow density reduction, particle size reduction, soil warming, moisture management, pest management, surface levelling, and residue management. Secondary soil management can be summed up as “seedbed preparation.” All the secondary tillage/ residue management implements described below are capable of being equipped and set for cover crop seeding and nutrient incorporation. Some designs are multi-functional, capable of performing primary and secondary functions.

### Secondary Soil Management Operation Parameters:

Operating Depth	1” – 3”
Soil Disturbance	15% to 100%
Residue Incorporation	25% to 100%

## Secondary Implement Type and Soil Management Effect

*Described in sequence starting with the least aggressive to most aggressive.*

### S1. Heavy Harrows

Heavy harrows have three to seven ranks of tines for soil surface levelling, soil firming and residue redistribution. These tools are effective across the full range of soil types and can be used on soils that are too wet for the use of any other tool. Their limiting factor is the risk of compaction from the tractor being used.

#### Best Management Practices:

Use heavy harrows across a wide range of soil types and moisture conditions for residue management. They are effective levelling tools in warm moist soil conditions on soil that has had previous primary or secondary disturbance creating loose soil. These designs can be used for surface levelling following primary tillage where additional levelling and residue management is required. Use when soils are moist or dry. They have levelling abilities in lighter loamy soils or following a primary tillage operation where the crop residue is sized into smaller pieces and incorporated.

#### Cautions:

Use in rotation with other residue management practices as these tools can create extreme soil surface compaction especially when used late in the fall on cold, wet soil.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	10	10	8	9	6	5	7
No Crop	9	8	7	8	6	1	7

### S2. Vertical Tillage

These tools have two to four ranks of coulters mounted straight on spacings of 5” to 7.5”. Some models incorporate chopping reels. These tools were designed to condition and maintain residue on the soil surface so there is very little residue incorporation. These tools are almost always equipped with soil finishing and residue management options.

Residue mixing / incorporation:	0% to 15%
Soil disturbance:	<25% in high moisture conditions and heavy soils

#### Best Management Practices:

For corn and other cereals, the recommended seedbed prep operating depths in most soils is shallower than planting depth; for oilseeds it is slightly greater than planting depth. This class of tool can be effectively used for post-harvest residue management and shallow primary tillage.

Vertical tillage tools can be used in a very wide range of soil types and soil moisture conditions. They are used effectively for shallow nutrient mixing with some soil and residue. They are very good for planting cover crops, most cereals and small oilseeds especially in high moisture conditions.

The true vertical tools are often used to improve deep ripping and strip till performance, improve seedbed conditions after planting, break crusted soil more effectively than a rotary hoe to improve seedling emergence and to reduce the volume of cover crop residue in the fall without killing the crop.

#### Cautions:

These tools can operate in wet to very wet conditions, which can result in severe soil damage from the weight of the tool and the weight of the tractor. Because there is a layer of surface residue to carry the roller and the rollers are operating at very high rpm, they are not as subject to plugging in wet soil. This means that roller plugging, as an indicator of soils being too wet to operate in, is **not** reliable.

Some of these tools offer angle mounted spike-rolling harrows, which do a great job of finishing however; they can result in windrowing of soil and residue if not properly adjusted for the conditions.

You can expect heavy seedling weed germination in the early fall and in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	9	8	10	10	6	8	6
No Crop	7	7	8	8	3	6	6

### S3. Hybrid Vertical Tillage

These hybrid models are constructed using the front half of the machine equipped with individually mounted, shallow compound angle discs at 13 degrees and the rear half equipped with individually mounted straight coulters. This group of tools has excellent obstacle protection required for high-speed operations up to 9 mph.

These implements are always equipped with soil finishing and residue conditioning equipment. They are often used as one-pass stale seedbed preparation tools.

Adjustments enable these tools to be capable of performing primary tillage, secondary tillage and residue management.

Blade spacing options:	5" and 7.5"
Disc blade diameter range:	20" to 22"
Weight per blade:	250 lbs. to 350 lbs.
<b>Nutrient Placement Shank Option:</b>	
Shank spacing:	30"
Operating depth range:	8"
Residue mixing / incorporation:	35% to 80% depending on the post-harvest residue levels and type
Soil disturbance:	75% to 100% in depths ranging from 3" to 4"
Weed or pest management:	Very good

#### Best Management Practices:

These tools are compact discs combined with vertical elements and finishing systems. This design allows them to be utilized as primary soil management and secondary soil management.

They can be effectively used to manage shallow soil density and residue. They have roughly the same soil moisture limits as a standard chisel plow. The limiting factors being tractor weight, traction and plugging.

These hybrid tools operate across the full range of soil types however when compacted low organic matter soils are dry, soil penetration becomes a limiting factor. Warm moist soils result in the best performance.

These tools are less likely to create secondary density layers than gang mounted discs or C-shank field cultivators as the individually and compound angle mounted discs send vibrations into the soil below operating depth. The compound angles lift the soil rather than scrape the soil sideways. They are exceptional tools for establishing cover crops and are reasonably effective in managing cover crop residues.

#### Cautions:

These tools can operate in wet to very wet conditions, which can result in severe soil damage from the weight of the tool and the weight of the tractor.

Because there is a lot of surface residue to carry the rollers and the rollers are operating at very high rpm, they are not as subject to plugging in wet soil. This means that roller plugging, as an indicator of soils being too wet to operate in, is **not** reliable.

You can expect heavy seedling weed germination in the spring as they create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	9	10	8	8	8	9
No Crop	5	7	9	7	7	6	9

#### S4. S-Tine Field Cultivators

The frame design on an S-tine consists of 5 to 7 ranks (toolbars) spaced at 25" to 30" and equipped with spring steel shanks bent in an S shape. The shanks or tines are usually spaced at 4"

to 6" with some optional spacings available. Residues are stirred and lightly mixed. These tools rely mainly on primary tillage to bury 80% of previous crop residue.

Shank tip pressures vary from 75 psi at 1" deflection to 125 psi at 1" deflection. The tines are springs, which provide excellent obstacle protection. The S-tine vibrates in an elliptical motion, which gives it superior seedbed capabilities.

These tools almost always include harrow finishing systems or rear tow hitches for the use of transport harrows for extra finish or optional use when soil conditions are not suitable. S-tine cultivators are lighter than C shank cultivators, vertical tillage tools, compact discs and disc harrows. They require substantially less horsepower per acre than other secondary soil management tools.

Operating depth range:	1" to 3"
Soil disturbance:	100%
Weed or pest management:	Very good weed management in heavy or hard soil

#### Best Management Practices:

These tools perform best in heavy to medium soil types and are very durable at high speeds in rocky soils.

S-tines are very good at shallow incorporation of herbicides, nutrients and cover crop seed. They can operate in high organic loams and lighter soils in higher soil moisture conditions however weed control is only fair in these conditions.

#### Cautions:

In two pass scenarios, these tools can produce very fine soil particles which will result in surface crusting on low organic soils and clay soils. Soils will be susceptible to wind and water erosion. These tools should be used sparingly and with care on rolling highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	9	9	7	10	8	10
No Crop	1	8	8	6	8	5	10

### S5. S-Tine Soil Finishers

These tools are S-tine field cultivators with a front mounted disc gang using straight or curved blades. Residues are stirred and lightly mixed. These tools rely mainly on primary tillage to bury 60% of previous crop residue. The two-piece high clearance models are capable of being used as primary tillage in oilseed residues or where wheat is cut short and removed for straw.

Equipment consists of angled or straight discs or coulters usually 20" in diameter spaced 7.5" or 9" apart. The disc gang is followed by 4 to 5 ranks (toolbars) spaced at 25" to 30" equipped with spring steel shanks bent in an S shape. The shanks or tines are usually spaced at 4" to 6" with some optional spacings available.

Tip pressures vary from 75 psi at 1" deflection to 125 psi at 1" deflection. The tines are springs, which provides excellent obstacle protection. The S-tine vibrates in an elliptical motion, which gives it superior seedbed capabilities.

These tools almost always include harrow finishing systems or rear tow hitches for the use of transport harrows for extra finish or optional use when soil conditions are not suitable.

Operating depth range:	1" to 3"
Soil disturbance:	100%
Weed or pest management:	Very good weed management in heavy to medium soil types

#### Best Management Practices:

These tools perform best in heavy to medium soil types and are very durable at high speeds in rocky soils.

S-tines are very good at shallow incorporation of herbicides, nutrients and cover crop seed. They can operate in high organic loams and lighter soils in higher soil moisture conditions

#### Cautions:

In two pass scenarios, these tools can produce very fine soil particles which will result in surface crusting on low organic soils and clay soils. Soils will be susceptible to wind and water erosion. These tools should be used sparingly and with care on rolling highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	9	9	6	10	8	10
No Crop	0	8	8	5	8	5	10

### S6. High Speed Shallow Angle Tandem Disc Harrows

These designs consist of concave discs mounted at 5 to 10-degree angles on a gang axle. (Often incorrectly described as vertical tillage). Gangs are mounted in tandem and some models offer gang angle adjustability from 0 to 5 degrees. Smooth or fluted discs are options.

For corn and other cereals, seedbed prep operating depths are usually shallower than planting depth; for oilseeds it is slightly greater than planting depth. Residue incorporation varies from 25% to 100%.

These tools are almost always equipped with soil finishing and residue management options. They are also used for post-harvest residue management, shallow primary tillage, and nutrient and cover crop seed incorporation.

Blade spacing options:	3.5" to 4"
Disc blade diameter range:	20" to 24"
Weight per blade:	140 lbs. to 220 lbs.

#### Best Management Practices:

These tools are improved versions of traditional finishing disc harrows and are now capable of being combined with finishing systems.

They can be effectively used to manage shallow soil density and residue. They have roughly the same soil moisture limits as a compact disc. The limiting factors being tractor weight, traction and plugging. Tandem disc harrows are effective across a wide range of soil types they quickly release soil moisture therefore caution must be used in the spring prior to planting.

When heavy, low organic matter soils are extremely dry, soil penetration and the creation of large lumps of soil become limiting factors. Warm, moist, healthy soils result in the best performance.

These tools can be adjusted for establishing and managing cover crops when equipped with their soil finishing attachments.

These tools need to be used rotationally with other soil management tools as they can set up secondary density layers and they should never be used in wet soils.

**Cautions:**

These tools should never be used when you can form a ball of soil in your hand. They are best used in soils with few stones as they are subject to mechanical damage and they will also be bringing stones to the soil surface, which can become planting and harvest hazards.

When operated at high speeds and shallow depths they can mask irregularities in the seedbed which places higher demands on planting equipment and puts more onus on the operator to recognize and adapt to the seedbed quality.

Disc harrows can ridge and make your soil uneven if not properly adjusted or if operated at high speeds.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	10	10	6	10	7	9
No Crop	1	9	8	5	9	4	9

**S7. Finishing Compact Discs**

These tools consist of two ranks or rows of individually mounted disc blades, mounted on compound angles ranging from 10 to 13 degrees. These discs are capable of very high speeds and provide very good obstacle protection when operated at high speeds. They are equipped standard with residue conditioning and soil finishing attachments.

Blade spacing options:	5" (usually)
Disc blade diameter range:	18" to 22"
Weight per blade:	150 lbs. to 250 lbs.
Operating depth range:	1.5" to 3"
Residue mixing / incorporation:	75% to 100%
Soil disturbance:	100%
Weed or pest management:	Very good

**Best Management Practices:**

Compact discs can be effectively used to manage soil density up to 3" or 4" deep and incorporate heavy residue. This class of tool is designed for secondary soil management but is often used for shallow primary tillage to manage heavy residue in the fall.

Compact discs have a lower tolerance for operating in high soil moisture than tandem discs; the limiting factors being tractor weight, traction and plugging of the finishing system. The compact

disc design operates across a wide range of soil types in spring and fall, however when compacted low organic matter soils are dry, penetration into the soil becomes a limiting factor.

They should be used rotationally with other tools as they can set up secondary density layers. These tools are less likely to create secondary density layers than gang mounted discs or C-shank field cultivators as the individually and compound angle mounted discs send vibrations into the soil below operating depth. The compound angles lift the soil rather than scrape the soil sideways.

When used on heavy residue (e.g. wheat stubble with no straw removed or high yielding corn) they can create a residue mat at or just below seeding depth. If operated in wet soils this will result in poor germination and uneven emergence. Warm moist soils result in the best performance.

These tools can be adjusted for establishing cover crops when equipped with the soil finishing attachments.

**Cautions:**

This class of tool uses the rear mounted finishing roller or consolidator to determine the operating depth. There are two main types of finishing systems. One is a solid rubber or steel wheel. The steel and rubber roller systems when used in high moisture conditions on heavier soils with high clay content often compress the soil enough to discourage germination. The other option is a round or flat bar roller. The solid rubber or roller systems are less likely to roll up with wet soil, however they press oxygen out of the soil which may slow down residue digestion especially when operated at a shallow depth and / or in residue with high carbon to nitrogen ratios (e.g. wheat and corn). The round and flat bar rollers are more likely to plug in wet soil. When they are plugging, this is a good indication that you are damaging your soil. This flat or round bar roller option is less likely to reduce the amount of oxygen in the soil and therefore can be operated at shallower depths in high residue with less risk of slowing residue digestion.

If you select the round or flat bar depth control system, you can expect heavy seedling weed germination in the spring as these bar rollers create very good seedbed conditions. A secondary tillage operation or herbicide treatment will result in excellent long season weed control.

These tools create very fine soil particles, which can result in surface crusting following heavy rains on low organic soils and clay soils. These soils are susceptible to wind and water erosion. These tools should not be used on rolling highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	10	9	7	10	8	8
No Crop	0	9	8	5	10	6	8

**S8. C-Shank Field Cultivators**

Equipment consists of 4 to 6 ranks (toolbars) spaced at 27” to 36”, which are equipped with hardened heavy-duty steel shanks bent in a C shape. The shanks or tines are usually spaced at 6” to 7.5” apart with some optional spacings available. Residues are stirred and lightly mixed. These tools rely mainly on primary tillage to bury 50% of previous crop residue.

Tip pressures vary from 125 psi to 275 psi at rest. The C-shanks do not vibrate but they are spring loaded and designed to trip over obstacles.

They almost always include harrow finishing systems to improve seedbed characteristics and rear tow hitches for the use of transport harrows for extra finish or optional use when soil conditions are not suitable. C-shank systems can be set and used for nutrient and cover crop seed incorporation.

Operating depth range:	2" to 6"
Soil disturbance:	100%
Weed or pest management:	Excellent

#### Best Management Practices:

C-shank systems are best suited to medium and lighter soils for improved weed control compared to an S-tine which vibrates in response to soil resistance. In lighter soils the S-tine is not active enough to take out all the plants.

Include the harrow finishing system options to improve seedbed characteristics and rear tow hitches for the use of transport harrows for extra finish or optional use when soil conditions are not suitable.

Best performance occurs in moist soils and high organic loams. In heavy dry clay soils, they can leave the soil surface lumpy, which will require a second pass and possibly with a packer attached for optimum seedbed performance.

#### Cautions:

In two pass scenarios, these tools can produce very fine soil particles which will result in surface crusting on low organic soils and clay soils. Soils will be susceptible to wind and water erosion. These tools should be used sparingly and with care on rolling, highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	9	9	7	10	8	10
No Crop	1	8	8	6	8	6	10

### S9. C-Shank Soil Finishers

Equipment consists of angled or straight discs or coulters usually no more than 20" in diameter and spaced at 7.5" to 9" apart. This single gang is followed by four to five ranks (toolbars) spaced at 27" to 36" equipped with hardened heavy-duty steel shanks bent in a C shape. The shanks or tines are usually spaced at 6" to 7.5" apart with some optional spacings available. Tip pressures vary from 125 psi to 275 psi at rest.

Residues are stirred and lightly mixed. These tools rely mainly on primary tillage to bury 40% of previous crop residue in high residue conditions. They are capable of being used as primary tillage in oilseed residue or where wheat is cut short and removed for straw.

Operating depth range:	2" to 6"
Soil disturbance:	100%
Weed or pest management:	Very good

### Best Management Practices:

C-shank systems are best suited to medium and lighter soils for improved weed control compared to an S-tine which vibrates in response to soil resistance. In lighter soils the S-tine is not active enough to take out all the plants.

Include the harrow finishing system options to improve seedbed characteristics and rear tow hitches for the use of transport harrows for extra finish or optional use when soil conditions are not suitable.

Best performance occurs in moist soils and high organic loams. In heavy dry clay soils, they can leave the soil surface chunky, which will require a second pass and possibly with a packer attached for optimum seedbed performance

### Cautions:

In two pass scenarios these tools can produce very fine soil particles, which will result in surface crusting on low organic soils and clay soils. Soils will be susceptible to wind and water erosion. These tools should be used sparingly and with care on rolling highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	8	9	9	7	10	8	10
No Crop	0	8	8	6	9	7	10

### S10. Culti-Packers

The design consists of packing rollers followed by combinations of S-tine or C-shanks, which are again followed by another set of packing rollers. Residues are stirred and lightly mixed. These tools rely mainly on primary tillage to bury 90% of previous crop residue. These tools are excellent cover crop seeding tools.

Harrow finishers and rear tow hitches are available but seldom used as the seedbed finish prepared by a cult-packer is difficult to improve on.

Operating depth range:	1" to 3"
Soil disturbance:	100%
Weed or pest management:	Excellent

### Best Management Practices:

These tools perform best in slightly moist to dry soils. They are very effective in reducing secondary tillage passes in heavy clays and often capable of one pass seedbed preparation in loam and sandy soils. They are extremely good at shallow incorporation of herbicides, fumigants, fertilizer and cover crop seed.

### Cautions:

This tool creates very fine soil particles, which will result in surface crusting following heavy rains on low organic soils and clay soils. Soils are susceptible to wind and water erosion. These tools should not be used on rolling, highly erodible land.

Management Challenge	Erosion Control	Soil Texture	Moisture & Temperature	Residue Management	Weeds Other Pests	Density Reduction	Surface Levelling
Crops	7	10	10	6	10	8	10
No Crop	0	9	8	3	10	6	10

## Case Studies

These four case studies are examples of how farmers might address different field challenges.

### Scenario 1

Field Information	
Land Tenure	Owned
History	Cash crop
Livestock Manure	No
Crops	Corn, soybean
Rotations Including Cover Crops	1 corn, 2 soy rotation
Herbicide Resistant Weeds	No
Soil Type	Heavy clay
Primary Nitrogen Source	NH <sub>3</sub>
Organic Matter %	Less than 2% organic matter
Soil pH	5.4 – 5.7
Drainage	Pattern tile – 40 ft
Surface Drains	No
Drainage Performance	Fair
Topography	Moderately rolling
Stones	No
Soil Erosion	No
Soil Management Practice	Fall disc chisel disc. Spring prep with compact disc and C shank cultivator.
Available Tools	Disc ripper disc, compact disc, C shank field cultivator
Symptoms	Crop emergence and growth rates are uneven, ground slow to warm up in spring. Some ponding.
Probable Cause	High soil density with zones of compaction below 7 – 9” deep

### Spring Solution

Delay secondary tillage until soils are dry to planting depth. Limit seedbed preparation to one shallow pass preferably with an S-tine cultivator or vertical tillage tool. Plant early maturing soybean varieties to allow time for fall treatments. Consider application of Calcium lactate prior to soil disturbance. Fall treatment – establish compaction depth and perform deep ripping followed by a shallow tillage pass or no till planting to establishing a cover crop blend to maintain soil structure and harvest maximum photosynthesis to trap minerals over winter and release those and other minerals in the spring.

### Fall Solution

Establish compaction depth and deep rip up to 2” below the compaction layer. For tight clay soil choose a 30 “or 40” spaced straight shank. Perform the ripping operation during or immediately following harvest when soil conditions are dry to moist. Operate across the grade or direction of water flow as much as possible to prevent erosion. Establish a cover crop as soon as possible after deep ripping. For guidance refer to the Midwest Cover Crop Calculator guidelines <http://mccc.msu.edu/>. Consult Conservation authority for support on riparian buffer and grassed waterway establishment.

## Scenario 2

Field Information	
Land Tenure	Rented
History	Vegetables, fruit
Livestock Manure	No
Crops	Corn, soybeans, wheat
Rotations Including Cover Crops	Corn soy corn soy wheat with under seeded clover
Herbicide Resistant Weeds	Yes
Soil Type	Sandy clay loam
Primary Nitrogen Source	Liquid 27% 0-0-1%
Biological Amendments	Yes
Organic Matter %	2%
Soil pH	6.5% – 6.8%
Drainage	Random
Surface Drains	No
Drainage Performance	Excellent
Topography	Flat
Stones	Few
Soil Erosion	Occasional
Soil Management Practice	No till
Available Tools	Planter, no till drill, vertical tillage, deep ripper
Symptoms	Lots of weed escapes
Probable Cause	Not rotating chemicals, resistant strains coming in with seed, machinery or birds

### Spring Solution

Use vertical tillage early to warm the soil and remove excess moisture which will promote weed seed germination. Make a second pass at an angle to the first pass before seedlings reach 2 inches in height and before root systems reach 3” in depth. Select a pre-plant herbicide program accordingly. Consider biological soil amendments. Reference Publication 75 and 75A Guide to Chemical Weed Control. <http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm>. Chemical selection to address weeds and pests can be found at [www.managingresistancenow.ca](http://www.managingresistancenow.ca).

### Fall Solution

Moldboard plow if available or heavy disc followed by very shallow secondary tillage with vertical tillage. Moldboard plow is best. Wait for soil to settle at least one week and broadcast cereal rye, oats and radish and incorporate with vertical tillage or plant with no till drill. Broadcast incorporation provides better resistant weed suppression with less seed. For seeding rates and other cover crop suggestions refer to the Midwest Cover Crop Calculator guidelines <http://mccc.msu.edu/>. Consult conservation authority for support on riparian buffer and grassed waterway establishment.

### Scenario 3

Field Information	
Land Tenure	Rented and owned
History	Livestock, cash crop
Livestock Manure	Yes
Crops	Corn, soybeans, wheat
Rotations Including Cover Crops	Corn, soybeans, soybeans, corn, soybeans, wheat with clover after harvest.
Herbicide Resistant Weeds	No
Soil Type	Medium to heavy clay
Primary Nitrogen Source	28%
Biological Amendments	Yes
Organic Matter %	3 – 4 %
Soil pH	5.8 – 6.2
Drainage	Pattern tile – 40 feet
Surface Drains	Yes
Drainage Performance	Fair to good
Topography	Flat – Very low slope
Stones	No
Soil Erosion	Occasional
Soil Management Practice	Rotational tillage and no till
Available Tools	Heavy high-speed disc, field cultivator, deep ripper, vertical tillage
Symptoms	Ponding and run off causing erosion after heavy rains on the no till fields and fields that require more than one secondary tillage pass.
Probable Cause	High soil density in the top 3 inches. Low root density and low biological activity in soil after harvest.

#### Spring Solution

Choose earlier maturing hybrids to give you a larger window for soil moisture and temperature to be optimum and allow for cover crop establishment in the fall. Minimize soil disturbance prior to planting. Inter seed corn with companion cover crops at the V4 to V6 stage.

<http://www.omafra.gov.on.ca/english/crops/field/news/croptalk/2019/ct-0619a4.htm>. A

Canadian App created by AAFC on the selection of appropriate cover crops can be found at

[www.decision-tool.incovercrops.ca](http://www.decision-tool.incovercrops.ca).

#### Fall Solution

Terraform surface drains and establish grassed waterways that resist traffic. Establish buffer zones between field edge and drainage ditches. Broadcast incorporate or no till cover crops after harvest or after fall tillage. Refer to the Midwest Cover Crop Council Calculator

<http://mccc.msu.edu/>. Consult conservation authority support for riparian buffer and grassed waterway establishment.

## Scenario 4

Field Information	
Land Tenure	Rented
History	Livestock, cash crops
Livestock Manure	No
Crops	Soybeans and wheat
Rotations Including Cover Crops	Soybeans, wheat, soybeans, wheat
Herbicide Resistant Weeds	Yes
Soil Type	Clay loam
Primary Nitrogen Source	28%
Biological Amendments	No
Organic Matter %	Less than 2%
Soil pH	6.0
Drainage	Random
Surface Drains	-
Drainage Performance	Good
Topography	Rolling hills
Stones	Yes
Soil Erosion	Severe
Soil Management Practice	Compact disc after wheat harvest, 2 <sup>nd</sup> pass mid fall to control weeds
Available Tools	No till drill, compact disc
Symptoms	Poor soybean germination and uneven emergence, crop does not mature uniformly, crop yield is low and lacks consistency. Soybean herbicides losing effectiveness.
Probable Cause	Poor soil health, excessive tillage, no living roots for much of the growing season, topsoil loss.

### Spring Solution

Do not fill in erosion sites. Trying to repair in the spring will only result in greater soil loss. No-till plant cereal rye as early as possible preferably on frost. As much as possible plant across the direction of water flow. Leave the rye crop to grow as late as possible in the spring then plant early maturing soybeans into the green crop. Apply burn down 2 days after planting. Wait for the driest season predicted for the region and repair the eroded areas. Plant those areas into permanent grassed water ways. Establish grasses in blends of fast-growing deep-rooted broadleaf crops like sunflowers and corn. For guidance refer to the Midwest Cover Crop Council Calculator <http://mccc.msu.edu/>. Consider biological soil amendments to improve soil biological activity.

### Fall Solution

Repair eroded areas and establish permanent grassed water ways in the dry season. Harvest early and plant a cover crop blend of legumes, root crops and cereal rye planted across the direction of water flow. Do not terminate the cover crop or plant wheat. Refer to the Midwest Cover Crop Council Calculator <http://mccc.msu.edu/> and consult with local conservation authority.

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