Does It Pay To Irrigate Pasture In Wisconsin?

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Brian Nischke, Alex Crockford, Paul Onan, and Tom Kriegl

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This is an update of the initial (February 2012) version of this report, to benefit from the additional years of experience since the first report.

DOES IT PAY TO IRRIGATE PASTURE IN WISCONSIN?
By Brian Nischke, Alex Crockford, Paul Onan, and Tom Kriegl[1]

Production agriculture greatly depends on adequate rainfall for crop quality and yields. Farm operators employing managed grazing (in which animals are moved regularly to maximize forage quality and quantity) in their dairy and livestock operations try to utilize as much forage as possible from their managed pastures. The more high quality forage available in a pasture, the more daily dry matter (DM) intake from pasture livestock can ingest. This is important, since pasture is usually the most economical feed produced. Maximizing pasture feeding also means that farm operators will feed less of their winter feed inventory during the summer season.

Extended drought periods during the summer growing season are common in Wisconsin. Depending on the soil texture, pastures on some farms fare better than others during drought conditions. Farms with predominantly sandy soils will be challenged to consistently grow high quality forage on pasture during extended drought periods.

In addition, climate fluctuations have resulted in unpredictable precipitation and temperature patterns. It's not unusual to experience an extended drought period with hot temperatures during the growing season, or a winter with little snow accumulation. These dry weather patterns introduce challenges to the farm operators growing and managing high quality pasture, especially on farms with sandy soils.

One way to mitigate the impacts of dry periods is to plant summer annuals, such as sorghum/sudangrass, that can tolerate hot and dry conditions and still provide grazing opportunities for livestock. These annuals would also offset the summer slump in production of cool season pasture grasses. Another strategy would include planting drought-tolerant perennial forages, such as alfalfa or reed canarygrass, into pastures to provide forage during dry periods. However, if these options are not possible, farm operators could also purchase additional feed in order to get through drought periods.

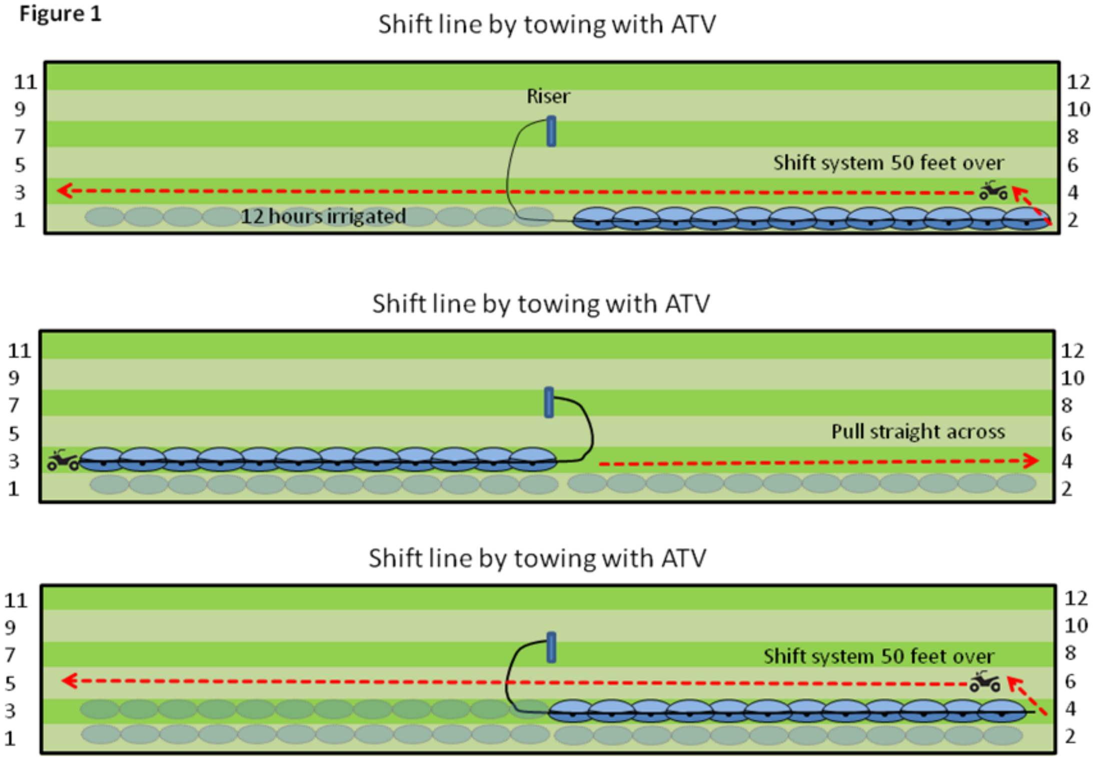
Irrigation, used in combination with the previously mentioned strategies, is another method of managing dry periods. Irrigation has proven to be extremely useful for annual vegetables and grains in the central sands region of Wisconsin. However, irrigation of forages has only been economically viable in water deficient areas of the United States. As annual drought periods become regular and prolonged, farm operators using managed grazing may consider irrigation as an opportunity to extend grazing periods during periods of drought. A research project conducted during the 2009 and 2010 growing seasons set out to determine the financial requirements and economic return of irrigation systems on pasture.

Using Pod Line Irrigation in Pastures

Pod line irrigation was used to supply the supplemental water for this research project. Pod line irrigation is an alternative to center pivot or traveling gun irrigation systems. Pod line systems offer flexibility which is important in a managed grazing situation. The system consists of an above ground poly line of two-inch tubing with individual irrigation sprinkler pods connected to the line. The water source to supply the system can be groundwater or surface water. The farm operator can decide how many sprinkler pods to connect to the line. As many as 13 individual pods can be connected to the line spaced 50 feet apart. Each pod can irrigate a diameter of 50 feet. The irrigation line must be moved manually and is usually done with an all-terrain vehicle (ATV) or similar vehicle. K-line is the brand name of the pod line irrigation system in this study.

The farm operator moves the irrigation lines in a pattern (Figure 1) so that the all of the field receives water. It takes multiple days to cover the field.

Figure 1



Multiple irrigation lines can be used on a farm with installations covering anywhere from tens to hundreds of acres. The water delivery cost of the pod line systems should be relatively constant on a given farm on a per acre basis. The supply well and feed line water development on the farm will depend either on the capacity of the planned system or supply capacity of the water source.

For more information about pod line irrigation contact K-Line Irrigation-North America, or Universal Irrigation Sales Corporation, or a nearby irrigation equipment dealer and installer.

Maximizing The Economic Return Of A Pasture Pod Line Irrigation System

Few Wisconsin pastures need irrigation the entire season. NRCS recommendations for the central Wisconsin region during the months of June, July, and August state that an acre of pasture grass should receive, on average, a minimum of one inch of water (rain and/or irrigated) per week to maintain production.[2] Pasture irrigation can supplement rainfall to bring moisture up to the recommended level and maintain forage production. To maximize the economic impact of the irrigation investment, apply adequate water to as many acres as possible. By using pressure gauges at the well head and at the last pod on each line, the study participants determined that with the well operating at full capacity, each line can deliver approximately an inch of water to 0.75 acres in six hours of continuous watering without moving. If moved every six hours, one line could put nearly an inch of water on three acres in one day (four moves every 24 hours). Therefore, one line could apply an inch of water on approximately 21 acres every week if it was operated continuously.

It could be economically advantageous to move the system four times a day in a short critical dry period to water 21 acres per week with one line even if someone was hired to do one or two moves a day. Doubling the number of acres irrigated with the same investment halves the ownership cost per acre and any yield response will therefore be gained on 21 acres instead of on 10.5 acres. Obviously, there is an operational cost for each pass on each acre. However, if the yield response is enough to pay for irrigating 10.5 acres per line (achieved by moving the lines only twice a day), the yield response should also pay for the operational costs for irrigating 21 acres per line per week by moving the lines four times daily.

If one person were operating the irrigation system along with all other farm duties and also obtained eight to nine hours of continuous sleep every 24 hours, only three moves a day would be possible and two moves a day would be more comfortable. Also, because the 12 pod K-lines represent a small part of the entire irrigation investment, it may be more convenient and even as cost effective to buy more lines to maximize coverage with less moves. Therefore in practice, few if any operators move lines more often than twice a day.

Table 1 shows combinations of intensity of use and land area irrigated per day and per week plus impact on ownership cost.

Table 1: Combinations of Intensity of Use and Land Area Irrigated per Day/per Week and Impact on per Acre Annual Ownership Cost Using One or Two 12-Pod K-Lines				
Daily Moves	1	2	3	4
Watering Hours per Move	6	6	6	6
Inches of Water per Acre per Move	1.00	1.00	1.00	1.00
Theoretical Acres Watered per Move with 1 K-Line	0.75	0.75	0.75	0.75
Theoretical Acres Watered per Day with 1 K-Line	0.75	1.50	2.25	3.00
Theoretical Acres Watered per Week with 1 K-Line	5.25	10.50	15.75	21.00
Onan per Acre Annual Ownership Cost with 1 K-Line*	$343	$172	$114	$86
Theoretical Acres Watered per Move with 2 K-Lines	1.50	1.50	1.50	1.50
Theoretical Acres Watered per Day with 2 K-Lines	1.50	3.00	4.50	6.00
Theoretical Acres Watered per Week with 2 K-Lines	11.00	21.00	31.50	42.00
Onan per Acre Annual Ownership Cost with 2 K-Line**	$214	$107	$71	$54

*The per acre annual ownership cost for one pod K-line is based on 5, 10, 15, and 20 acres respectively.

**The per acre annual ownership cost for two pod K-lines is based on 10, 20, 30, and 40 acres respectively.

It obviously is not economically practical to make the investment in the irrigation system to support only one line. However the one line scenario is shown to help illustrate the economic impact of using the investment at low capacity.

The Research Project

Paul Onan has been grazing Holsteins and crossbred dairy cattle on 80 acres of pasture in Amherst Junction in central Wisconsin since 1994. His pastures are a mix of primarily orchardgrass, Kentucky bluegrass, and mixed legumes in a Rosholt Sandy Loam soil.

Following a few years of below average precipitation and below average pasture production, Mr. Onan was interested in collaborating with Golden Sands Resource Conservation and Development (RC&D) Council to study irrigation on managed pastures. Golden Sands RC&D received a Grazing Lands Conservation Initiative grant to study the financial feasibility of irrigation on managed pastures for grazing livestock.

In the spring of 2009 Golden Sands RC&D purchased two 12-pod K-line irrigation lines for installation on Mr. Onan's dairy farm. The research project used K-line irrigation because of its relative affordability and therefore its potential as a legitimate alternative to other irrigation technologies for use in managed pastures. In order to accommodate the K-line irrigation system, Mr. Onan needed to install a new six-inch well drilled 103 feet deep. The well has the ability to provide 100 gallons per minute. Theoretically this system will provide the necessary volume of water with 100 psi at the well head and 50 psi at the last pod at the end of each K-line for three pod lines.[3] However, only two were purchased and used in 2009. Mr. Onan purchased a third line for use in 2011.

Of the 80 available acres for grazing on Mr. Onan's farm, only 40 were made accessible to irrigation. A three-inch supply line was buried from the well to supply the designated 40 irrigated acres. Twenty acres of Mr. Onan's farm received regular irrigation during the study. Approximately 10 acres of the 20 regularly irrigated acres were studied as part of the research project. The other 10 acres were irrigated by default due to the design and use of the K-line system. The participants' decided to irrigate only 20 acres in both years for several reasons:

1. Everyone was learning how to use the system.
2. When doing a research project, extra time and effort is needed to monitor, measure, and record information compared to running the system for production only.
3. Covering 20 acres minimized the irrigation line movements. This was important because every move could add some inconsistency to the research.

Six 50 x 600 ft. strips were established in two separate paddocks for a combination of 12 research strips. Each strip represented the approximate area of 0.75 acres that each 12-pod K-line can irrigate without being moved. There was one K-line system in each of the two research paddocks. Four of the 12 research strips, or approximately three acres, were randomly selected as the non-irrigated control strips. Two strips were to be irrigated according to guidance provided by soil moisture sensors. The remaining research strips were to be irrigated according to the operator's discretion.

Irrigation began in both paddocks on July 1, 2009, about two weeks later than desired, because the system was not ready earlier. The last 2009 irrigation pass occurred September 24th. The schedule began with irrigation occurring only overnight to take advantage of discounted, off-peak electric rates. Therefore, each 12-pod line would irrigate for 12 hours overnight, and then would be shifted to its next location. During this irrigation schedule, each line applied two inches of water over approximately 0.75 acres during a 24-hour period.

There were no changes in pasture production after a week of irrigating only overnight. Consequently, the irrigation schedule was changed to 24-hour irrigation with a shift of each K-line every 12 hours. During this irrigation schedule, each line would apply two inches of water over 0.75 acres in a 12-hour period, or two inches of water over 1.5 acres during a 24-hour period. Over the duration of the season, 9.5 inches of water was applied per 0.75 acre strip over the six monitored acres, which required approximately six irrigation rotations across the research acres. Grazing that had been suspended on June 15th due to lack of grass was resumed 25 days later on July 20th.

In order to monitor pasture response to irrigation, a digital pasture plate meter was used to measure weekly pasture yields. Forage samples were also collected and analyzed for quality. There were no additional fertilizer applications made to the research plots before or during the project beyond manure deposited by the cows.

The research project concluded on September 1, 2010.

Production Response

The summer of 2009 was very dry. Total rainfall amounts for Paul Onan's farm were 7.25 inches from June 15 to September 30, which was well below the normal of 15.5 inches for the region. Unirrigated pastures became dormant near the end of June.

The 2010 season was very wet in comparison to 2009. Total rainfall amounts on the Onan Farm were 24.5 inches from June 15 to September 30, which was well above the regional average. The above average precipitation resulted in just over 2.5 inches applied per 0.75 acre strip over the six monitored acres (including the 3 non-irrigated acres). Results show there was not a significant difference in production averages between irrigated and non-irrigated forage yield.

Tables 2 and 3 illustrate production response to irrigation. In 2009, irrigated plots produced approximately two tons of forage per acre compared to 0.5 tons of forage per acre on the non-irrigated plots. Therefore, irrigation produced an additional 1.5 tons of dry matter forage per acre. Crude protein and relative feed value were also statistically significantly higher for the irrigated forage.

In 2010 there was no statistically significant difference in production between the irrigated and non-irrigated plots.

Table 2: Pasture Response to Irrigation Summer 2009 Consumable Tons DM/Acre[4]

Onan	kg DM/ha*	lb DM/ac	tons/acre
Non-irrigated	1140	1016	0.51
Upland irrigated	4371	3895	1.95
Lowland irrigated	4512	4005	2.00
Average irrigated	4441	3950	1.98

*Kilograms of dry matter per hectare

Table 3: Pasture Response to Irrigation Summer 2010 Consumable Tons DM/Acre[5]

Onan	kg DM/ha*	lb DM/ac	tons/acre
Non-irrigated	4153	3705	1.85
Upland irrigated	3767	3361	1.68
Lowland irrigated	4453	3973	1.99
Average irrigated	4110	3667	1.83

*Kilograms of dry matter per hectare

Economic Analysis of Actual Performance in 2009 and 2010

The investment in the new well, electric service, electric pump, two 12-pod K-lines plus piping from the well to the K-lines was tallied and annualized over their expected life of 20 years.

The annualizing period should not exceed the expected useful life of the asset. A longer annualizing period makes it easier to justify an investment on an annual basis but lengthens the time in which the investment is recovered.

The ownership costs of depreciation, interest, repairs, taxes and insurance were all accounted for to calculate annual fixed or ownership costs per acre and per acre inch (of water) based on 10, 20, 30, and 40 acres irrigated.

No cost was charged for land or other equipment since such costs exist with and without irrigation, nor was time value of money calculated.

Actual operating costs accumulated in irrigating 20 acres in 2009 plus some unpaid labor and interest opportunity cost were used to calculate operating costs per acre and per acre inch. The annual ownership costs were combined with the annual operating costs to determine total costs and total costs per acre and per acre inch.

Table 4: Investment in Paul Onan's Irrigation System (Including Amount Paid by Grant)

System Investment Cost	Initial Cost
4-500 ft rolls 3" supply pipe	$2,500.00
1200ft-40mm K-line tubing	$1,215.00
24 K-line Pods with sprinklers	$2,288.00
Miscellaneous K-line Parts	$725.00
Installation Labor and Sales Tax	$2,900.00
Total Cost Of Irrigation Equipment	**$9,628.00**
Investment Cost Pump	$5,800.00
Investment Cost 103' Well	$6,755.00
Total Investment In Well, Pump And Water Delivery Equipment	**$22,183.00**

The investment per acre in an irrigation system can be as much or more than the price of land. Mr. Onan's investment per acre would be $2,218.30 if he only ever irrigated 10 acres. The investment per acre declines to $554.58 if he routinely irrigated 40 acres.

Clearly, in a year with adequate rainfall adequately distributed in the growing season, irrigation adds expense but no income. That was the case in 2010.

Some pasture growth potential is lost if one waits to start irrigating until drought stress is apparent in the crop. Consequently, there is often more to lose by not irrigating soon enough than to irrigate once or twice and then learn that it wasn't needed. Because the system wasn't ready as soon as needed in 2009, irrigating started later than it should have. The opposite happened in 2010. Irrigation in 2010 was roughly equivalent to two inches of water applied to the 20 acres in two passes before it was obvious that irrigating wasn't needed. Consequently, there was some operating cost along with the annual ownership cost in 2010.

The increased forage yield resulting from irrigation was assumed to be consumed by the lactating dairy cows and was assigned a value equal to the market value of 150 relative feed value (RFV) hay. Since a goal in managed grazing is to harvest forage at the higher feed value vegetative stage, the production response is potentially more valuable than what was calculated here. The total annual per acre cost was subtracted from the calculated value of the increased yield.

The approximate annual total cost of owning ($107.06/acre) and operating ($82.34/acre) the system in 2009 was $189.40 per acre (based on 20 acres), but returned 1.5 tons dry matter per acre of dairy quality forage valued at $258.75 (1.725 as fed tons X $150/ton) for a $69.35/acre net return.

In 2010, the ownership ($107.06/acre) and operational costs ($19.62/acre) of the pod-line system were $126.68 per acre, representing a loss from no gains in production. The cumulative loss of pod-line irrigation two years into operation is approximately *$57.33 per acre, per year.*

<u>"What If" Economic Analysis with Higher Value Forage and if System Used to Full Potential in 2009</u>

Several factors limited the production response and economic performance in 2009. These factors included:

1. Inexperience in irrigating pastures and using the K-line system, along with the need to monitor and measure performance, limited the irrigated acres to 20 instead of the 40 acres that the system theoretically could have irrigated adequately.
2. The yield increase in 2009 may have been somewhat undervalued in the previous presentation of 2009 results, as vegetative stage forage would be more valuable than the 150 RFV hay originally used to estimate value. The above calculations didn't credit the irrigation system with any forage quality gains.
3. Timely installation of the irrigation system likely would have increased the yield to 3,500 instead of 3,000 lbs. of DM per acre.

If, in another dry year like 2009, the farm crew committed themselves to:

- Adequately irrigating 40 acres
- Productively applying the irrigation knowledge gained in 2009
- Having the lactating cows consume half of the yield increase in the vegetative stage
- Having the cows consume half of the yield increase at 150 RFV

Then the economic performance of the next season could improve over the economic performance calculated for 2009. To see the potential for greater economic performance, eight scenarios were examined. The first four scenarios include:

1. 1.5 ton DM yield gain valued at $150/ton from 20 acres – the original reported 2009 results
2. 1.5 ton DM yield gain valued at $150/ton from 40 acres
3. 1.5 ton DM yield gain (half valued at $150/ton and half valued at vegetative stage) from 20 acres
4. 1.5 ton DM yield gain (half valued at $150/ton and half valued at vegetative stage) from 40 acres

The next four scenarios were based on the scenarios above but also assume irrigation started two weeks earlier with an extra yield response.

5. 1.75 ton DM yield gain valued at $150/ton from 20 acres
6. 1.75 ton DM yield gain valued at $150/ton from 40 acres
7. 1.75 ton DM yield gain (half valued at $150/ton and half valued at vegetative stage) from 20 acres
8. 1.75 ton DM yield gain (half valued at $150/ton and half valued at vegetative stage) from 40 acres

Table 5: Potential Economic Impact of Irrigating Based on Eight Scenarios

Scenario #	Acres Irrigated	Yield Increase Ton	Value of Yield Increase	Ownership Cost	*Operating Cost	*Total Cost	Gain From Irrigating
		Ton/Acre	$/Acre	$/Acre	$/Acre	$/Acre	$/Acre
2009 Results 1	20	1.5	$258.75	$107.06	$82.34	$189.40	$69.35
2	40	1.5	$258.75	$53.53	$82.34	$135.87	$122.88
3	20	1.5	$409.78	$107.06	$82.34	$189.40	$220.38
4	40	1.5	$409.78	$53.53	$82.34	$135.87	$273.91
5	20	1.75	$301.85	$107.06	$103.59	$210.65	$91.20
6	40	1.75	$301.85	$53.53	$103.59	$157.12	$144.73
7	20	1.75	$478.11	$107.06	$103.59	$210.65	$267.46
8	40	1.75	$478.11	$53.53	$103.59	$157.12	$320.99

* Operating costs are higher in Scenarios 5-8 due to additional rounds of irrigating.

In Scenario 1, the value of the yield increase ($258.75) minus the ownership cost per acre ($107.06) and the operating cost per acre ($82.34) resulted in a gain of $69.35 per acre from irrigating in 2009

In Scenario 2, the irrigation system would be used at double the capacity that it was in 2009, without the limitations of inexperience or the need for measurements. It is theoretically possible to use the system at full capacity. **If** the two 12-pod K-lines had been used to full capacity (four moves a day delivering an inch per move to deliver an inch per acre per week to 40 acres), **and if** the same response was achieved on 40 acres **and if** the increased production was harvested in good condition and consumed by the dairy herd, then the added per acre value of the dry matter forage increase could have been higher and the annual per acre ownership cost would have been cut in half from $107.06 per acre to $53.53 in 2009 and 2010.

Scenarios 3 and 4, capture the extra value of half of the forage in a vegetative state. Forage harvested by lactating cows in a managed grazing system is ideally harvested in the vegetative stage. Since neither hay nor haylage are mechanically harvested at the vegetative stage, one cannot buy hay or haylage to match the high quality range of the vegetative stage forage. Tall grasses are in the vegetative stage only until exceeding a height of 10 to 14 inches. [6]

Consequently, the increased pasture DM yield increase is at least somewhat undervalued when assumed to be equivalent to 150 RFV hay priced at $150 per ton as fed (13 percent moisture).

In order to put a value on the vegetative stage forage, researchers used a spreadsheet developed by Dr. Dave Mertens at the USDA Dairy Forage Research Center. It was used to estimate the amount of milk that could be produced by the increased dry matter yield harvested in the vegetative stage. The milk was then valued at Paul Onan's average milk price of $13.23 in 2009.

It was then assumed that half of the yield increase was harvested in the vegetative stage and the other half was valued as 150 RFV forage, because it would be very difficult to time the grazing event so that all the forage harvested would be in a perfect vegetative state. Applying this extra value to the vegetative state forage increased the net return per acre more than three-fold when applied to 20 acres (Scenario 3) and nearly four-fold when applied to 40 acres (Scenario 4). **The same impact also occurs in scenarios 7 and 8 above.**

Scenarios 5 through 8 are parallel to Scenarios 1 through 4 but also assume that the irrigation would have been started about June 15, rather than July 1, 2009. It is likely that if irrigation had been started on June 15, the yield increase from pasture could have been as much as another 0.25 ton of DM or 0.287 ton as fed. This extra forage would have been worth $43.10 (0.287 as fed tons X $150/ton) as 150 RFV forage and $140.19 in the vegetative stage.

The operational cost per acre for the extra 14 days of irrigating would have been an additional $21.25 per acre with the two extra inches of water per acre. Since the annual fixed costs were already included in the above calculations, a projected gain of $21.85 ($43.10 minus $21.25) added to the gain calculated in Scenario 1 of $69.35 would have been $91.20 for Scenario 5 in 2009.

Increasing from 20 to 40 acres increased the net margin by $53.53 per acre (Scenario 1 vs. 2; 3 vs.4; 5 vs.6; 7 vs.8).

Increasing the value of half of the forage from $150 per ton to $373.86 per ton (vegetative stage) increased the net margin by $151.03 per acre (Scenario 1 vs. 3; 2 vs. 4; 5 vs. 7; 6 vs. 8).

Increasing the yield of forage (with forage valued at $150 per ton DM) from 1.5 to 1.75 ton DM increased the net margin by $21.85 per acre (Scenario 1 vs. 5 and 2 vs. 6)

Increasing the yield (with forage valued at $262.88 per ton DM) increased the net margin by $47.08 per acre (Scenario 3 vs. 7 and 4 vs. 8).

Collectively the scenarios illustrate three factors that can improve the economic performance of the irrigation system which include:

1- Increasing the yield response increases the economic benefit.
2- Using the system up to full capacity (watering more acres) increases the economic benefit.
3- Increasing the proportion of the yield increase at the highest quality level increases the economic benefit.

Other factors that enhance the economic performance include:

1- Minimizing the investment
2- Minimizing operational costs (mainly by not irrigating when it obviously was not needed)
3- Increasing the frequency of years in which an adequate production response is achieved. This is done by investing in an irrigation system only for land that responds to irrigation.

It's obvious that when moisture is severely limited on a droughty soil as it was for Paul Onan in 2009, that his level of investment in irrigation equipment can produce enough of a yield response to more than pay the cost of irrigation in that year, but can it pay for itself over the 20-year amortization period? And how many non-response years can be subsidized by the economic gains of a dry year like 2009 in each of the eight potential scenarios? This is estimated in Table 6.

Scenarios 9 and 10 were added to table 6 in this edition to more closely reflect the experiences in years 2011 to 2014.

9. 1.75 ton DM gain valued at $150/ton from 30 acres (30 acre version of scenario 6).
10. 1.75 ton DM yield gain (half valued at $150/ton and half valued at vegetative stage) from 30 acres (30 acre version of scenario 8).

Table 6: Years of response needed for irrigation to break even in ten scenarios.

A	B	C	D	E	F
Scenario	Acres	Net Gain from Irrigation $/acre in Dry Year (2009)	Per Acre Ownership and Operating Cost in One Year of No Response (2010)	Years of Response Needed to Recover Investment*	Consecutive Years of this Scenario Needed to Recover Investment
1	20	69.35	126.68	2 of 3	8.89
2	40	122.88	73.15	1 of 2.68	3.68
3	20	220.38	126.68	1 of 2.74	4.02
4	40	273.91	73.15	1 of 4.74	1.84
5	20	91.2	126.68	3 of 5	7.56
6	40	144.73	73.15	1 of 3	3.22
7	20	267.46	126.68	1 of 3	3.43
8	40	320.99	73.15	1 of 5.39	1.59
Scenarios 9 and 10 are the 3 line, 30 acre versions of scenarios 6 and 8.					
9	30	121.63	97.49	1 of 2	4.66
10	30	297.89	97.49	1 of 4	2.21

*Column E = Ratio of Column C to Column D and rounded in some cases.

Using Scenario 1 in table 6 as an example, the added value of increased yield per acre was $69.35 in 2009. The per-acre ownership and operating cost experienced in 2010 was $126.68 or nearly double the gain achieved in 2009. Consequently, Column E shows it would take about two years similar to 2009 in order to offset the irrigation costs in a no-response year like 2010.

Because the other scenarios benefitted more from the irrigation system, the number of years with adequate rainfall (no response) that could be covered by the increased value from irrigation in dry years increased. For example, in Scenario 2, the added value of increased yield per acre would have been $122.88 in 2009 on 40 acres, compared to the combined per acre annualized ownership and operating cost of $73.15 in 2010 requiring one year like 2009 to nearly break even with 1.68 years like 2010. Therefore, one response year out of 2.68 or 3 years is needed to pay for the irrigation system in scenario 2. The gain projected for several other scenarios are doable.

It is unlikely that any of the ten scenarios in Table 6 will have consecutive years. However, it can be instructive to calculate how quickly the irrigation investment could be recovered if any scenario occurred in consecutive years.

Column F in Table 6 shows how many consecutive years of any of the ten scenarios are needed to recover the entire investment (plus cover all operating costs) in the irrigation system. If the irrigation system produced scenario one results each year, it would take 8.89 consecutive years of scenario one performance to recover the irrigation system investment and all other costs. Consecutive years of any other scenario performance would recover the irrigation system investment and all other costs much faster.

Research data was not collected after the 2010 growing season. Still, the experience of the 2011-2015 seasons can provide additional insight into the system's productive and economic performance.

Table one illustrates how using each K-line to maximum capacity (4 moves per 24 hours) would deliver one inch of water per week to 20 acres. Although the original two K-lines could theoretically deliver one inch of water per week to 40 acres, to conveniently irrigate more than 30 acres with 2 K-lines, Paul would have to install another underground pipe on rented land and extra labor would be needed to use the two K-lines to maximum capacity.

Recognizing the potential value of watering more acres plus the limitations imposed by labor, land access, and water lines, Paul Onan purchased a third K-line for the 2011 season, making it relatively easy to deliver an inch of water per week to 30 acres (with additional underground water lines and more labor, the three lines could theoretically deliver one inch of water per week to 60 acres). In practice, Paul Onan used the third line to increase the adequately watered acres from 20 to 30 beginning in 2011.

The third line reduced Mr. Onan's annual ownership costs per acre because the third line spread the initial investment cost of $22,183 (includes amounts paid for by grants) over 30 acres instead of 20 acres to reduce the annual per acre cost from $107.06 (scenario 1) to $71.37 (scenario 9 or 10) or a reduction of $35.69 per acre. The additional investment of $1,506 for the third line added only $4.77 to the annualized per acre ownership cost. In practice, increasing capacity by 50 percent for only 7 percent more investment reduced the total annual ownership costs by a net amount of $30.92 per acre and has been economically beneficial. Even more important than the reduction of total annual ownership cost per acre was the increase in income potential from the additional 10 acres watered by the third line. The smallest gain from irrigating per acre shown in table 5 among the 8 scenarios of $69.35/acre is more than double the per acre reduction of total annual ownership costs.

Because the changes to the ownership cost caused by the purchase of the third line were relatively small and because the actual operating costs have turned out to be fairly close to (and a bit lower than) the operating costs that were originally projected, tables 1 through 5 were not updated from the last edition of this paper. Scenarios were 9 and 10 were added to Table 6.

2011 weather turned out much like 2010. Realizing that the cost of irrigating too late is greater than the cost of irrigating too early, Paul Onan irrigated three times on 30 acres in 2011, once in mid-June, in July and again on August 18th. In June, the acreage was watered for eight hours. The July and August applications lasted 12 hours. Soon after the irrigation applications, adequate rain fell. In addition, Mr. Onan irrigated 1.5 inches of water on three to four acres of new forage seeded on the 13th of August, which caused the seeding to germinate ten days earlier than the un-watered seeding. Collectively, it is estimated that about 5.3 inches of irrigation water were applied to 30 acres in 2011.

Although precise data wasn't recorded after 2010, Paul Onan saw no production response, making it reasonable to assume the same economic outcome from the irrigation system as experienced in 2010, which was a combined operating and ownership cost of $126.68 per acre.

2012 ranks along with 1988 as one of the driest growing seasons in a century. Paul Onan irrigated early and aggressively to keep 30 acres of pasture growing productively all season. Again, although little data was maintained, Paul noticed that adequate water with abundant sunshine made the plants grow more productively than Paul has observed in cooler years with adequate rain but less sunlight. Consequently, the production response was likely much better than in 2009. The per acre net gain from irrigating was likely close to $300.00 (scenario 10 in Table 6) and obtained from 30 acres compared to 20 acres in 2009. In fact, given the shortage of and high price of feed in 2012, the economic gain may have been even higher than $300 per acre.

Again, little data was recorded in 2013 and 2014. Paul Onan estimates that he watered 30 acres about 4 times each year, and for a per acre yield response each year that was about half of what was achieved in 2009. Again any yield increases in 2013 and 2014 were obtained from 30 acres instead of from 20 acres in 2009. Consequently, the combined economic benefit of irrigating in 2013 and 2014 was likely close to the economic benefit from 2009.

In 2015, water was applied for 5-6 days in late July before adequate timely rains returned for the rest of the season. The operating costs were about $300 in electricity and some labor with an unknown yield response.

Reviewing the seven years, three years (2010, 2011 and 2015) provided minimal or no response, two years (2009 and 2012) provided responses that were economically attractive and two years (2013 and 2014) were each about half way in between. It is likely that the production and economic response was better than the equivalent of 2009 three of the seven years.

As near as can be determined all costs (investment, ownership, and operating costs) in the irrigation system have likely been recovered in the first six years of operation. Unless Paul Onan uses the system extensively with very little or no additional production response from the irrigation system in the future, his cumulative added income over added expense should increase over time.

The irrigation system has also reduced the constant uncertainty about feed supply previously faced by Paul Onan much of his farming career. This has helped Paul to achieve other goals.

Approaching retirement age, Paul Onan has hosted some farming interns in the last eight years in part as a farm transition plan. It would have been difficult to support an intern and his own family with the 40-50 cows and 140 acres that Paul Onan had for much of his career. The irrigation system helped Paul Onan increase his herd size to 100 cows. Increasing rented crop acres to 120 helped too.

For those who are thinking about investing in an irrigation system, it's important to recognize that Paul Onan's soil has very limited water holding capacity. Owners of farmland with soil of much greater water holding capacity might not be able to justify the investment.

Irrigation Performance on Two Other Wisconsin Grazing Farms

Two other farms, Rick and Val Adamski and Wayne and Kay Craig, also invested in K-line irrigation systems in time to use for the 2009 growing season via other arrangements. Data was collected from both farms in 2009 and 2010 in the same manner as data collection on Paul Onan's farm. The soils on the Adamski (Onaway fine sandy loam and Soloma Loam) and Craig (Hochheim loam and Lamartine silt loam) farms have much greater moisture holding capacity than Paul Onan's soils. No yield response was measured on these farms in 2009 or 2010. In 2012, both Adamskis and Craigs used their irrigation systems on their pastures. Both were able to keep their irrigated pastures growing and producing forage the whole growing season. In contrast, Craig's non-irrigated pastures went dormant for part of the summer. Adamskis were less affected by the drought than many others were in 2012.

Although precise measurements were not taken on either farm since 2010, 2012 was the one year out of six in which both farms achieved some production quantity response from their irrigation systems. Although it is unlikely that their irrigation systems will pay for themselves, Adamskis and Craigs view their irrigation systems as many people view insurance (as something better to have and not need rather than need and not have). The Adamskis and Craigs have soils that are much more typical in Wisconsin than is the case for Paul Onan. Consequently, unless the future brings climate changes that cause dry years like 2012 to repeat far more often than has occurred in the last several decades, it is likely that a relatively small percent of Wisconsin graziers could expect to recover their investment in a system to irrigate pastures.

Conclusions

1. Without a production response, no investment in irrigation would pay.
2. Paul Onan's Rosholt sandy loam soil has a relatively low water holding capacity. Therefore a yield response to irrigation is much more likely from it than from many other Wisconsin soils.[7]
3. In scenario one, irrigation more than paid its annual costs on Paul Onan's farm in 2009 but not enough to also offset the cost for no return in 2010 and 2011. He likely achieved scenario 3 results in 2009.
4. It should not be assumed that all of the increased yield will be in the vegetative stage making it worth $373.85/ton dry matter. The scenarios using a higher value for vegetative stage forage assumed only half would be harvested at this stage. This should be achievable and economically advantageous.
5. Looking at all the above scenarios, Paul Onan has likely obtained the equivalent of 1.75 TDM/A with at least half consumed in the vegetative stage by lactating cows every other year. Therefore, Paul's irrigating system likely was fully paid for in 6 years – much faster than the 20 year projected system life.

Recommendations and Precautions

1. Inexperienced irrigation managers usually wait too long before starting to irrigate. Waiting too long usually means that some potential yield is lost and the irrigation manager has to play catch up to avoid losing more yield response.
2. Applying one inch of water per acre per week will use water more efficiently compared to applying two inches of water per acre in one pass for the next fourteen days for several reasons. First, some of the irrigation water will likely run off because two inches applied at one time will exceed the water holding capacity of most soils that will respond to irrigation. Secondly, more of the moisture in the two-inch application is likely to be evaporated. Thirdly, if adequate rainfall resumes one week after the two inches are applied, a portion of the two inches that was applied would not have been needed. Also, weather forecasts for periods eight to 14 days in the future are less accurate than forecasts in the next seven days. Delivering two inches of water in two passes doubles the labor cost compared to delivering two inches in one pass with the K-Line system. However, labor cost was only about $1.00 per acre inch in 2009. Therefore, it doesn't take much gain in efficiency of water use to offset the added labor cost.
3. The operating cost for two acre inches was $21.25 in 2009. It would only take a dry matter yield increase of 283 lbs. of dry matter valued at $150 per ton to pay the operating cost for the two inches of water.
4. Increasing yields typically increases the need to add nutrients. Monitor fertility (tissue testing, etc.) to ensure that fertility is adequate to consistently achieve higher yields from irrigation over a period of years.
5. Like any other capital investment, an irrigation system is more likely to pay for itself if used close to full capacity.
6. Ask if irrigation is the best use for your investment dollars. Even if this investment will pay for itself, look to see if there would be another way to invest those dollars for a higher return.
7. This study happened to use the K-Line system. The same economic principles apply regardless of the irrigation equipment or system used.
8. This study did not attempt to measure any environmental impacts associated with irrigation.
9. Before investing in an irrigation system, learn as much as you can about the principles of irrigation, the characteristics of your soils, and your micro climate. With this knowledge, try to project your potential costs and gains before investing. Get estimates of the cost and labor requirements of the irrigation equipment you would use. Your County Agricultural Agent can help find the information.

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Endnotes

[1] Golden Sands Resource Conservation and Development Technician
University of Wisconsin-Extension Langlade County Agricultural Agent
Owner and operator of farm upon which this research was conducted
University of Wisconsin-Extension and Center for Dairy Profitability Farm Financial Analyst etc.

[2] USDA. (No date.) National Resource Conservation Service (NRCS) Report: Irrigation Water Requirements: Crop Data Summary. Accessed March 1, 2011. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/?&cid=nrcs143_010855 .

[3] K-Line North America. (No date.) Accessed March 1, 2011. http://www.k-linena.com .

[4] Crockford, Alex. (August 24, 2011.) Irrigation of Rotational Grazed Dairy Pastures. UW-Stevens Point, Unpublished master's thesis. Appendices A-D. The table has had a minor heading name change for clarity from the original unpublished master's thesis.

[5] Crockford, Alex. (August 24, 2011.) Irrigation of Rotational Grazed Dairy Pastures. UW-Stevens Point. Unpublished master's thesis. Appendices A-D. The table has had a minor heading name change for clarity from the original unpublished master's thesis.

[6]Brink, Geoff. (March 1, 2011) Personal communication, Research Agronomist at the USDA Dairy Forage Research Center, Madison, Wisconsin.

[7] The water holding capacity of several soils and much additional information about irrigation management is found in a NRCS 754 page irrigation guide found at the following website:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/?&cid=nrcs143_010855 .