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DEFICIT IRRIGATION OF A DIVERSE IRRIGATED ROTATION: JAKE MADISON

FARMER-TO-FARMER CASE STUDY SERIES: INCREASING RESILIENCE AMONG CEREAL-BASED FARMERS IN THE INLAND PACIFIC NORTHWEST

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DEFICIT IRRIGATION OF A DIVERSE IRRIGATED ROTATION: JAKE MADISON

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Abstract

Jake Madison farms in Echo, Oregon, growing wheat, corn, alfalfa, canola, and onions. He also leases ground to other farmers for production of potatoes, peas, beans, and grass seed. In this publication, Madison discusses how deficit irrigation of wheat, corn, and alfalfa allows him to conserve water for onions and other high value crops. The strategy has enabled him to run a profitable farm business despite limited access to irrigation water. This video provides an overview of the major challenges and limitations of Madison's deficit irrigation strategy.

This case study is part of the Farmer-to-Farmer Case Study project, which explores innovative approaches regional farmers are using that may increase their resilience in the face of a changing climate.

Information presented in the case study is based on growers' experiences and expertise and should not be considered as university recommendations. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement. Grower quotes have been edited slightly for clarity, without changing the meaning.

Readers interested in other case studies in this series can access them on the REACCH website as well as in the WSU Extension Learning Library.

Jake Madison. Photo: Darrell Kilgore, Washington State University.

Location: Echo, OR

Average Precipitation: 9 to 10 inches (mix of irrigated cropping and dryland ranching)

Cropping System: Irrigated diversified vegetable rotations. Madison grows wheat (grain and seed), corn (grain and seed), alfalfa (hay and seed), other types of hay, winter canola, and onions. He leases ground to others for potatoes, peas, beans, and grass seed, including some organic crops. The farm also includes non-irrigated rangeland.

In this companion video, Jake Madison provides an overview of the farm's deficit irrigation strategy and the opportunities and challenges it provides.

Map: Kaelin Hamel-Rieken, Washington State University.

Jake Madison is a fourth-generation farmer in Echo, Oregon who grows irrigated vegetables in diversified rotations that include onions, wheat, corn, and alfalfa. He also leases ground to other farmers for production of potatoes, peas, beans, and grass seed, including some organic crops. Madison grew up on the farm, and has taken an active management role since 2009. He became owner of the operation in 2012, after purchasing it from his father. Today, his farm includes a little over 8,000 irrigated crop acres, mostly on sandy loam and fine sandy loam soils, and roughly 9,000 acres of non-irrigated rangeland (NRCS 2013).

The Madison Farm faces challenges because of limited water rights for irrigation. To remain profitable, Madison deficit irrigates wheat, corn, and alfalfa, giving these crops less water than they would need to achieve maximum yields, but, hopefully enough water to be profitable. This strategy saves water for the farm's most valuable crops, primarily potatoes and onions.

Making Every Drop of Water Count

Throughout the 1980s, when the farm was run by Madison's father, Kent, it had two water rights: a small surface water right from a creek running through the property, and a junior water right for ground water with an instantaneous rate of up to 1,000 gallons per minute. They used the water to grow 1,500 to 2,000 acres of irrigated crops. In the late 1980s, their groundwater right was revoked when the area was classified as a critical ground water area, because water in the underlying aquifer was declining at an unsustainable rate.

Rising to meet this seemingly insurmountable challenge, Kent was able to negotiate new water rights from the state of Oregon, through a highly unusual partnership. Through this partnership, he expanded the farm's irrigated acreage and ensured the farm's continued viability. Today, Madison relies on four sources of irrigation water.

About 70 to 90 percent of the farm's water in any given year is pumped more than 600 vertical feet over a 30-mile trek from the Columbia River. The water right underlying this use allows up to 9,600-acre feet of water per year, and an instantaneous limit of 15,000 gallons per minute. The instantaneous limit is substantially lower than a typical water right for a fully irrigated farm—and this limitation was a key reason this unique new water right was granted in 1989. At the time, the Madisons were collaborating with Marshall English, Professor and Irrigation Extension Specialist at Oregon State University, on the demonstration and refinement of deficit irrigation methods. (See the sidebar *Research on Deficit Irrigation of Wheat in the Columbia Basin*.) No new year-round water rights have been issued by Oregon on the Upper Columbia since this water right was granted, due to concerns related to threatened and endangered fish species (Santen 2013).

About seven percent of the farm's annual water is wastewater supplied from a nearby potato processing plant. This water is applied to the land on the Madison farm and is generally enough to irrigate one circle per day, throughout the year. Timing of re-use water application must be consistent with some food safety restrictions, but given the significant acreage and variety of crops Madison grows, meeting these regulations has not been difficult. During the winter, they generally spread the water on ground that is used to grow alfalfa hay, monitoring to make sure that they don't over-fill the soil profile.

Depending on the year, as little as 2 percent and as much as 20 percent of the farm's water may come from Butter Creek, which runs through the property. The creek is fed from mountain snowpack, and dries up entirely in years when snowpack is low. Madison explains, "We pump as much as we legally can out of [Butter Creek], but we can't rely on it. Some years it starts in February and runs until June. Some years it starts in March and is done in April."

Less than two percent of the farm's water comes from an on-farm aquifer storage and recovery (ASR) well that was developed by Madison's father. The well was the first of its type used for agricultural purposes in the world. (See sidebars, *Kent Madison* and *Aquifer Storage and Recovery*.) Before the ASR well could be installed, the state had to pass legislation that allowed water to be stored and used in this way. Since it is dependent on precipitation, the amount of water stored is quite variable from year to year. When mountain snowpack is high and high flows start in early spring, the aquifer can store more water for irrigation. In a notably wet year, they can store as much as 1,000 acre-feet of water in the aquifer, whereas in a notably dry year like 2012 they were only able to store 101 acre-feet of water. Although the strategy is not yet widely used on other regional farms, this ground-breaking method for storing excess water for irrigation use later in the year could eventually have profound effects for this region and other agricultural areas of the world.

Kent Madison

Kent Madison. Photo: Darrell Kilgore.

Kent Madison has been an innovator his whole life. Not only did he develop the first aquifer storage and release (ASR) well for agricultural purposes in the world, but in the process, he invented a water regulation valve that maintains a constant pressure under variable injection levels. He was also an early grower of canola and now is working to produce canola oils for the retail food market. Kent says that his attitude towards innovation came from necessity. "The farming lifestyle, especially in the deficit irrigated systems and the natural resource-based systems that we live in, caused me to think outside the box. If I had developed this farm with a full water right, and had all the water I needed, I wouldn't have developed deficit irrigation technology, and I wouldn't have developed ASR technology—because I wouldn't have needed it."

When Kent considers the differences he has seen in water management throughout his years of farming, he thinks that the physical aspects of managing water have become much easier, while the social and regulatory aspects have become considerably more challenging. "In Jake's generation it's literally the computers that are telling the pumps how to speed up and slow down, and talking to the circle and asking if it has adequate pressure. If it doesn't have adequate pressure it automatically adjusts the variable drive too. So it's become easier in my opinion from a management standpoint. From a regulatory standpoint it's become much more difficult, and from a societal standpoint it's also become much more difficult."

Though these last two sources provide relatively small amounts of water, they are critically important in a deficit irrigation context. Because many crops are not receiving optimal irrigation, even a small amount of additional water can benefit yields. As Madison says ruefully, "It doesn't take much water on ground that's 'short-watered' to have a big impact."

Aquifer Storage and Recovery

Karen Hills, Center for Sustaining Agriculture and Natural Resources, Washington State University; and Georgine Yorgey, Center for Sustaining Agriculture and Natural Resources, Washington State University

Aquifer Storage and Recovery (ASR) is a method used to store high-quality surface water by injecting it in an underground well during times when it is readily available and recovering it later, generally through the same well. ASR wells are used to inject and recover water for municipal drinking water supplies, agricultural irrigation, and ecosystem restoration projects. Though they can be expensive, ASR systems can be cost effective compared with alternative options for above-ground storage, which may require the construction of reservoirs and be limited by space availability. ASR wells avoid some of the negative environmental impacts created by other methods for storing water, as they do not require installation of a dam on a stream. They are also more efficient in that they have a smaller footprint and avoid the potential risk of evaporation and contamination that faces water stored in open reservoirs.

The layout of ASR projects varies depending on the site where they are installed, though the general process is similar. At the Madison Farm, water is collected from shallow alluvial groundwater, which is abundant during the spring, in specially engineered basins (Figure 1). Water drains from the basins through the soil profile to a shallow alluvial well. It is then pumped to a basalt ASR well, where it is stored in a deep regional aquifer for later use. During the summer, when the farm needs the water for irrigation, they pump an amount equal to the amount of water they have injected into the well out of their ASR well for application to fields.

The water in ASR systems must meet strict water quality standards before injection. The goal of the ASR system is to recover a high percentage of the injected water of sufficient quality to be immediately put to beneficial use (Rambags et al. 2013). In the case of freshwater aquifers, 100 percent recovery is not uncommon.

Careful planning and design are essential to the development of a successful ASR project. Water availability, water demand, source water characteristics, and aquifer characteristics guide the initial design and type of the ASR system. Depending on these factors, an ASR facility design might consist of shallow or deep infiltration wells, and horizontal or vertical wells. Pre- and post-treatment facilities and monitoring wells may need to be included in some cases (Rambags et al. 2013).

The development of ASR systems is subject to state and local regulations that vary by location. The Madison farm's ASR project, which has been in operation since 2006, obtained required ASR limited licensing from Oregon Water Resources Department. For more information on regulations governing ASR systems in the Pacific Northwest, refer to Washington, Oregon, and Idaho's websites.

Figure 1. Schematic showing the design of the ASR project on the Madison Farm. Image: GSI Water Solutions, Inc.

Research on Deficit Irrigation of Wheat in the Columbia Basin

Longstanding regional research in the Columbia Basin suggests that the deficit irrigation strategy Madison uses can be profitable when water is constrained (English 1990). Under these conditions, when land is not limiting, water saved through deficit irrigation can be used to irrigate additional land and increase farm income. Generally, one would expect that the optimum level of water use would be reached when the reduction in income from reducing irrigation is less than or equal to the income derived from irrigating the additional increment of new land. In other words, when the additional costs of the strategy outweigh its benefits. However, the optimal amount will vary from year to year, due to relative changes in crop and input prices, and variable crop production response to water, fertilizer, weather conditions, diseases, pests, and other factors. Successful deficit irrigation is thus most likely for crops with low water requirements and good potential for profitability over a wide range of irrigation or rainfall scenarios, such as winter wheat (English 1990).

Deficit irrigation has long been used by some farmers in the Oregon Columbia Basin. An analysis of 31 fully-irrigated and partially-irrigated wheat fields on nine farms in the Columbia River Basin from 1984 to 1986 indicated that, at that time, deficits ranged from 30 to 70 percent of the full water requirement (English et al. 1990). Some deficit-irrigating farms used high-frequency irrigation (for example, daily), while others irrigated less often, as infrequently as every few weeks. Under experimental conditions in Hermiston, frequency of irrigation did not affect yields under deficit irrigation (English and Nakamura 1989; Musick 1991). Sustained yields were attributed to the deep rooting potential and drought tolerance of winter wheat, the high water holding capacity of the soil, and the absence of salinity effects at the site.

Economic analysis of deficit irrigating farms in the Oregon Columbia River Basin suggested that deficit irrigation has been a profitable long-term strategy for farms with limited water supplies, but also indicated that water reductions may have been greater than economically optimal in some cases (English et al. 1990). Overall profitability of deficit irrigation stemmed from marked reductions in farmers' costs of production. Although both were important, savings from reduced variable production costs (such as seeding, harvest, and chemical application) were larger than savings from reduced variable irrigation costs (such as energy, labor, and maintenance). Reduced fixed costs for irrigation were also important for some, but not all, farms (English et al. 1990).

Current Irrigation Strategies

Deficit Irrigation

To put into perspective just how limited the Madison's water is, he points out, "To irrigate our full 8,000 acres you'd be well over 60,000-gallons a minute for a fully appropriated water right, even with today's irrigation technology (compared to 15,000 gallons per minute for their main water right)…So our water is stretched pretty thin."

To achieve profitability within this context, Madison uses deficit irrigation to spread his water over more acres and prioritize where it will have the greatest financial benefit. As Madison explains, "The only things that get irrigated fully are the vegetable crops, the potatoes and the onions (Figure 2). Even our corn doesn't get full irrigation all of the time." By strategically managing the timing and amount of water stress for less valuable crops including alfalfa, corn, wheat, and mixed stand barley–pea hay, Madison aims to produce the most profitable yield and quality that he can of these secondary crops.

Water stress can be mitigated to some extent by adjusting irrigation timing, especially for more deeply rooted crops. During the early part of the season, when the farm has access to plentiful water, Madison irrigates to fill the soil profile with water. Later in the season, when crops are experiencing water stress, their root systems are able to extend further into the soil profile, tapping into the stored water.

Crop mix is also important. For example, winter canola is grown on fields that they know will get very little water in the spring, as it performs relatively well under these conditions. It thus plays an important role in keeping their water demands in line with water availability.

Figure 2. High-profit vegetable crops, including potatoes and onions, receive full water, while wheat, corn, alfalfa, and other types of hay are deficit irrigated. Photo: Darrell Kilgore.

Even with these strategies, using deficit irrigation means accepting that crop yields will be lower than normal. As Madison explains, "The hardest part of that is knowing that our yields will never be as high as those of our fully irrigated neighbors and so it's been a tough pill to swallow in managing this place…I'm never going to be able to keep up with everybody else's hay yields. I'm never going to be able to keep up with everybody else's wheat yields."

Madison modifies his crop management practices to reduce costs and ensure that lower-yielding crops are still of high quality. "We can't plant and fertilize at the same rate as our neighbors, because we know we're not going to get the water to support similar yields. If we do that, we end up producing soft white wheat that's 55-pound test weight and has protein in the 17 percent range. (Target test weight for this class of wheat is 60 pounds per bushel and target protein levels range from 8.5 percent to 10.5 percent for US No 1 soft white wheat). So we'll try to plant 20, 30, sometimes 40 pounds [of seed per acre] less than what our neighbors are planting, to get a 60-bushel yield that's decent quality, that has good test weight and the appropriate protein."

Crops are fertilized based on a yield goal that may vary across the farm depending on water availability at different locations. Split fertilizer applications help reduce financial obligations until Madison has a better sense of water availability for that year. "We normally put down 40 to 50 percent of what we figure the crop is going to need in the fall. That's allowed us to control some of our input costs. If we're having a dry spring and we know we're not going to be able to get the yield that we're hoping for, we won't put any more fertilizer on. If things are looking great, and we're having a good, wet spring, then we'll come back and do an additional liquid application of fertilizer and some fungicide through the irrigation system."

Deficit irrigation also has implications for managing weeds and diseases. "While controlling weeds is critical in any irrigated cropping system, it is *really* critical under deficit irrigation because those weeds are competing for limited water. If they consume the water, there's a big negative impact on crop yields." Disease impacts are indirect, a result of his more limited crop rotation options, compared to fully irrigated farms. For example, Madison grows a lot of wheat, because its deep root system can access water deeper in the profile, helping it overcome water stress late in the season. Thus, because of the limited crop rotation, Madison struggles to manage some wheat diseases, especially in areas of the farm where the ground is not suitable for growing potatoes or onions. To address this issue, Madison is exploring other alternative crops to increase diversity, including alfalfa seed, additional hay, or irrigated pasture that he could graze directly.

Reduced yields from deficit irrigation also impact crop marketing strategies. For example, Madison generally finds it most profitable to produce lower-quality hay for haylage or silage, rather than export-quality hay or even higher-quality feeder hay. "If there's only $10.00 or $15.00 a ton difference between the two we'll go for the tonnage and usually end up doing better going for big tons at a lower price than going for a few tons at a higher price."

Irrigation Equipment and Management

Under deficit irrigation, even small increases in the water available for deficit-irrigated crops can greatly improve productivity and profitability. This incentivizes Madison to invest in efficient irrigation equipment and management. As Madison points out, "It doesn't take very many inches of water in June or July to go from 75-bushel wheat to 120- or 130-

bushel wheat, and that has a big impact on profitability because most of your costs are the same.… You have a little bit higher seed cost if you're going to shoot for a higher yield, a little bit higher fertilizer cost. Your spraying costs are the same.… as far as equipment [expenses] and labor, costs per acre are the same. It's the same. It's just a matter of pumping a little bit more water and the opportunity to see some big impacts."

Over the last ten years or so, like many other irrigated farms, the Madison farm has converted all of their irrigation pivots to 15 psi low-hanging nozzles that use 7.5 gallons per minute (Figure 3). Drip irrigation is the next step. Though he has not yet made the switch, Madison is considering using drip irrigation on onions. Other growers have told him that drip systems use about three quarters of the water used by overhead irrigation, while increasing yields. However, drip systems are costly. The main lines, filter bases, and other parts can be reused for more than one season, but the drip hose itself needs to be purchased every year.

Figure 3. Madison's 15 psi low-hanging irrigation nozzles use just 7.5 gallons per minute. Photo: Darrell Kilgore.

Given his water limitations, Madison is motivated to schedule his irrigation as efficiently as possible. (Common irrigation scheduling methods in the Pacific Northwest are described in the sidebar *How is Irrigation Scheduled in the Pacific Northwest*. A tool that can be used to improve irrigation scheduling is described in the sidebar *Irrigation Scheduler Mobile*.)

In order to monitor soil water conditions, Madison uses neutron and real-time probes throughout the season on all fields. Neutron probes, which are read weekly, help ensure that he is not overwatering. Too much water increases the risk of leaching nitrates to the groundwater, wasting both precious irrigation water and nitrogen fertilizer, while polluting the aquifer. Real time probes, which give readings every half hour, are heavily used in onion and alfalfa fields, since these crops are sensitive to both underwatering and overwatering.

Working with a consultant, Madison gets a weekly water report that shows water applied, soil moisture, and evapotranspiration that is calculated for the top foot of soil as well as the full root zone. This report helps Madison to fine-tune irrigation applications and ensures that he is not pushing water below the rooting zone of the crop. It also helps him prioritize his water applications to get the most benefit.

A unique feature of Madison's farm is that most fields are wireless "hot spots" and much of their equipment is internet-enabled. Data on water and power use can be accessed from the office or a smart phone in real time. Madison and his employees can easily monitor and control their irrigation systems from anywhere using their smart phone or a computer (Figure 4).

Figure 4. Information about water and power use is relayed via the internet. The system can be monitored and adjusted from the office or elsewhere in real time. Photo: Erin Brooks.

How is Irrigation Scheduled in the Pacific Northwest?

In 2013, the Farm and Ranch Irrigation Survey (FRIS), carried out by the National Agricultural Statistics Service (NASS) of the United States Department of Agriculture, indicated that farmers in the Pacific Northwest use a variety of methods for deciding when to irrigate. As indicated in Figure 5, 75 percent of irrigators used “condition of the crop” to decide when to irrigate, while 40 percent used “feel of the soil” (USDA NASS 2014). (Note that respondents could select more than one answer.) The soil-feel method is often considered to be prone to error, and can be off by ten percent or more, depending on the experience of the grower (Schneekloth et al. 2002). In contrast, seven percent or fewer used each of the following: soil moisture sensing devices, scheduling services, reports on daily crop water evapotranspiration, or computer simulation models, which can better match irrigation to plant needs. For one such tool that can help schedule irrigation, see the sidebar *Irrigation Scheduler Mobile*.

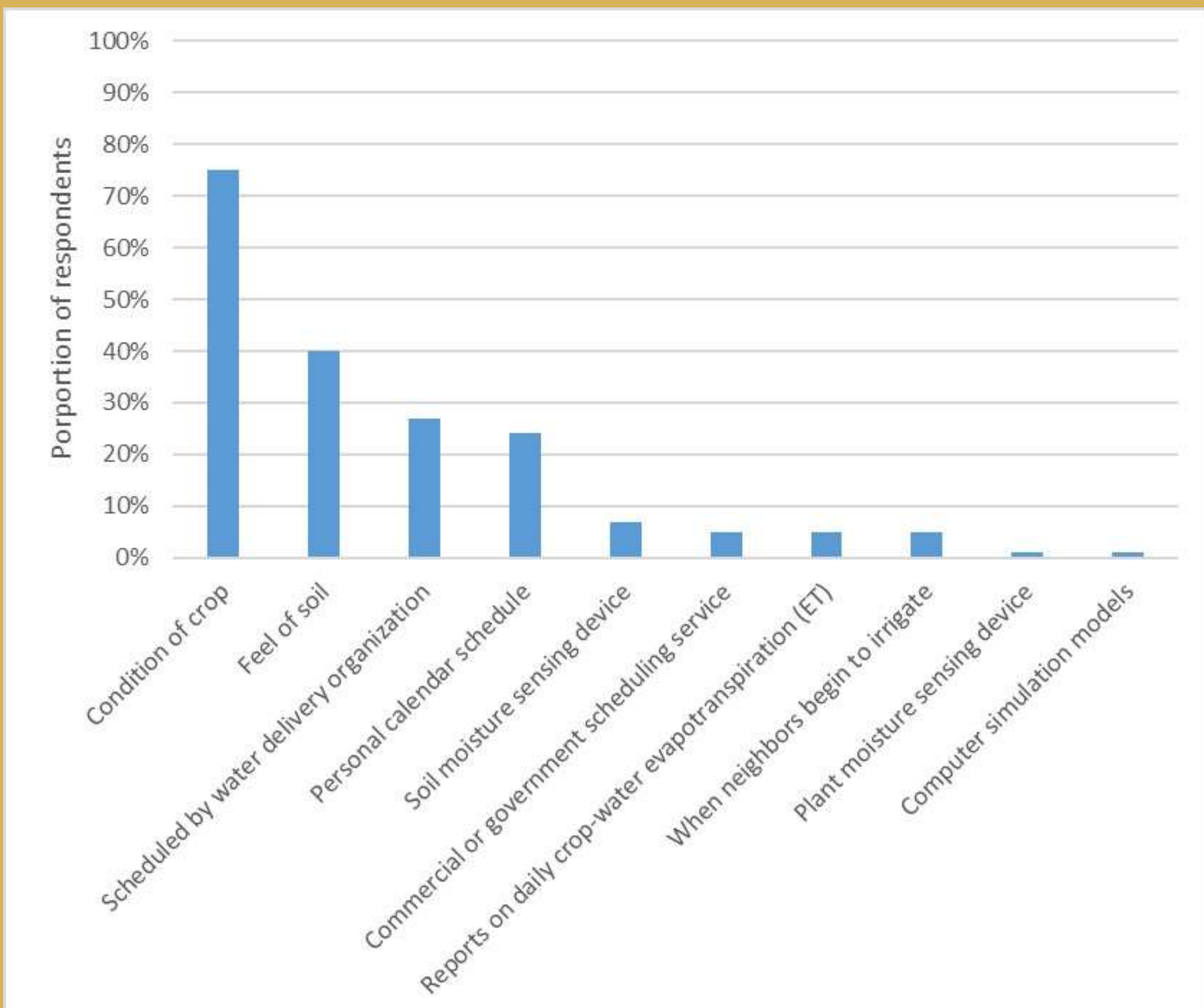

Figure 5. Methods used in deciding when to irrigate in 2013 in the Pacific Northwest, which contains all of Washington, most of Oregon and Idaho, and a section of western Montana. Data are from USDA National Agricultural Statistical Service (2014).

Irrigation Scheduler Mobile

R. Troy Peters, Department of Biological Systems Engineering, Irrigated Agriculture Research and Extension Center, Washington State University; and Georgine Yorgey, Center for Sustaining Agriculture and Natural Resources, Washington State University

When do I turn the water on, and how long do I leave it on? Although these are straightforward questions, finding good answers can be quite complex. Most growers realize, however, that getting it right has big payoffs. Good irrigation water management can increase yields, improve crop quality, decrease fertilizer requirements, save pumping energy costs, conserve water, and reduce non-point source pollution. In short, both the farm operation and the environment benefit from smart water use.

There are a variety of different data-based tools to help with irrigation scheduling but many of them are complicated and time consuming to use. In contrast, the Irrigation Scheduler Mobile is a free online tool that is easy to learn and use, and it is accessible in the field via a mobile phone (Peters et al. 2013). The tool can be accessed by searching "irrigation scheduler mobile" in iTunes or the Google Play store or online at http://weather.wsu.edu/ism. Those who would like more detailed instructions for using the irrigation scheduler mobile can watch two videos: Part 1 covers creating an account, and Part 2 covers logging in and entering field information to get started using the Irrigation Scheduler Mobile.

Irrigation Scheduler Mobile estimates how much water the soil can hold in the plant's root zone and tracks how much water is used by the crop. It then estimates the current soil water content and calculates water application time and rates needed for optimal crop production. Two useful output screens are the Daily Budget Table (Figure 6) and the Soil Water Chart (Figure 7). These screens track soil water content over time, the soil water deficit (how much more water the soil can hold before it is lost to deep percolation), and the current percent of the total soil available water.

Figure 6. An iPhone screenshot of the Daily Budget Table screen. Colors indicate the level of water stress, from green (adequate) to yellow (warning), and red (water stressed). The Edit button is used to add irrigation amounts or a soil moisture measurement to correct the model on that date. Selecting the date gives more information on calculations.

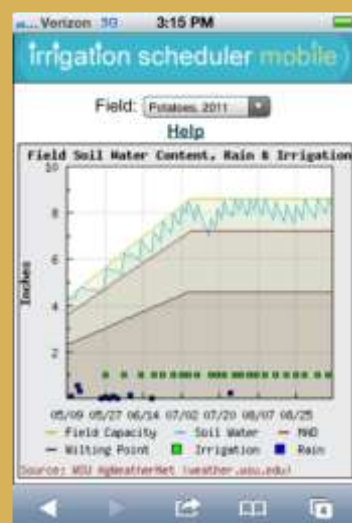

Figure 7. An iPhone screenshot of the Soil Water Chart. The estimated soil water content is plotted in relation to the field capacity, the management allowable deficit (the point where the crop will begin to experience water stress), and the permanent wilting point (the point where the crop dies). All of these increase over time, consistent with a growing root zone. Also plotted are irrigation and rainfall events.

The Irrigation Scheduler Mobile can also provide graphs of estimated:

- daily and cumulative crop water use,
- crop coefficients (properties of crops used in predicting evapotranspiration, or ET),
- root zone depth,
- amount of water lost to deep percolation,
- degree of water stress, and
- estimated crop yield loss from water stress.

This tool works with weather networks in Washington, Oregon, Idaho, California, Nevada, Utah, Arizona, North and South Dakota, and Colorado. Setting up a field simply involves selecting the crop, identifying the soil texture, and finding the nearest weather station that provides crop water use and rainfall data. From these selections the model is automatically populated with default values for the crop and soil water holding characteristics. After setup, all the grower needs to do is to add the irrigation amounts on the dates the field is irrigated. The model can be corrected or updated on any date with soil moisture measurements or estimates. The model uses a daily time step and takes into account the effects of a growing root zone as well as any decreases in plant water use due to moisture stress. A one-week forecast based on projected maximum and minimum daily temperatures from the National Weather Service is also included.

Soil Quality and Water Holding Capacity

In recent years, Madison has also begun strategizing to improve water holding capacity by increasing soil organic matter. He sees this as a logical extension of his other strategies to save water. "The reason we started looking at no-till was strictly for water savings and hopefully being able to hold more water in the soil profile…. We've already looked at the water application efficiencies, and pumping efficiencies and all that kind of stuff, and one of the last pieces to our puzzle was looking at improving soil health and organic matter to be able to hold more water in the soil."

Madison has used three primary strategies to improve soil health so far. First, he applies locally-sourced dairy manure to his fields when he can, to build soil organic matter and carbon over time. Though Madison would also like to use cover cropping or double cropping strategies to further increase soil organic matter inputs, his water limitations will likely make these practices unrealistic.

Second, Madison has been trying to reduce soil compaction and improve soil aggregation, based on the fact that soil with more pore space between soil particles can hold more water. This has been a challenge in some crops, particularly potatoes and onions, which often require field operations when soils are wet. However, new field equipment with increased working width has reduced the overall tire footprint on the field. It also allows him to cover acreage more quickly, so that he can coordinate field operations and irrigation to avoid the wettest conditions. Precision guidance is also important. It "allows us to run a 60-foot tool within six inches or better of our last pass… It's allowed us to run the sprayer in the same spot every time so that we have fewer compaction issues."

Madison's third strategy for increasing soil water holding capacity has been experimenting with reduced and no-till practices. Replacing a 36-foot conventional grain drill, he purchased a 60-foot wide no-till drill in late 2013 under a cost-share provided by the [NRCS Conservation Stewardship Program](#) (CSP). "If we see less than a ten percent increase in yield on wheat and corn, it will pay for the drill. Then we also get fuel and labor savings from having a bigger tool and from not having to run tillage equipment…so it was kind of a no-brainer." He also sees a potential benefit in terms of reducing wind erosion, which causes soil loss and crop damage.

Benefits

Madison feels that the greatest benefit of his deficit irrigation strategy is that it allows him to farm more acres with strategic irrigation methods that maximize his productivity and profitability. "The primary benefit is being able to irrigate the number of acres that we do with the little bit of water that we have." This strategy allows them to grow a mix of higher-value and lower-value crops that works financially for the farm.

The farm's water limitations increase incentives for using water efficiently, which has also decreased other costs, particularly electricity and labor. For example, the remote system that monitors and manages their center pivots provides feedback to regulate water pressure in order to limit electricity use and avoid overwatering. Madison says, "We've seen a significant energy savings from being able to do that. And it's handy—it's amazing how much fuel a guy can save. And time. We can sit in one high spot out on the farm and look at three quarters of the farm, and then get on our laptops and turn on the ones we want and turn off the ones we don't want. It saves us literally hundreds of miles a week in driving." Labor and electricity for pumping water are Madison's two largest expenses, so decreasing them provides important financial benefits.

Challenges

Managing deficit irrigation is challenging. Planning starts up to two years ahead of time and water availability is considered in combination with all the other factors typical to an irrigated farm, such as market conditions, plant-back restrictions, and crop rotations. Cropping patterns, seeding rates, and fertility applications all need to match anticipated water availability. In the spring when Madison can better anticipate water availability, he makes initial water allocations for the upcoming crop year. These allocations are fine-tuned throughout the growing season. The reuse water also requires a bit more management because it has limitations on where it can be applied, and details about its use must be reported to both the Oregon Department of Environmental Quality and the company that supplies the reuse water. All of these management details require skilled people who understand the operation. Thus, hiring, supervising, and retaining good people, a common challenge to all farms with employees, is especially key in this management-intensive operation.

Madison also spends a lot of time on longer-term projects that directly or indirectly relate to water. "Probably the biggest single thing that I spend my time trying to figure out is water—trying to make sure that we're doing an efficient job at using what we have and trying to get more…. And beyond the day-to-day stuff, …most of the projects I'm working on are developing more water or ways to store water, like the no-till stuff and increasing organic matter."

But the biggest challenge with Madison's water management strategy is how it limits his options. "The hardest challenge is being able to adapt to market conditions quickly, because we can only grow a certain number of acres of onions, a certain number of acres of potatoes, and we have to have a certain number of acres of wheat. We can fudge those numbers a little bit one way or the other—and you wouldn't want to make a wholesale change every year anyway—but we're very limited as far as the changes that we can make, strictly because of water availability."

Managing Risk

There is no question that deficit irrigation has higher risks associated with it than growing irrigated crops on land with a reliable water supply. "If we don't get those last few inches of rain in April and March to help finish out some of the crops, then there's not much we can do about it and we end up cutting 75-bushel irrigated wheat instead of 125-bushel irrigated wheat. So there's some substantial risk with deficit irrigation." The tradeoff is that by accepting higher risk, Madison has been more profitable than if the farm had responded to the water constraints by reducing irrigated acreage based on traditional water requirements for each crop.

To help mitigate risk associated with lower crop yields, Madison tries to minimize risk coming from other sources when he can. This contributes to his cost-conscious attitude. "Any time input costs increase, your risk increases."

Within the limitations of his water constraints, Madison also uses as much crop diversity as he can to limit his market-based risk. "Being able to grow many different things is one thing that has allowed us to be successful. It's the same for most farmers. Having diversity and being able to withstand dips in two or three markets because you've got two or three other crops that are doing okay—that's what has allowed agriculture in general to survive. The more flexibility we can have to grow different things, whether it's through efficiencies, or through technology, or through additional water, or all of the above, the more likely we'll be successful in the long run." To make diversity a workable strategy, Madison strategically leases out some of their farm ground, so that he is not taking on all of the risk associated with growing each crop.

Looking Forward

When Madison looks to the future, the biggest threat he sees is that his farm business is not quite as nimble and adaptable as other irrigated farms. "As technology changes, and climates change, and markets change, [our limited water supply] severely limits our adaptability."

He is also very concerned in any given year about "not getting any rain from Mother Nature." Though the water from the Columbia River is quite reliable even in a drought year, he depends on snowpack to supply the water in the ASR well and Butter Creek. While these sources are secondary in terms of the total quantity of water provided, they are critical to maintaining good yields, especially in this unique operation where every drop counts. Given this, Madison says "We're very concerned about future climate change, and the possibility of negative impacts on water availability." (See sidebar, *Climate Change Impacts to Water Availability*.) Improved seasonal forecasts would be beneficial if they provided him with the necessary information to adjust his seeding and fertility rates. (See sidebar, *Seasonal Climate Forecasts*.) However, there is still only so much he can adapt to without water.

Climate Change Impacts on Water Availability

John Abatzoglou, Department of Geography, University of Idaho

Variations in winter temperatures across the Northwest have important impacts on mountain snowpack, streamflow, and seasonal water availability. Colder than normal winters allow for more precipitation to fall as snow in mountain headwaters and remain there in snowpack. These frozen reservoirs then gradually melt with warming temperatures in the spring and early summer, nicely accommodating the increasing seasonal water demands.

Conversely, warm winters similar to those seen in recent years—including the 'snow drought' of the winter of 2014/2015—result in subpar mountain snowpack, and more precipitation running off during the winter. This means less water is available in the summer months for irrigation, most notably among junior water rights holders or those dependent on more variable surface water resources, such as seasonal creeks.

While there is some uncertainty regarding how climate change will impact the overall amount of precipitation across the region in the coming decades, there is little uncertainty that it will get warmer. Average temperatures across the Pacific Northwest are projected to warm by one to four degrees Fahrenheit compared to late 20th century averages over the next few decades. This warming will cause more winter precipitation to fall as rain rather than snow across lower elevation mountains, and will also lead to earlier mountain snowmelt and runoff. Near McNary Dam on the Columbia River in Benton County, Oregon, streamflow is projected to increase due to climate change in winter and spring and sharply decline from June to September (Figure 8). Across the region, the largest reductions in April 1 snowpack are expected for the Cascades and Olympic Mountains, with smaller reductions in higher elevation colder watersheds over central Idaho and the headwaters of the Upper Snake River near Yellowstone National Park (Figure 9). The impacts on smaller creeks that are used as a surface water supply may be more acute, depending on the degree to which snowmelt historically contributes to the flow regime.

Another way to understand the likely impacts of climate change is to consider how these anticipated changes may be similar to recent experience. For example, exceptionally warm winters including the snow drought of 2014/2015 are likely to become more frequent with warming, whereas years with abundant mountain snowpack in the late spring will become increasingly scarce.

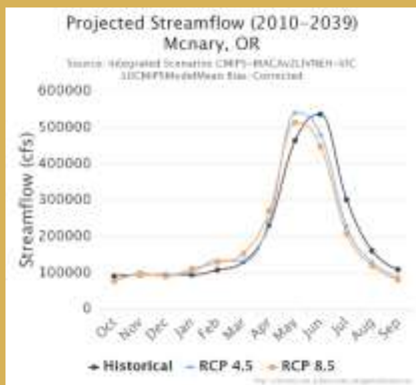

Figure 8. Modeled streamflow on the Columbia River near McNary Dam, OR for historical (1971–2000; black) and future (2010–2039) climate for high (orange) and low (blue) emissions pathways. Results were simulated by the VIC model as part of the Integrated Scenarios Project.

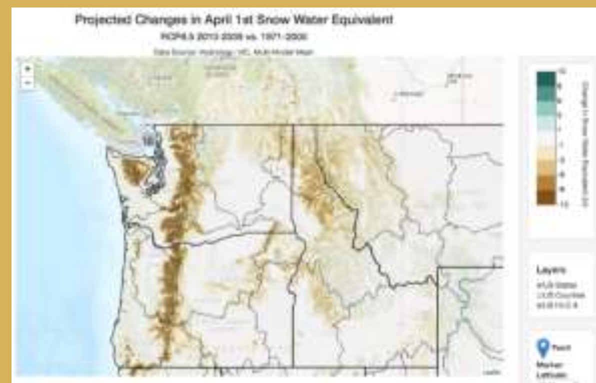

Figure 9. Projected changes in mean April 1st snow water equivalent for the early 21st century (2010–2039) versus late 20th century (1971–2000). Results show the average change simulated by the Variable Infiltration Capacity (VIC) model using 10 different climate models.

One way that Madison hopes to mitigate this future threat is to make more water available for agriculture in his area. "We've been working on some projects with the state and with a group of guys in the local area. We're trying really hard to work with everybody: the environmental agencies, the state, irrigation districts, and critical groundwater areas. We're trying to put together plans that are going to benefit the whole region." He sees the effort to collaborate as a sizeable, but not impossible, challenge. "The biggest challenge that agriculture has in general is public perception. I think the majority of the population doesn't understand what agriculture is about, how we do what we do, how efficient we try to be. Quite frankly, it's partly our fault, because for a long time we weren't efficient, and we weren't responsible. That's changed, both because it's not right and because it was wasteful, and it cost a lot of money. And meanwhile, technologies improved, so we have tools that let us make better, more informed decisions that reduce our environmental impact."

Seasonal Climate Forecasts

John Abatzoglou, Department of Geography, University of Idaho

While most farmers utilize weather forecasts for the coming week to guide operations, longer-term forecasts for the next season or two are not typically used to support agricultural decision making. For some, the ‘Old Farmer’s Almanac,’ derived from a “*combination of solar science, meteorology, and climatology*” has been the gold standard for planning for the coming year. However, advances in computational abilities and global climate science now provide the potential for scientifically credible seasonal forecasts that could inform decisions, such as crop and variety choices, seeding and fertilization rates, and fallowing decisions.

Weather forecasts rely on current conditions and a set of numerical equations that govern atmospheric motion to create forecasts for the next several days. Forecast accuracy typically degrades with time, making guidance useful only for a 7- to 10-day period. Seasonal climate forecasts utilize the same set of equations but also account for other components of the climate system, such as ocean temperatures, soil moisture, and sea ice that can influence atmospheric conditions for the coming months. For example, the presence of unusually warm ocean waters off the coast of Peru associated with an El Niño event typically result in a southward displacement of the jet stream, resulting in warmer and somewhat drier conditions across most of the northwestern US. The main difference between a weather forecast and a seasonal climate forecast is that the latter is not intended to provide forecasts for specific days. Instead, seasonal climate forecasts project how the coming months or seasons will differ from normal.

Seasonal climate forecasts for the next six to nine months are developed by several modeling groups globally. Similar to weather forecasts, the accuracy of seasonal climate forecasts typically degrades with time; however, the forecasts show reasonable accuracy for predictions several months out. Unlike local weather forecasts that are available through numerous outlets, local climate forecasts remain challenging to access and use in long-term planning. Moreover, their use is inhibited by the fact that their level of accuracy is usually not clear to users.

To address this issue, a joint research effort that included the Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCH) Project and the Applied Climate Science Lab at the University of Idaho has developed a system to provide local seasonal climate forecasts for the western U.S. and estimate the accuracy of these forecasts over the past 30 years. Seasonal climate forecasts are updated monthly and available through: http://climate.nkn.uidaho.edu/RangelandForecast/. Seasonal forecasts of temperature and precipitation downscaled to local scales (around 2.5 miles) can be visualized in two ways: geographically across the western U.S. for a single point in time, or for the next 8 months at a single location.

Figure 10 shows monthly precipitation forecasts for March–September 2017 for Echo, OR developed in February 2017. Seasonal forecasts from several models are provided as well as the model average (ENSMEAN). To provide added value to these forecasts, users can also examine how accurate forecasts from different models and time periods have been. Figure 11 shows a skill matrix for 4-month precipitation (e.g., March–June precipitation totals) forecasts issued in February for Echo, OR. From this example, one can see some skill (r=0.33) in spring precipitation outlooks for this location developed in February. However, forecast accuracy is widely variable depending on forecast month, lead period, and variable.

Seasonal climate forecasts will never be as accurate as short-term weather forecasts, and inherent forecast error might make them unreliable for many. Yet, continued advances in modeling and appropriate means to communicate this information will lead to improved potential to inform agricultural decision-making and seasonal planning. These forecasts may not tell you exactly how much rain might fall on your fields in spring, or on a specific day in May, but they do help give an indication of likely irrigation demands in the months ahead, which could help with a range of water-related decisions.

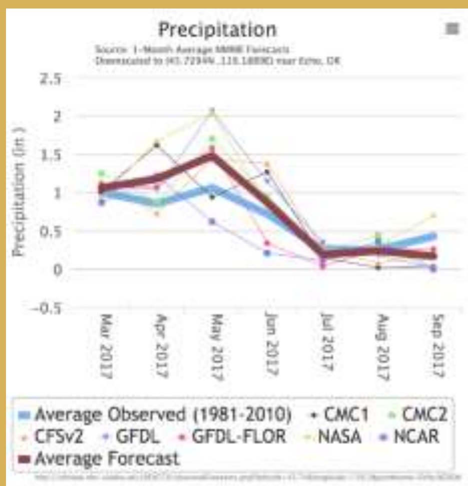

Figure 10. Example of a seasonal forecast for Echo, OR, developed in February 2017, showing monthly precipitation forecasts for March–September 2017 from seven individual climate prediction models as well as a 7-model mean (ENSMEAN). The average monthly precipitation from 1981–2010 is shown in light blue for reference.

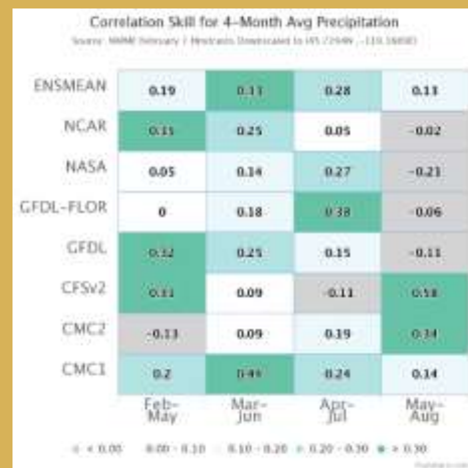

Figure 11. Matrix showing the skill of 4-month precipitation forecasts for Echo, OR issued in February 2017. Different time periods are listed on the x-axis, whereas different models are listed along the y-axis. The skill values shown here are Pearson's correlation coefficients, where a perfect forecast is assigned a value of one and a random forecast is assigned a value of zero. Cells highlighted green (>0.3) and teal (0.2–0.3) have higher accuracy.

Advice for Others

Madison was asked what advice he has for other growers who are adopting new practices, whether to deal with water limitations, improve soil health, or make other changes.

Do your research, especially on costs, before trying something new. "It all comes down to knowing your costs and having a sharp pencil. You need to research the projects, research the practices, talk to guys that have done it…[but] just because your neighbor is doing it doesn't mean that it's right for your place." For finding out more about new practices, Madison depends on a variety of information sources, including experiment station results, conferences, and private specialists.

University-based resources may help support analysis of likely costs related to new practices including:

- For Oregon, Oregon State University has published enterprise budgets at http://arec.oregonstate.edu/oaeb/.
- For Washington, Washington State University has published enterprise budgets for a variety of crops at http://ses.wsu.edu/enterprise_budgets/.
- For Idaho, the University of Idaho AgBiz website has enterprise budgets and crop input price summaries (both at https://www.uidaho.edu/cals/ idaho-agbiz/crop-budgets).

For the inland Pacific Northwest region, budgets by rainfall zone are available at: https://www.reacchpna.org/farm-enterprise-budgets.

References

English, M. 1990. "Deficit Irrigation. I: Analytical Framework." Journal of Irrigation and Drainage Engineering 116(3): 399-412.

English, M., L. James, and C.F. Chen. 1990. "Deficit Irrigation II: Observations in Columbia Basin." Journal of Irrigation and Drainage Engineering 116(3): 413-426.

English, M., and B. Nakamura. 1989. "Effects of Deficit Irrigation and Irrigation Frequency on Wheat Yields." Journal of Irrigation and Drainage Engineering 115(2): 172-184.

Musick, J.T. 1991. "Effects of Deficit Irrigation and Irrigation Frequency on Wheat Yields (Discussion)." Journal of Irrigation and Drainage Engineering. 117(5): 806-808.

NRCS (Natural Resources Conservation Service). 2013. Web Soil Survey. Natural Resources Conservation Service, United Stated Department of Agriculture.

Peters, R.T., S.E. Hill, and G. Hoogenboom. 2013. Irrigation Scheduler Online.

Rambags, F., K.J. Raat, K.G. Zuurbier, G.A. van den Berg, and N. Hartog. 2013. Aquifer Storage and Recovery (ASR). Design and operational experiences for water storage through wells. Report for the Seventh Framework Programme.

Santen, J.D. Jr. 2013. Water Wars: Battles, compromises, and resolutions abound in a state flush with water. Oregon Humanities. November 8, 2013.

Schneekloth, J., T. Bauder, I. Broner, and R. Waskom. 2002. "Measurement of soil moisture." *Colorado State University Cooperative Extension Drought and Fire Tip Sheets*.

USDA NASS. 2014. 2012 Census of Agriculture, Farm and Ranch Irrigation Survey (2013), Volume 3, Special Studies, Part 1. AC-12-SS-1.

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