High Residue Farming under Irrigation: What and Why

WASHINGTON STATE UNIVERSITY EXTENSION • EM071E

Part of the High Residue Farming series

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High Residue Farming under Irrigation: What and Why

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This is the first in a series of publications on High Residue Farming under Irrigation. This publication provides an overview of **high residue farming** (HRF), including its benefits and challenges. It also discusses some special considerations for high residue farming in the irrigated agriculture regions of the far western United States (the "**Far West**").

For anyone wanting to implement or know more about a high residue farming system, the series includes:

EM072—High Residue Farming under Irrigation: Crop Rotation covers choosing a cropping sequence, specific cover crops, and special considerations for irrigated cropping systems in the far western United States.

EM073—High Residue Farming under Irrigation: Residue Management through Planting explains how to plant crops into high residue conditions with a planter or drill. It covers residue management, planter and drill modification, and soil fertility adjustments.

EM074—High Residue Farming under Irrigation: Pest Management Considerations gives an overview of the effects of adopting HRF on the management of weeds, insects, and diseases.

EM036—High Residue Farming under Irrigation: Strip-till covers the benefits, challenges, and implementation of strip-till planting. This particular high residue farming system combines some of the benefits of clean tillage systems with those of high residue cover.

Introduction

Farming is risky business. Markets and weather, two critical factors, are out of your control. In such a business, it pays to be conservative about changing a system that has worked over many years. But this should not keep you from reexamining your past choices, or those of your predecessors, in light of advances in knowledge and technology. The decisions that you were comfortable with a few years ago, or that your grandparents made generations ago, may not represent the optimum solution anymore. This is the case for an increasing number of farmers who have re-evaluated tillage-based farming systems and found a better solution. That solution is called high residue farming, and they are using today's knowledge and tools to make it work within irrigated cropping systems in the far western states of Washington, Oregon, Idaho, California, Arizona, and New Mexico (Figure 1).

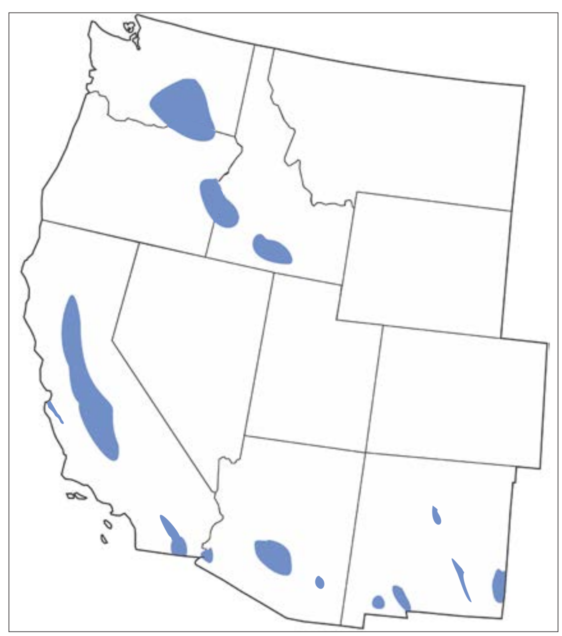

Figure 1. Irrigated vegetable-growing areas of the far western United States. ➔

Table 1. Classification of tillage systems by tillage intensity and residue coverage.

Classification		Primary Tool(s)	Tillage Intensity	Residue Coverage
Clean-till		Moldboard plow	High, soil inversion	<30%
Clean-till		Heavy offset disk	High	<30%
Reduced-till		Chisel plow, disk	High	<30%
Reduced-till, Minimum-till, Mulch-till	High residue farming (Conservation tillage)	Chisel plow	Moderate	>30%
Strip-till		Strip-till implement	Non-uniform, moderate-none, 6–12″ deep	60–80%, bare soil in planted strip
Zone-till, Vertical tillage		Gang of coulters on planter, row cleaners	Non-unifrom, moderate-none, 1–2″ deep	60–80%, bare soil in planted strip
Direct seed, No-till*		Planter with row cleaners	None	60–80%, 0–80% in planted strip
Direct seed, No-till*		Planter without row cleaners	None	80–100%

*Direct seeding and No-till refer to the same practice.

What is High Residue Farming?

High residue farming (HRF) is an umbrella term that covers cropping systems in which the volume of soil that is tilled is reduced in order to maintain residue cover of the soil. **Crop residue** covering the soil provides the many benefits of HRF, though the specific amount of residue will depend on the previous crop, the current crop, and soil and climate factors.

No-till, **strip-till**, ridge-till, and **vertical tillage** are all variations of HRF. Many of these terms describe the type of tillage used (for instance, strip-till) or not used (no-till), and most have other names, such as **direct seeding** for no-till or zone tillage for shallow strip-till. Table 1 shows the range of tillage practices.

Benefits

Farmers are adopting HRF for numerous benefits, including:

- Time and labor savings
- Fuel and equipment savings
- Water conservation
- Improved soil tilth
- Increased double-cropping options

Each of these benefits is described in more detail below.

Time and labor savings

How you spend your time is how you spend your life. If you prefer tillage and you accept the tradeoffs of tillage (see the section on Questioning Tillage, below), then maybe HRF is not for you. But if you would rather be doing something other than tilling a field, consider what this time savings could mean for you. Assuming that tillage takes 7 to 24 minutes per acre, depending on the crop, you would save up to 48 hours for a 120-acre field during the busy time of the year. Some farmers use this time to farm more acres and increase profits, while others choose to use it for recreation, improving their quality of life. Family members of farmers who have adopted HRF also see this benefit. As the wife of one no-till farmer from Ohio said, "The only thing that improved the quality of my life more than no-till was electricity."

If you pay someone else to do your tillage, the time savings from HRF translates to reduced labor costs.

Fuel and equipment savings

Reducing tillage also saves fuel. Fuel savings range from 1.2 to 4.0 gallons per acre, or even more in rotations that include high residue crops. Fuel prices are volatile, depending on global markets and geopolitical events. Farmers using HRF decrease their risk related to fuel price spikes and supply crunches.

Some farmers using HRF find that they can manage with less equipment, especially those implements involved in primary tillage—and the equipment they do retain experiences far less wear and tear. Some farmers have even financed their move to HRF through the sale of the tillage equipment that will no longer be needed. Even if you need the same number of tractors, the elimination of primary tillage means that you may not need as much horsepower.

Water conservation

Crop residue left covering the soil saves water. By blocking sunlight and slowing air movement at the soil surface, crop residue reduces evaporation and makes more water available to the crop. Just how much water you will save depends on the type of residue and other factors. Savings are generally higher in irrigated systems than in dryland systems; see Figure 2 (Todd et al. 1991; Klocke 2004).

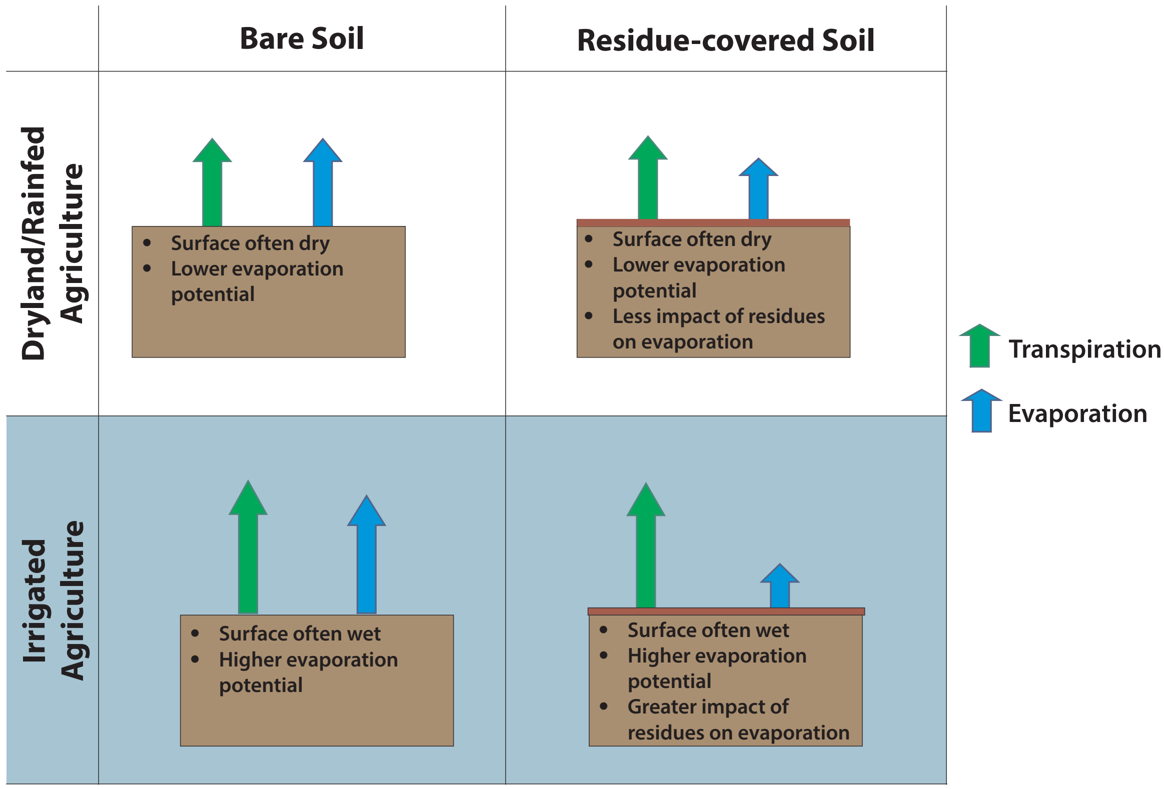

*Figure 2. Relative amounts of **transpiration** and evaporation from bare and residue-covered soil in irrigated and dryland environments.*

In irrigated corn in Nebraska, a mulch of wheat residue saved about 4 inches of water over the growing season. Additional water was saved during the winter due to increased snow catch and reduced runoff (Klocke et al. 1986).

Eliminating tillage also conserves water. Depending on the implement used for tillage, 0.3 to 1 inch of water per pass can be saved. Total water savings from using HRF practices can be over 6 inches per year (Table 2). This can represent significant dollar savings for those who pump from deep wells and have expensive power or expensive water rates, or all three.

Table 2. Total potential water savings from HRF.

Source of water savings	Water savings (inches)
Reduced evaporation	2–3.8
Elimination of tillage	0.3–0.7 per pass
Increased water storage	1–2
Total	**3.3–6.5**

Reducing water use can also provide non-economic benefits which are increasingly important as farmers face continuing pressure to increase irrigation efficiency because of ongoing issues related to hydroelectric power generation, salmon recovery, and urban growth.

Improved soil tilth

Maintaining residue cover and minimizing disturbance by tillage can slow, or even reverse, the long-term decrease in soil quality associated with tillage-based agriculture. The improvement process begins as residue cover increases the concentration of soil organic matter at the surface. Through biologic processes, this leads to increased soil aggregation (see sidebar) and improved structure, enabling a soil to better resist compaction, move water and air, and provide habitat for soil microorganisms and larger creatures like earthworms. Over time, these soil-building processes can improve soil function and increase crop yields.

The speed and degree of soil building depends on soil texture, crop rotation, residue management, and climate, but many benefits begin to accrue as soon as tillage ends and a residue mulch is established.

Some researchers have proposed that the stratification of soil organic matter—how much organic matter is in the surface soil layer vs. the amount in deeper layers—could be used as a measure of soil quality, a "putting organic matter where it matters most" strategy. This stratification of organic matter can be changed much faster than the organic matter content of the bulk soil.

As one example of why stratification matters, just keeping crop residue on the soil surface can increase infiltration enough to allow more water to be applied in a shorter time, and to eliminate the need for "dammer-diking" or other reservoir tillage.

Improved **soil tilth** may be a benefit of HRF that is more important to farmers in the West than in other regions. In the Midwest, prairie soils started with high levels of soil organic matter, but these levels decreased over time when farmed. Farmers there are looking for ways to stop the decline and maintain soil organic matter levels. In contrast, farmers in the irrigated Far West have soils that developed under desert conditions, often with soil organic matter levels less than 1%. With high yielding crops under irrigation, soils have responded with increased organic matter levels in some regions (Cochran et al. 2006).

HRF has the potential to build soils even further by adding and conserving soil organic matter. These increases can be expected to be greater in soils with greater than 60% silt + clay than in lighter textured soils, but even in sands, HRF can increase soil organic matter levels (Hao and Kravchenko 2007).

> A **soil aggregate** is cluster of soil particles held together by a combination of plant roots, fungal growth, and "soil glues" produced by bacteria and fungi. Visible macroaggregates range in size from several millimeters to several centimeters and are important for soil structure, water infiltration and retention, and aeration. Microbial decomposition of organic materials such as crop residue stabilizes aggregates in soils. The soil needs a regular supply of organic matter to maintain stable aggregates and structure (Kladivko 1994).

Crop residue also protects existing soil tilth by shielding the soil from wind and water erosion. Wind erosion is usually the primary concern in the western U.S. Wind removes the fine silt and clay particles along with soil organic matter – the most valuable components of many light textured, low-organic-matter soils. Maintaining residue cover on the soil often eliminates any significant wind erosion. It also reduces wind-driven sandblasting of seedlings and eliminates the need to irrigate to keep the soil from blowing (Collins et al. 2010).

Although the potential water erosion is often much less in the western U.S. than in regions that receive more rain, we can still get thunderstorms with intense rains. Residue breaks the impact of raindrops, preventing crusting, allowing more of the water to infiltrate into the soil, and reducing both in-field and off-site runoff. Soils under long-term HRF management have much higher infiltration rates than tilled soils, and so can handle even more intense storms, which, if climate change predictions are right, will be more frequent in the future.

Protection of the soil by crop residue is also a benefit when irrigating. Sprinkler systems can apply more water than the soil can take in, especially toward the ends of long center pivot systems. This leads to runoff and ponding, which decrease the uniformity of water (and nutrients applied via fertigation) in the soil, leading to non-uniform crop growth. Runoff can move nutrients such as nitrogen (N) and phosphorus (P) into streams or rivers. Runoff can also be a great concern in dairy production regions where manure applications are common. The ground-covering residue of HRF can help moderate all of these problems.

Increased double-cropping options

With the elimination of primary and secondary tillage before planting, HRF can reduce the time required to go from harvest of one crop to planting the next. This opens up new opportunities for double cropping. Specific sequences will depend on your location, but some examples from the Columbia Basin are sweet corn after green peas, oat forage after wheat, and dry edible beans or buckwheat after first cutting of alfalfa or grass hay. These double-crops can increase profits per acre for farmers using HRF.

Economics

Are HRF systems more profitable than tillage-based systems? It depends on how many of the previously mentioned benefits you receive and to what extent. It also depends on how much you value your time and your soil.

There are very few studies comparing HRF to conventional tillage systems in the Far West. In a 2008 survey from the irrigated Columbia Basin of Washington (author, unpublished data 2008), farmers reported using HRF for sweet corn, grain corn, green peas, dry edible beans, and wheat. Across these crops, they reported an average cost savings of $39.64 per acre. All of those surveyed reported reduced fuel use, 91% reported reduced labor costs, and 70% reported increased profits. You will have to calculate enterprise budgets for your own operation because the variables on your farm (crop rotations, soils, location, yields, current machinery, labor costs, acres farmed, water costs, etc.), will determine the results.

Challenges

In addition to benefits, there are challenges, both real and perceived. Some challenges that were once real have been largely overcome, usually through farmer innovation and persistence. Many farmers, when first considering HRF, often focus on these problems:

- Weed management without tillage
- Increased incidence of insects and diseases
- Difficulty planting through residue
- Compacted soils, restricted root penetration and poor water infiltration
- Reduced availability of surface-applied nutrients to the crop
- Reduced yields because of cool soils at planting
- Management challenges resulting from the high diversity of crops
- Prohibitive cost of new equipment

These challenges are perceived to be the result of lack of tillage, too much residue, or both. Let's see how real these scenarios have turned out to be.

Weed management without tillage

One of the main reasons farmers continue to use tillage is to control weeds. When tillage is reduced or eliminated, farmers fear that weeds will get out of control. It is true that if you just eliminate tillage and do not make other adjustments, then weeds can get out of control. Yet farmers who adapt to the new HRF conditions find they can control weeds through a combination of preventative, cultural, and chemical practices. Yes, herbicides become more important, and yes, this can, in some cases, increase costs, but overall, farmers have found the benefits outweigh the costs. For details on weed management in HRF, see the WSU publication EM074—*High Residue Farming under Irrigation: Pest Management Considerations*.

Increased incidence of insects and diseases

When farmers were first considering no-till corn, they expected all sorts of problems with insects and diseases. Overall, these difficulties have failed to materialize, although the pest pressures are generally different under HRF than under conventional tillage. The details of management vary with the pest and the crop, but in general, farmers have found that, just as in tilled systems, thoughtful crop rotation and judicious use of insecticides and fungicides can keep pests in check. Even when farmers ignore crop rotation, as many Midwest farmers do with continuous no-till corn, they can still successfully manage insects and diseases. For more details on pest management in HRF, see the WSU publication EM074—*High Residue Farming under Irrigation: Pest Management Considerations*.

Planting through residue

Farmers accustomed to seeing bare fields usually have concerns about planting through all that "trash." Those concerns would be justified if they tried to plant using the same tools they are using to plant bare ground – it would be a nightmare. The reality is that farmers have figured out how to plant through high volumes of residue with both drills and row-crop planters. They do this using a combination of residue management, planter/drill attachments, and planter/drill adjustments. The specifics of this topic are addressed in the WSU publication EM073—*High Residue Farming under Irrigation: Residue Management through Planting*.

Compacted soils

What about compaction? The fear is that, without tillage, compacted soils will eventually reduce crop yields. It is, however, misleading to bring your thinking about compaction in a tilled soil system to HRF. It turns out that although tillage loosens the soil (it can also cause compaction below the tillage depth, i.e. plow pan), tillage also makes it more prone to re-compaction. When the loosened soil re-consolidates, more tillage is required to alleviate this compaction, and so begins the tillage-compaction cycle (see Compaction & High Residue Farming, below). Farmers who have stopped tilling their soil find that untilled soils gradually become more resistant to compaction as their soil structure rebuilds. But farmers also find that it is critical to stay off wet soils, limit axle loads, and avoid other practices that could cause compaction.

A related objection is that crop roots will not be able to penetrate the soil unless it is tilled to a loose condition. Here again, several hundred years of tilling the soil to control weeds has made us forget that plants seem not to have trouble penetrating the soil in natural systems, where tillage is rare. Think about your lawn, or 3-year stand of alfalfa. Are the roots of bluegrass turf or alfalfa limited by lack of tillage? No, because a firm soil does not mean a compacted soil. In a firm, untilled, uncompacted soil, roots are able to find their way between aggregates, through cracks, through earthworm burrows, and through old root channels.

Similarly, farmers in the habit of tilling the soil sometimes think that untilled soil will not take in water as fast as tilled soil. Although it is true that the first application of water after tillage is quickly absorbed in macro-pores created by the tillage, the loose tilled soil soon reconsolidates. Because the soil is bare, irrigation may also produce a soil crust that actually reduces water infiltration. Untilled (uncompacted) soil, protected by residue from the impact of falling water droplets, is much less likely to form a crust. In time, the untilled soil will have stable macro- and micro-pores capable of absorbing much more water than the short-lived macro-pores of a tilled soil. Dwayne Beck, farm director of the Dakota Lakes Research farm in South Dakota, demonstrates this to visiting farmers. He applies an inch of water to a no-till field. Immediately afterwards, he has farmers walk out into the field. Most are surprised

Compaction & High Residue Farming

Compaction is the loss of pore space from a soil. These pores, or "holes," are important for infiltration of water, movement of air, and promotion of root growth. In *The Biology of Soil Compaction*, the authors state that compaction "...is fundamentally a biological problem caused by a lack of actively growing plants and active roots in the soil. Increased organic matter levels promote soil aggregation and make the soil less susceptible to soil compaction. Finally, crop residue on the soil surface has been shown to cushion the effects of soil compaction. No-till soils can be driven on at relatively higher water contents and have less susceptibility to compaction than tilled soils at the same water content." (Hoorman et al. 2009)

The beneficial loosening effects of tillage on the soil are temporary, with reconsolidation typically occurring weeks to months after tillage. This is why the benefits of deep ripping are often short lived: continued machine traffic or grazing animals recompact the loose, tilled soil, necessitating more tillage. Furthermore, the beneficial effects of tillage decline after years of annual tillage so that the recompacted state will be worse than the year before. Increased tillage is often required to obtain the same results. This deterioration of soil structure by tillage and the associated reduction in soil organic matter levels (Warkentin 2001) results in a downward spiral of soil function, the tillage-compaction cycle (Figure 4), or "tillage treadmill":

1. Tillage is used to break up compaction.
2. This creates loose soil.
3. The tractor and other heavy equipment are operated on loose soil.
4. This compacts the soil, necessitating more tillage.

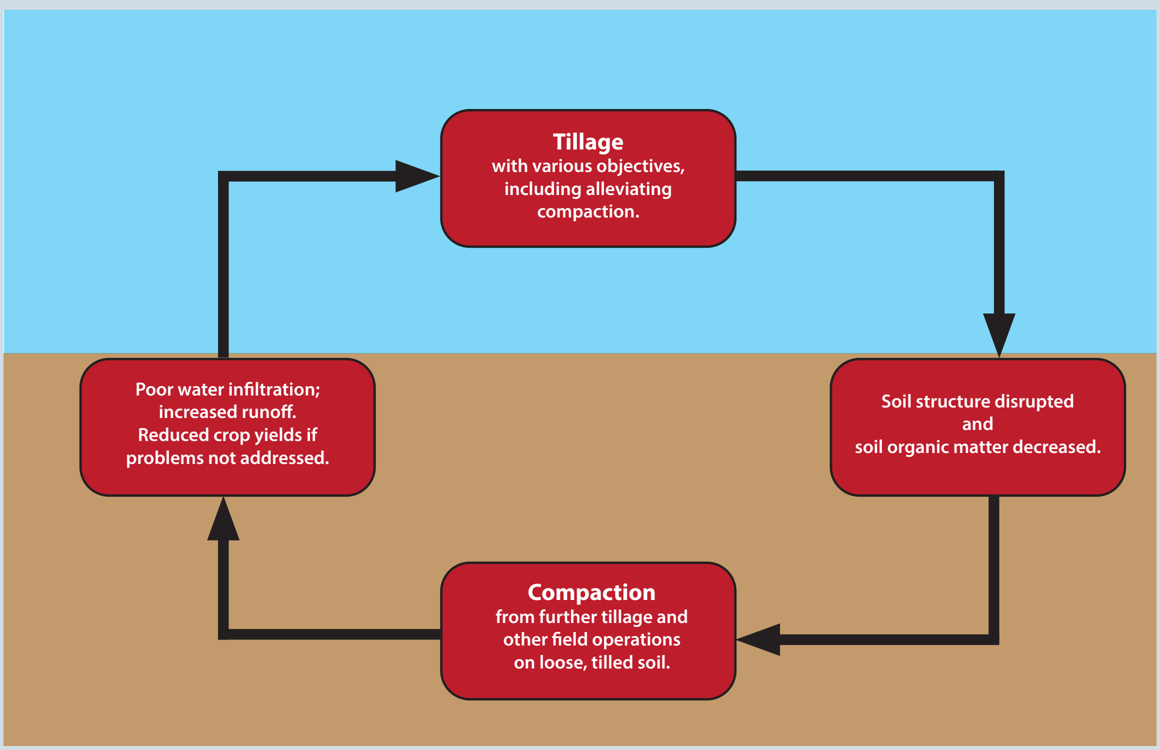

Figure 4. The tillage-compaction cycle.

To break this cycle you must allow structure to build within your soil while avoiding re-compaction. HRF can do this, replacing the tillage treadmill with a slow but steady building of soil structure:

1. Untilled soil, covered by crop residue, builds soil structure.
2. Equipment is operated on firm ground, less easily compacted than tilled soil. In addition, the rolling resistance of a tractor is less on firm soil than on tilled soil.
3. Compaction is minimal.
4. Tillage is not needed to alleviate compaction; soil organic matter increases, further contributing to soil structure.

Complicating the issue, it is often difficult to reliably determine whether a compaction problem exists. Compaction is usually measured with a penetrometer, a device which measures the force required to push a metal cone of specific size (attached to a rod) through the soil. Although highly dependent on soil water content, if used judiciously, penetrometer readings can show where yield-reducing compaction exists. But in firm, untilled soils, penetrometers can give misleading results. Because a penetrometer must travel in a straight line, it must penetrate *through* aggregates, which increases resistance. Roots, however, do not have to move in a straight line as a penetrometer must and can find pores, weak spots, or old root channels that are conducive to root growth (Rasse and Smucker 1998). Hence, a firm, structured soil may look compacted according penetrometer readings, but would be capable of producing high yielding crops.

Especially in HRF systems, avoiding compaction in the first place is the best strategy. The recommendations here are generally the same as in tillage agriculture (Hamza and Anderson 2005):

1. Do not drive on wet soils.
2. Minimize field traffic by reducing the number of passes and limiting traffic to controlled lanes.
3. Reduce the pressure on the soil by decreasing axle load, by increasing the contact area of the tires with the soil, or both.
    a. Use radial tires with the *minimum* pressure required.
4. Build soils resistant to compaction by:
    a. Increasing soil organic matter;
    b. Including cover crops in your rotation.

If, despite your efforts, you compact your soil, tillage is still the only remedy—at least for deep compaction. After deep tillage, however, you can use HRF practices with tillage to prevent your soil from reconsolidating.

Carry out deep ripping in the presence of organic soil amendments like compost, crop residue, or livestock manure.

Plant a cover crop in the newly loosened soil to build root channels and provide soil binding. You can incorporate P and K at the same time, raising soil test levels to the mid to high range. If cover cropping is not possible, a vigorous crop like corn is a good alternative, as long as you minimize the re-compaction of the soil during planting.

Use strip-till to treat compaction (EM036—*High Residue Farming under Irrigation: Strip-till*). Re-compaction is avoided by driving on the firm row middles (controlled traffic). In this way, a deep strip-till operation that alleviates compaction can lead out of the tillage-compaction cycle to a shallow or no-till system, with or without residue removal from the crop row.

Following these recommendations is even more important in sandy soils than in soils with more silt and clay. Lower soil organic matter levels in sandy soils make them more prone to compaction in the first place, and more likely to reconsolidate quickly after tillage.

that they neither sink in nor get muddy. Beck then challenges them, “Would you walk out like this on your tilled ground?”

The root of these misperceptions is that tillage is often used to provide a short-term solution to problems related to poor soil quality, such as poor infiltration and aeration. While HRF cannot fix these problems quickly, it does offer a long-term solution that will improve soil structure over time. It can get you off the tillage-compaction treadmill.

Decreased availability of surface-applied nutrients

The concern here is that crops will not be able to take up immobile nutrients such as phosphorus (P) and potassium (K) from broadcast fertilizers unless they are incorporated with tillage. (There is a similar concern about lime for pH adjustment.) However, residue-covered soils remain wet right up to the surface for much longer periods than bare soils do. The wetter soil allows plant roots to grow right up to the soil surface (Figure 3) and take up the broadcast fertilizers. Liming also works in untilled soils, just at a slower pace.

Figure 3. Crop roots growing to soil surface under residue cover.

Cool soils at planting

This is a legitimate concern, but one that can be managed. It is especially a problem in Northern latitudes (like the Columbia Basin) where research has shown the most consistent benefits of practices that lead to warmer soils (Archer and Reicosky 2009). An extensive review of research results in the Corn Belt revealed that while the overall difference between no-till and conventional corn yields was negligible, no-till corn yields in the northern U.S. (> 43° N) were lower (by 5.5% on average) than conventional yields (DeFelice et al. 2006). In northern latitudes, residue covering the soil delays soil warming in the spring and slows corn germination and early plant growth, resulting in reduced yields. The solution is to move some residue off of the planted row to allow the soil to warm more quickly. This can be done in various ways, with or without shallow tillage, and results in comparable yields while maintaining the benefits of the residue on the soil between rows. See WSU publication EM073—*High Residue Farming under Irrigation: Residue Management through Planting* for a more detailed description.

Management challenges from the high diversity of crops

Perhaps the most serious challenge to using HRF in the irrigated Far West is the diversity of crops we grow. Midwest farmers growing continuous corn, simple rotations of corn and soybeans, or “diversified” rotations including wheat, alfalfa, and pasture, have relatively few cropping factors to think about when using HRF. In contrast, out west we grow all these crops, plus numerous vegetables, seed crops, and perennial crops including mint, specialty herbs, ornamentals, and nursery crops. While this diversity is a benefit and keeps our agriculture resilient, it also poses great challenges in implementing HRF. Continuous no-till is rarely an option because of crops such as carrots, potatoes and sugar beets whose harvest is a tillage operation. Because of these important cropping differences, Midwest no-till research will not always be relevant to HRF in more complex rotations.

For these reasons, researchers must develop HRF systems for each of the dominant cash crops in each region. For specialty crops, it will take time and resources to develop HRF systems that work well, but it can be done. In 2011, ten years after starting their research, University of California researchers demonstrated that cotton and tomatoes grown under high residue conditions can yield as well as conventional clean tillage systems. In the Columbia Basin of Washington, innovative farmers are producing onions using a HRF system that they developed without formal research support. These successes point the way to using HRF with other crops.

Prohibitive cost of new equipment

The cost of new equipment to make the move to HRF depends completely on your situation. Your current crops, equipment, land base, pumping costs, labor needs, stage of life and financial state all come into play. Current and future prices for fuel, crops, new and used equipment (if selling unneeded equipment) and land all make it a complex decision. For example, if you need a new drill anyway, it is much easier to justify buying one that can direct-seed through residue than if you have a relatively new drill. Similarly, if you are building your operation and want to farm more land but need more time to do so, the move to HRF makes more sense than if you are looking to retire soon. This is one calculation that cannot be generalized; you must do your own assessment for your operation.

High Residue Farming Requires a New Way of Thinking

As we have seen, many of the perceived problems of HRF come from tillage-based thinking. We forget, because their management is so routine, that tillage based systems have their own set of problems. In contrast, because they are new, the problems of HRF seem much more difficult. But the strategy is the same in either system: Take advantage of the upside and then manage the downside risk. For example, you benefit from better soil structure over time from eliminating tillage, and then manage the challenges of cooler spring soil temperatures and planting into residue.

Do tilled systems sometimes fail? Yes. Then you can also expect there to be failures in HRF. When it happens, your response should not be that "HRF does not work," but rather "what part of the system can I change to fix this?"

Dwayne Beck, South Dakota State University no-till specialist, likes to stress that, before you change your equipment, you have to change how you think. The first step is adopting a new way of thinking that looks for solutions to problems that do not involve tillage.

Successful HRF requires a whole system approach. In addition to the changes mentioned above, HRF will likely require changes in crop rotation, planting equipment, soil fertility, pest management, and irrigation water management (Figure 5).

Is Tillage Needed?

Tillage has traditionally been used to control weeds, incorporate fertilizers, and chop and bury crop residues to prepare a seedbed (Table 3). Farmers adopting HRF are finding that other tools can be used to accomplish some of these tasks, and that other tasks are not necessary. Crop rotations and herbicides can control weeds. Fertilizers can be effective when banded or broadcast on untilled soil. Crop residues, rather than being removed, can be managed using a combination of tools (see EM073—*High Residue Farming under Irrigation: Residue Management through Planting*). Profits, and for many crops, optimum production levels, are maintained.

High Residue Farming Considerations in the Far Western U.S.

The irrigated vegetable-growing regions of the far western United States present unique conditions that affect the implementation of HRF. We will focus on the Columbia Basin of Washington State, but most of the information applies to similar regions in Oregon, Idaho, California, Arizona, and New Mexico (Figure 1). In these regions, farmers produce irrigated vegetables

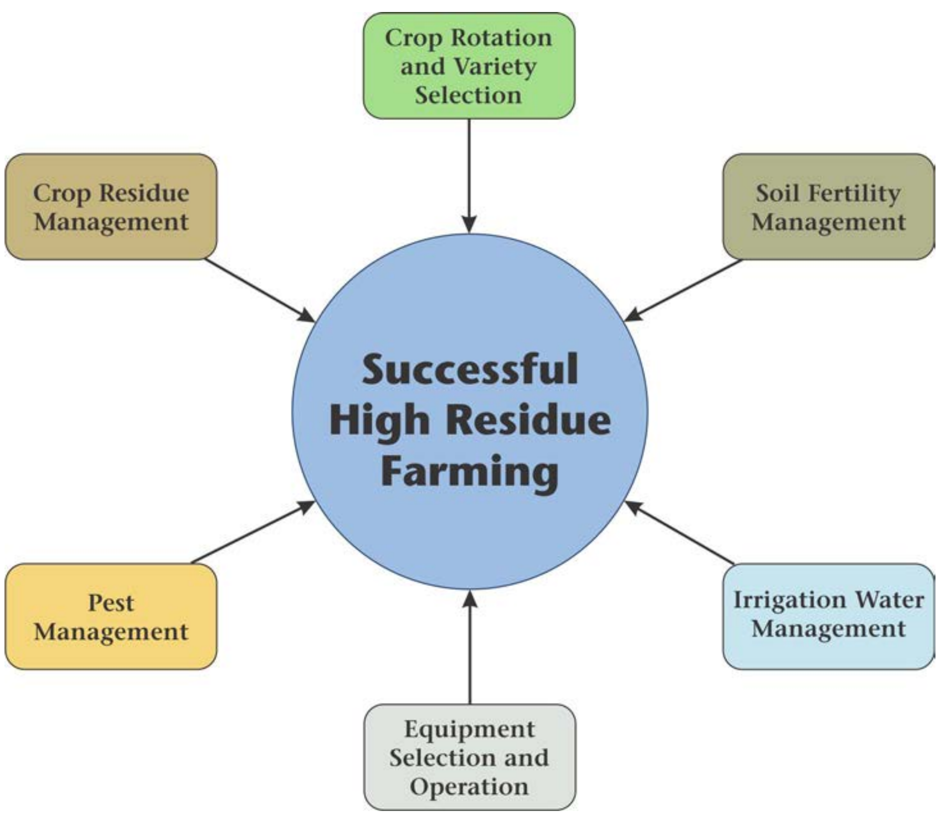

Figure 5. Components of a successful high residue farming system.

Table 3. Positive and negative aspects of tillage.

Positive aspects of tillage	Positive or Negative, depending on situation	Negative aspects of tillage
Short term: Kills weeds Buries weed seeds Produces uniform seedbed Disrupts some pests	***Short-term:*** Increases evaporation Dries soil Loose seedbed dries more quickly Removes residue cover Warmer soils	***Short-term:*** Digs up stones in some soils Requires energy and equipment ***Long-term:*** Disrupts beneficial organisms
Rough surface decreases wind erosion	⟷	Increased wind and water erosion
Increases mineralization of organic matter and associated nutrient release	⟷	"Burns up" organic matter
Promotes infiltration; Breaks surface crusts	⟷	Increased crusting of bare soil; Destroys macro-pores
Alleviates compaction	⟷	Compacts soils; Sets up soil for future compaction

in rotation with agronomic crops such as wheat, corn, and alfalfa. Irrigated HRF is relatively new to these areas, especially compared to the humid Corn Belt, the High Plains, and dryland agriculture areas in the West, where some variation of HRF has been in use for 30 or more years. Although lessons learned from other regions and systems are relevant, the irrigated Far West has some distinct conditions that necessitate modifications to HRF.

First, the Columbia Basin of Washington lies at 46–47° North latitude. This far north, spring soil warm-up is slow because of the lower angle of the sun compared to its angle in regions further south. Corn, especially, cannot produce top yields unless it grows fast enough to close canopy before the long days around June 21, the summer solstice. So for corn and other crops grown under HRF at northern latitudes, it is often necessary to move the residue off the planted row to allow for quicker soil warming. Details for this is covered in EM073—*High Residue Farming under Irrigation: Residue Management through Planting*.

Second, summers in most of the Far West are dry, impacting HRF in a number of ways. Because of the low rainfall in these regions, water erosion is not the primary driver of adoption of HRF as it is in the Midwest. Because of the low air humidity, residue decomposes slowly and builds up quickly. With irrigation, crops like wheat and corn produce high yields and large amounts of residue. This combination of high residue production and low decomposition rates makes it easier to maintain residue cover, but having too much residue can be a challenge. The dry climate also means that, in general, soil moisture at planting can be managed.

With irrigation, water savings from HRF can be greater than in non-irrigated regions. Although these savings can reduce pumping costs, they do not increase yields as they do in dryland/rainfed regions because, in irrigated areas, water is not a limiting factor for yield.

Third, because the soils in these far western regions of the U.S. are usually low in organic matter, any tool (such as HRF) that builds soil organic matter is particularly valuable. This is in contrast to other areas of the U.S. where no-till systems may only slow the ongoing loss of organic matter (Olson 2013). While a soil with 3% organic matter in Iowa is degraded, it is a high quality soil in the Columbia Basin of Washington. Therefore, HRF has potentially greater soil benefits in the Far West. On the other hand, sandy soils are common in the West. In these soils, structure may develop slowly or not at all, limiting the soil-building benefits of HRF.

Fourth, as mentioned before, the crop rotations in irrigated regions of the Far West are complex and dynamic, providing both challenges and benefits. The production of root crops such as potatoes, onions, and carrots requires tillage, so continuous no-till is not possible. The effect this has on the soil benefits of HRF is not known. In the growing of processed vegetables, problems with residue distribution and soil compaction may arise because the processor generally determines the timing of harvest and uses their own equipment.

The sheer number of crops grown in some of these regions (for instance, more than 150 in the Columbia Basin) makes it more difficult for farmers to adopt HRF. For many of these crops, there is little, if any, HRF research to provide guidance to farmers wanting to adopt HRF systems. In addition, agronomic crops such as wheat and corn, which do have proven HRF systems, may not be managed as intensively as vegetable "cash crops." Producing vegetable crops with HRF requires increased management on top of what is already a management-intensive operation.

Fortunately, complex crop rotations also benefit HRF management. While farmers in the Midwest have limited choices of crops to grow, farmers in the Far West can choose from a variety of crops. This benefit, however, is not always realized for HRF—producers' cropping decisions are largely determined by markets and other non-agronomic factors that can make achieving specific HRF goals through crop rotation more difficult. And yet, particular crops in these systems lend themselves particularly well to HRF systems. For example, direct seeding is often easier with hay and other forage crops because there is less residue in the field after harvest, and, because they are often perennials not needing to be planted each year, they require much less tillage over their production period.

Fifth, because of the specialized crop production, a large proportion of the land in these regions is leased every year. This may reduce the desirability of HRF because soil-building benefits may be less important to farmers of leased land. Management of the soil and crop residue is more difficult when farmers do not control the management of the previous crop. In addition, farmers focused on the production of one vegetable crop may be reluctant to buy needed HRF equipment for other crops.

Last, because HRF is relatively new to irrigated areas of the Far West, there is limited availability of HRF equipment. No-till drills, specifically, are rare in the Columbia Basin. The relatively small number of farmers using HRF (compared to the Midwest) also reduces the incentive for equipment manufacturers to develop specialized equipment that is specifically adapted to the conditions in the far western United States.

These factors limit quick adoption of the HRF systems developed in other regions, but HRF is slowly gaining ground. Research on various crops is being conducted in all the major irrigated regions. Farmers are taking equipment and systems from other regions and successfully adapting them to their unique conditions. And equipment manufacturers are taking notice and offering products designed for the crops and conditions of the irrigated Far West. Where it fits, HRF is being adopted.

Getting Started with High Residue Farming

We started by recognizing that farming is a risky business. To reduce risk, you manage those factors under your control and try to provide your crop with optimal growing conditions. This is true whether you use a tillage-based or an HRF system. The goals are also the same in both systems: short-term profit and good stewardship of resources, allowing future production and long-term profits. The difference between the two systems lies in the conditions that you have to manage and the tools you use to manage them.

Similarly, both tillage-based and HRF systems require tradeoffs: tradeoffs between profits and stewardship, between higher input levels and efficient use of those inputs, between maximizing plant growth and conserving soil. In this give-and-take of farming, your job is to find the optimum solution for balancing these tradeoffs. As you learn more about HRF, ask yourself if our increased understanding and improved technologies may have changed the balance of tradeoffs for your operation (see questions in sidebar).

There are still many unanswered questions about implementing HRF in the irrigated Far West. Can cover crops and green manures maintain soil quality in

Here are some questions to consider that might indicate whether HRF is likely to benefit you:

1. Do you grow some agronomic crops like wheat, corn, dry beans or alfalfa?
    a. These crops have been grown successfully under HRF and are a good place to start.
2. If you could plant without tillage after the first crop is harvested, would you have new opportunities for double cropping?
    a. HRF systems allow quick turn-around between harvest and planting the following crop
3. Could you use the time savings associated with HRF to farm more land, earn additional income, or make significant improvements in your quality of life?
4. Are you planning to replace your planter or grain drill soon?
5. Could you use custom farming to offset the cost of new equipment?
6. Are your pumping or water costs, or both, high?
7. Do you have problems with water infiltration, runoff, or wind or water erosion?

If you answered yes to one or more of these questions then you should run a more detailed economic analysis of your farm. Table 4 shows some general rules–of-thumb based on data from other regions.

Table 4. The effect of high residue farming on various expenses.

Expense	Increase	Decrease
Herbicides	✓	
Machinery purchases (upfront costs)	✓	
Machinery ownership (depreciation) and maintenance		✓
Fuel		✓
Labor		✓
Pumping/water costs		✓

rotation with crops requiring tillage? Will the benefits of HRF be diminished in our sandy soils? These questions will be answered over time, but for now, we can look to other regions for examples of HRF success.

In some regions, for some crops, HRF has become the norm. "No-till" management is now used on 259 million acres worldwide, including 65 million acres in the U.S. (Derpsch et al. 2010) Producers farming these acres are using planters and drills designed to handle high amounts of residue; modern combines that spread residue uniformly; pre-emergent and post-emergent herbicides and herbicide-tolerant crops; seed treatments; and modern varieties. Together, these tools allow them to produce high yields and maintain profits.

If you think that HRF is something you want to try, starting with the crops being produced with HRF in these other regions is a good place to begin.

Here are some tips from others who have decided the time was right and tried HRF.

1. Learn as much as you can from:
    a. Other farmers who are making it work;
    b. Publications; and
    c. Workshops and conferences.
2. Start small.
    a. Choose one crop sequence for one field.
    b. Hire someone who has the right equipment to do the planting.
3. Start easy.
    a. Choose your best field: best soil that is well drained, with a smooth surface and no compaction.
    b. Plant after coming out of a perennial crop like alfalfa.
    c. Plant into a field with low weed pressure.
    d. Do not try continuous corn to start.
4. Commit to making it work.
    a. Your first years using HRF will require commitment, ingenuity, compromise, and courage.
    b. Don't forget to change your way of thinking. As University of Nebraska no-till specialist, Paul Jasa says, "If you think no-till will work or that no-till will fail, you are right." Your attitude will affect your management and that will determine the outcome.

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Glossary

crop residue. The part of crop plants that remains in the field after harvest.

direct seeding. Planting directly into untilled soils, without seedbed preparation. Also known as no-till.

Far West. In the United States, the regions of Washington, Oregon, Idaho, California, Arizona, and New Mexico that produce irrigated vegetables in rotation with agronomic crops such as wheat, corn, and alfalfa.

high residue farming. An umbrella term for cropping systems in which the volume of the soil that is tilled is reduced in order to maintain residue cover on the soil.

no-till. See direct seeding.

soil aggregate. A composite of soil particles of soil that clump or bind together to give soil its structure. The spaces between aggregates provide conduits for air, water, and roots.

soil tilth. The physical condition of soil, especially in regard to its ability to grow a crop.

strip-till. A farming system in which the soil is tilled and crop residue removed from a 6- to 12-inch-wide strip where the next crop will be planted. The residue-covered area between the strips is left undisturbed.

transpiration. The movement of water through a plant and out of its leaves to the air. It is often considered along with the water evaporation directly from the soil to determine "evapotranspiration" or the total water loss from a cropped field.

vertical tillage. Tillage carried out by tools that engage the soil vertically rather than horizontally. They generally operate at shallow depths and at higher speeds than horizontal tillage tools. Vertical tillage is used to size residue, provide some incorporation of residue, and loosen the soil surface.

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