High Residue Farming under Irrigation: Crop Rotation

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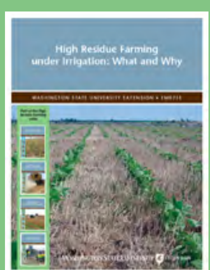
Part of the High Residue Farming series



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High Residue Farming under Irrigation: Crop Rotation

Andrew McGuire, Extension Educator, Ag Systems,
Washington State University Extension

This is the second in a series of publications on High Residue Farming under Irrigation. This publication discusses crop rotation for **high residue farming** (HRF) in irrigated systems. Specific topics include rotational diversity and sequencing, rotation for residue management, cover crops, and special considerations for irrigated cropping systems in the far western United States: Washington, Oregon, Idaho, California, Arizona, and New Mexico (the **Far West**).

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

EM071—High Residue Farming under Irrigation: What and Why 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").

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.

What is High Residue Farming?

High residue farming (HRF) is an umbrella term that covers cropping systems in which the volume of the 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.

Crop Rotation in High Residue Farming

Although it is often said that direct seeding begins with harvest of the previous crop, it actually begins with selection of the **crop sequence**. **Crop rotation** is a complicated matter. As with many farming decisions, there are many economic, agronomic, and environmental tradeoffs to consider:

- Economic
  - Price of each crop from year to year
  - Market potential
  - Amount of risk involved
- Agronomic
  - Expected yield
    - Previous crop
    - Soil
    - Climate
  - Impacts of pest control
    - Previous crop
    - Potential pest pressure
    - Available tools
      - Cultural
      - Chemical
  - Production

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.

- Equipment needed
  - Planting
  - Spray application
  - Fertilizer application
  - Harvest
- Experience and skill I have growing the crop

- Environmental
  - The crop's contribution to protecting future productivity of the land
  - Other stewardship impacts of the crop

When faced with an approach such as high residue farming that has significant upsides but also tradeoffs, a farmer should ask, "Can the downsides be controlled with management (timing, crop selection, marketing, etc.) or with technology (equipment, fertilizers, pesticides, etc.)?" If these can be controlled, then plan to manage the problem and take advantage of the benefits. Under HRF management, careful selection of crop sequence can be part of this solution.

A strategically planned crop rotation can have many benefits. It can reduce the risk of developing herbicide-resistant weeds by rotating herbicide programs. It can reduce the risks presented by bad weather and spread the workload more evenly over the year. In some cases, strategic crop rotation can also allow you to grow more crops per year.

Often, taking advantage of rotational benefits is more important in HRF systems than in systems relying more on tillage. This is because tillage can eliminate some pests and weeds, allowing a less diverse crop rotation to be successful. Once tillage is reduced or eliminated, crop rotation becomes a key management strategy for weeds and pests. Yet the benefits of crop rotation go beyond weed, disease and insect pest avoidance. Rotations with more diversity can also reduce economic risk (Francis and Clegg 1990) and improve soils (Karlen et al. 2006) better than less diverse rotations.

In general, the more diverse a rotation, the better the results, within your labor, time, market and other system constraints. Diversity is increased when you rotate:

- Crop types: grasses, legumes, and non-legume broadleaf crops
- Planting dates: early spring, late spring, and fall
- Crops with different temperature tolerances: cool season, warm season, and overwintering crops
- Perennial crops and annual crops: alfalfa and timothy hay are one good way to start with HRF and can be used to control some problem weeds.

Under HRF, you can often increase rotational intensity by growing more than one crop per year. The time saved from not having to clear the ground of crop residues before planting can open up double-cropping opportunities not available with clean tillage systems. Short season vegetables, forage crops, and crops such as buckwheat can fit into rotation with crops that are harvested early, such as green peas, early sweet corn, and small grains, or with hay crops coming out of production. Your season will only be limited by your climate and not by the time needed to deal with crop residue.

When evaluating crops, think in terms of crop sequences, rather than single crops. It may be that a single crop is marginal in terms of profits, but if it lets you improve soils, include a double crop, or break up pest cycles, it may prove profitable as part of the overall crop sequence.

Crop Rotation for Residue Management

Crop sequence is especially important to HRF because it affects the quality and quantity of the crop residue on your fields. Crops can produce residue that is small in diameter (as from small grains), large (as from corn), or viny (as from peas and beans). Some crops produce residue that is more lignified (woody) than other residues, making it more resistant to decomposition and harder to cut. Crops also differ greatly in the quantity of residue they produce. Grain corn, sweet corn, and small grains produce a large amount of residue, whereas silage corn, peas, beans, alfalfa (depending on when the last cutting occurred), and most vegetables produce relatively little residue. Both the residue quality and quantity can be managed to some extent after harvest, but you should be aware of the residue implications when choosing a crop sequence.

Residue Production by Crops. For grain crops, residue production is related to grain production. To estimate residue production, divide your expected yield, in bushels, by 40 for corn and sorghum or by 20 for wheat and other small grains. This gives you the amount of residue in tons per acre.

The production of residues from crops like dry beans and vegetables may or may not be related to yield. However, these low residue crops generally produce less than a ton of residue per acre.

REMEMBER:
Focus on crop sequences such as "wheat after beans," "beans after corn," or "buckwheat after alfalfa," rather than on individual crops or cycles of crops. This will help you better manage the residue of one crop for the benefit of the following crop.

If you have questions about how a specific crop sequence and tillage plan is likely to affect your soil's quality or erosion potential, your local Natural Resources Conservation Service (NRCS) office is a good place to start. NRCS soil conservationists can help you compare several crop sequences and the various HRF and non-HRF tillage practices to be considered, through computer models that calculate the likely impacts on soil conditioning index and soil tillage intensity rating.

In general, it is more difficult to plant after high residue crops. (See Table 1.) But if you grow only low residue crops, you may not reap the full benefits that come from maintaining residue cover. Considering some examples of sequences commonly used by farmers will show how they balance ease of planting with other considerations.

In the Midwest Corn Belt, direct seeded "soybeans after corn" is a popular sequence that balances multiple factors such as residue amount, planting dates, and tolerance to low soil temperatures. This rotation maintains residue cover by rotating a low residue crop with a high residue crop. In addition, because soybeans are planted later, the soil under the heavy corn residue cover has had time to warm up (except in northern locations). Then, the following spring, temperature-sensitive corn is planted into the lighter soybean residue cover.

Another common Midwest rotation, "corn after corn," is more difficult to manage and is chosen mainly for economic reasons. In this rotation, heavy residue cover reduces the soil temperature at the time of corn planting and increases the risk of pest problems. Farmers have figured out how to do back-to-back no-till corn, but it requires careful management of residue, soil fertility, and in some cases, pests (Jasa 2007).

Excessive buildup of crop residue can be a challenge in the irrigated far western U.S. High yielding, high-residue crops leave abundant residue that decomposes slowly in the arid climate (sidebar). In addition, corn in the Far West is often dried in the field, pushing harvest later in the year. It is not uncommon for corn harvest to take place in November or later for this reason, giving the residue less time on the ground to decompose.

After growing several high residue crops in a row, you may accumulate too much residue. Including low residue crops in your rotation can help avoid this problem.

Variety Selection

Crop varieties can differ significantly in the quality and quantity of residue they generate, their ability to germinate in cool soils, early seedling vigor/emergence and, in some cases, resistance to soilborne disease. For example, some seed companies now rate their corn varieties for their ability to thrive under high residue conditions. Ask for this information and when it is available, consider it along with other desired variety traits.

Cover Crops

The benefits of including cover crops in a crop rotation are well known and covered in other publications (see Resources). In HRF, cover crops can help provide optimum germination and emergence conditions for the subsequent crop in a number of ways. First, cover crops use water, drying the soil and allowing it to warm more quickly. This can help counteract the cooling effect of crop residue. In addition, the channels that the roots of cover crops leave after they decompose improve the flow of air and water through the soil. They also provide channels for growth of your cash crop's

Table 2. Difficulty of various HRF cropping sequences.

Crop to be Planted	Preceding Crop (residues[1] to manage, listed from most residue to least): Corn, grain	Small grain, winter	Small grain, spring	Sweet corn[2]	Green peas[2]	Dry edible beans	Alfalfa, spring killed	Timothy, grass hay, pasture	Corn, silage	Alfalfa, fall killed
Corn, grain or silage	A	A								
Small grain, winter		A		A					D	
Small grain, spring	D									
Sweet corn	A	A	A		B					
Green peas	A	A			?					
Dry edible beans					?		B	B		
Buckwheat, Summer annual forages			B		B		B	B		
Timothy, grass hay, pasture	C	C								
Alfalfa	C	C					E			E

[1]Removal of crop residues after harvest can make any crop sequence easier to manage, but may reduce other benefits.
[2]Poor residue management at harvest by the processor can make following these crops more challenging.

Key: Difficulty in management of HRF for this crop sequence

High	Moderate	Easiest	When a crop is followed by the same crop, yields are usually decreased; this is more pronounced with HRF systems.	Caution	Impossible sequence due to timing of planting

These ratings are based on the residue type and quantity, normal planting dates, and specific challenges to crop sequences, when known.

A - Residue may cool soil in spring and delay emergence if not managed

B - Double crop potential

C - Heavy residue makes seed placement a challenge

D - Not recommended due to high risk of fusarium head blight

E - Not recommended due to autotoxicity in alfalfa

? - Unknown

Decomposition of Residue

One of the big differences between the far western U.S. and the humid Corn Belt is the speed of residue decomposition. In the arid Far West, our low relative humidity, even with irrigation, results in low moisture levels in surface residue. This limits biological activity and thus decomposition, especially during the summer when temperatures are conducive to decomposition. (In the winter, low temperatures generally limit decomposition, even of wet residue.) Although the level of relative humidity that impedes decomposition varies with the characteristics of the residue, most organisms are inactive below 80–85%, and very little decomposition happens below 75% relative humidity (Bartholomew and Norman 1946). See Figure 1 for a comparison of the relative humidity levels of Yakima, Washington, and Waterloo, Iowa.

Even after irrigation, surface residue only remains wet enough to support biological degradation for a relatively short time. And while the potential for decomposition increases once the crop canopy closes and at night, the increase in decomposition is relatively small (Cavero et al. 2009). This is why residue levels tend to increase over time in HRF systems in the Far West, especially when growing continuous high residue crops, like wheat and corn. Arizona farmer, Ron Rayner, has found that after 8 years of using no-till, "The wheat straw in our no-till fields never really goes away". In contrast, farmers using long term no-till in humid climates often have trouble maintaining enough residue cover (Jasa, pers. comm.).

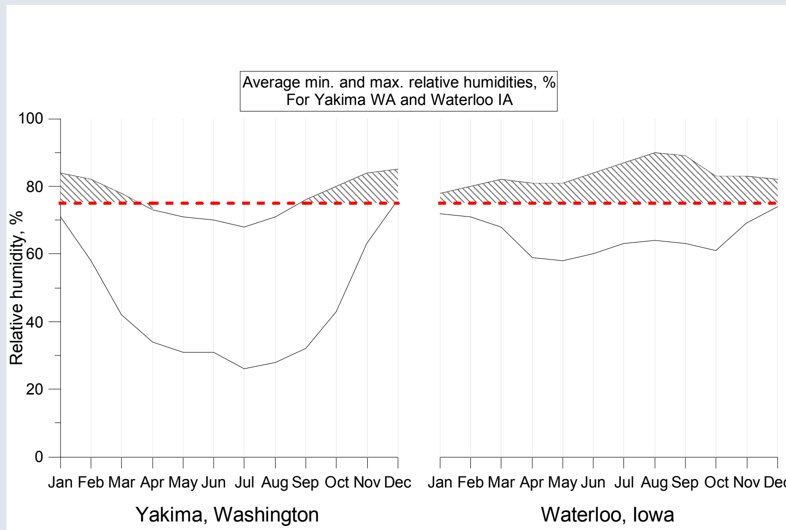

Figure 1. Comparison of the time when relative humidity levels are conducive to residue decomposition (>75%) in Yakima, Washington, and Waterloo, Iowa. Note that temperatures are most conducive to decomposition in the summer, when humidity levels are low in Yakima.

This slow decomposition can be a challenge with high residue crops. On the other hand, with lower residue crops, it can be an advantage. Lower residue crops such as peas or beans, which in humid areas could result in having bare soil because of rapid decomposition, can provide, in our arid climate, sufficient soil cover to obtain many of the benefits of HRF.

roots (Rasse and Smucker 1998). Over time, these root channels make the soil more resistant to compaction.

Cover crops add organic matter to the soil and contribute to better soil structure. The carbon and other nutrients added to the soil by a cover crop all help to increase nutrient cycling, especially of nitrogen and phosphorus. This can help replace the nutrients that were previously supplied by tillage-induced decomposition of crop residues.

Farmers in other regions have found that these benefits of cover crops are particularly helpful in easing the transition from clean tillage to high residue farming systems. Most producers using long-term HRF report going through an early transition stage (3–5 years) when they were challenged to maintain yields. Some of this transition can be attributed to the learning of new skills needed with HRF, but some of it is due to the changes in the soil over this period. Once through this transition, farmers found that yields stabilized or improved. Cover crops, in many cases, have been able to shorten this transition period, probably by accelerating the soil-building process.

In the past, single species cover crops have been the norm, with a few 2- or 3-way mixes tried at times. Now, farmers across the U.S., from places as diverse as North Dakota, North Carolina, and Colorado, are reporting the benefits of including multi-species cover crops in their no-till rotations. These cover crop "cocktails" are blends of five or more species that are allowed to grow for as little as six weeks, although many farmers allow them to grow much longer. Farmers using cocktails speak mainly of the benefits to the soil, but there is also the benefit of adding diversity to their rotation, especially if the species chosen are not also crops grown in the region. Although it may be a little more difficult to find a blend of non-crop species in the Far West's diverse agriculture, these cover crop "cocktails" are worth investigating.

Crop Rotation in Far West Cropping Systems

In the Columbia Basin of Washington State, and similar regions in Oregon, Idaho, California, Arizona, and New Mexico (Figure 2), farmers produce irrigated vegetables in rotation with agronomic crops such as wheat, corn, and alfalfa. In these regions, crop rotations in the sense of repeated crop sequences often do not exist. In their place, farmers take into account the many factors mentioned at the beginning of this publication, with HRF as just one more factor, and make the best choice of crop for their goals. The result is a dynamic, diverse crop sequence—not random, but also not a fixed sequence. While this can be a challenge to HRF, it can also be a benefit (Hanson et al. 2007). First, the challenges.

Figure 2. Irrigated vegetable-growing areas of the far western United States.

The sheer number of crops grown in some of these regions (more than 150 in the Columbia Basin of Washington) 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. Crops that do have proven HRF systems, such as wheat and corn, are often less intensively managed than vegetable "cash crops," but producing these agronomic crops with HRF will still require a level of management that farmers may not be accustomed to giving them, while producing vegetable crops with HRF will require experimentation to develop systems that work.

Specialization of crop production, the high level of leased land, and processing vegetables complicate matters further. For economic and management reasons, some farmer specialize in producing one or a few high value crops, such as garlic or potatoes. These farmers may be reluctant to buy needed HRF equipment for other crops. Because of this specialization, a large proportion of the agricultural land may be leased land every year. For leased land, the soil-building benefits of HRF are less important because no single farmer manages the land over the long term. If a farmer leasing land does want to implement HRF, managing the soil and residue is more difficult when they do not control the management of the previous crop. Similarly, with the production of processed vegetables, problems with residue distribution and soil compaction may arise because the processors generally determine the timing of harvest and use their own equipment. Root crops such as potatoes, onions, carrots, and sugar beets require tillage for harvest at a minimum, so continuous HRF is not possible. The effect that all this will have on the soil benefits of HRF has not been determined in these regions.

This is how Far West cropping can be a challenge to the adoption of HRF. Fortunately, the same crop sequences also benefit HRF.

The benefits of the dynamic, diverse crop sequences of Far West irrigated agriculture stem from the diversity and the variability of the crop sequences. The question is not "which crop rotation is the best?" but "what crop sequence best keeps pests at low levels, builds **soil tilth**, and optimizes profits?" (Pests will always be there—there is no utopian crop sequence or system that eliminates them.) Three principles, taken from crop rotation research, can be extrapolated to these ever-changing crop sequences:

1. Greater diversity in crops is better because it keeps any one pest from becoming a big problem.
2. Greater complexity in crop sequences is better because pests can adjust to simple crop cycles.
3. Greater diversity of crops also turns out to be best for building soils (Karlen et al. 2006).

HRF in the Far West can easily take advantage of Principle 1. Compare the diversity described above to the Midwest, where farmers who want to add more diversity are often working from the starting point of a two-year rotation, or even continuous corn. In contrast, while farmers in the Far West may not all grow 150 crops, each farm is generally already used for many more crops. This means that diversity is already there, with the accompanying benefits to pest control and soil building.

Variability (not random, but not a fixed sequence) of crop sequencing is also important, especially where tillage is no longer a tool for managing pests. Here again, Far West farmers have an advantage. The variability of Far West crop sequences, driven by ever-changing consumer and market needs, can be more beneficial than two- or three- year crop rotation cycles. The variable crop sequence results in changing conditions for weeds, insects and diseases, which, therefore, become less of a problem. This can also lead to greater efficiency in nutrient and precipitation use, reduce external inputs, and lower production risk (Hanson et al. 2007).

Furthermore, some of the many crops grown in cropping systems of the Far West are especially useful to HRF. For instance, hay and other forage crops are a good way to transition into HRF because they leave less residue in the field after harvest and require much less tillage to produce. Unlike other regions of the US where corn <u>or</u> wheat (but not both) are grown, farmers in the Far West often grow both of these crops in their crop sequences. These high residue crops can help maintain the beneficial residue cover for low residue vegetables.

This diversity and variability also mean that crop rotation studies are difficult for farmers in the Far West to interpret and use. Unless the stars align and a particular study happens to match their current plan—which may change at any time—the results may not apply. Nonetheless, by paying attention to particular crop sequences—wheat to potatoes, or carrots to dry beans—and to the frequency of the any one crop—"how long has it been since we grew potatoes on that field?—Far West farmers can still gain insight from crop rotation research.

Conclusion

Careful selection of crop sequence is sometimes bypassed in modern agriculture in favor of technology, equipment, fertilizers, and pesticides. Research, however, shows that the effects of crop sequence (and crop rotation, if the sequence is repeated) often outweigh those of pesticides, fertilizers, or other soil amendments. The only factor with a consistently larger effect is climate, which is out of anyone's control. To implement HRF successfully and to gain all its benefits, crop sequence must be managed thoughtfully. It is not an option.

Resources

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Glossary

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

crop rotation. A repeated sequence of two or more crops.

crop sequence. One crop followed by another crop in a field, as opposed to a **crop rotation** which is a repeating cycle of crop sequences.

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 soil that is tilled is reduced in order to maintain residue cover on the soil.

no-till. See **direct seeding**.

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 crop will be planted. The residue-covered area between the strips is left undisturbed.

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