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Forage Crop Irrigation Systems and Economics

Irrigation presents an opportunity for Missouri forage producers to mitigate production risk from drought. This guide explores three areas to consider before choosing a forage irrigation system: expected forage response, equipment options, and the economics of irrigating forage.

Factors in choosing a system

Each producer's irrigation situation is unique. Site-specific research is needed to determine if investing in forage irrigation would be a good economic decision. The following factors should be considered first to determine what systems are good options in your situation.

Water availability

In most areas in Missouri, water availability affects the decision to irrigate and how many acres can be watered. Carefully evaluate existing water sources: determine how much water can be withdrawn from them and at what rate it can be withdrawn (gallons per minute). Investigate how reliable those sources will be during prolonged droughts. If necessary, evaluate the cost of developing a new water source, such as a well or lake.

Land slope, shape and soil type

Land that is highly sloped may not be conducive to irrigation systems. Oddly shaped fields may allow only certain irrigation systems to be an option. Soil types affect the rate of water absorption, potential for forage growth, and potential for water runoff. Soils determine the total amount of water that will need to be applied, how much water will need to be applied per pass, and how often water will need to be applied.

Energy cost and availability

The cost of running power units to pump water can vary greatly. Wells where the water has to be lifted from a deep source or using irrigation systems that require significant pressure can drastically increase the cost of pumping water. Fields without close access to electricity would necessitate the use of a different energy source, such as diesel or propane.

Labor

Each irrigation system has certain labor requirements. Systems such as center pivots require less daily labor than manually moved systems, such as traveling guns or pod-line irrigations. You will need to have enough labor available during the times needed and understand its cost.

Irrigation system cost and return

Farmers make an investment in irrigation hoping it will bring an economic benefit. Information on how to evaluate the costs and returns of forage irrigation can be found further in this guide.

Forage response for irrigation

In Missouri, the highest irrigation water needs for most forage crops will be from June through August, when there is typically a rainfall deficiency. Rapid growth stages for forages represent times one can achieve the most forage yield improvement from irrigation if rainfall is inadequate. Figures 1 and 2 demonstrate the growth patterns and periods for efficient irrigation for cool-season and warm-season perennial forages.

Note that for cool-season species, rainfall is often adequate when temperatures are ideal for growth. Unfortunately, most producers interested in irrigating cool-season grasses wish to extend growth into the summer when temperatures are less than ideal for

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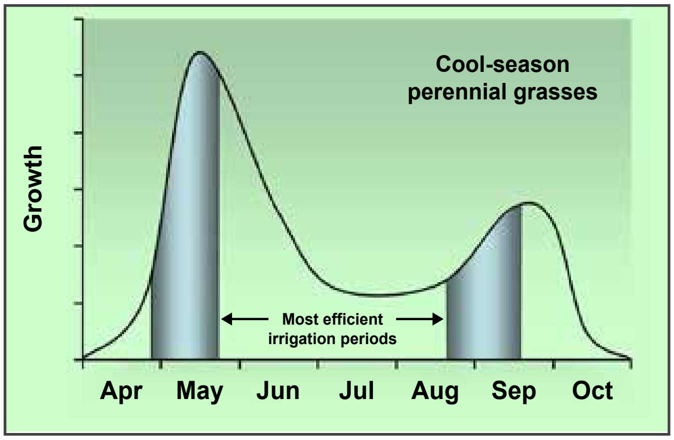

Figure 1. Typical growth patterns of cool-season perennial grasses. Shaded bars represent rapid growth phases and periods of efficient irrigation. (Source: Volesky and Berger, 2010.)

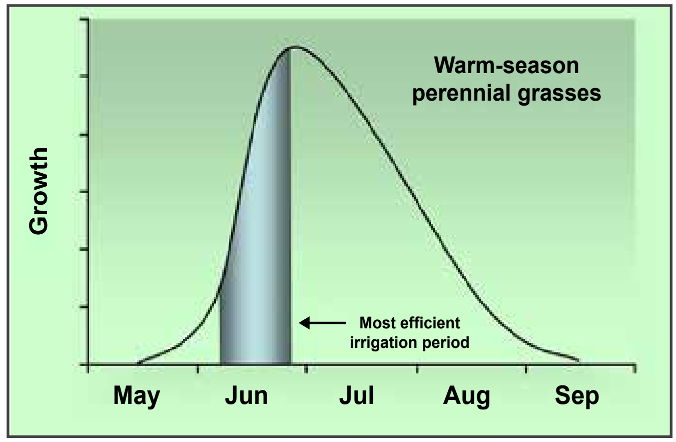

Figure 2. Typical growth patterns of warm-season perennial grasses. Shaded bars represent rapid growth phases and periods of efficient irrigation. (Source: Volesky and Berger, 2010.)

maximum growth and, thus, irrigation efficiency. Further, forage species vary in how effectively they convert irrigation water into additional forage (Table 1). Cool-season perennial grasses, such as tall fescue or orchardgrass, usually produce less response from irrigation than warm-season grasses, such as sudangrass or crabgrass. Growth responses to irrigation vary by soil type, species, plant stage of growth, season, total water available, and time of harvest. Strategic use of nitrogen fertilizer can optimize forage production as well.

Table 1. Missouri guidelines for forage response to irrigation.

Species	Pounds of dry matter per acre-inch water*
Cool-season perennial grass	450 to 700
Warm-season grass	600 to 1,000

*Response is based on effective water available (rainfall and/or irrigation) for plant growth. Soil water-holding capacity, growth conditions and application efficiency should be part of any irrigation planning program.

University of Missouri researchers conducted forage irrigation research through a SARE grant in 2017 and 2018. It was found that forage responses became more apparent when soil water availability was below 40 percent. Note that the forage growing conditions within those years were mostly adequate from a rainfall standpoint.

Types of forage irrigation systems

Missouri producers have many options for forage production irrigation, in both low-pressure and high-pressure systems. This guide focuses on four typical systems: pod-line irrigation, low-pressure traveling irrigators, high-pressure traveling guns and center pivots.

Pod-line irrigation systems (low pressure)

Pod-line irrigation systems are made up of a series of pod sprinklers on a drag hose (Figure 3). Optimal pressure needs for the sprinkler system are typically from 35 to 55 pounds per square inch (psi). Water requirements for this system vary by nozzle sizing and number of nozzles and range from 12 to 24 gallons per minute, but systems can be developed and sized according to the water quantity available from the source. Each pod has the capacity to irrigate a 2,500 foot, or 50-by-50 foot, area. A typical 12-pod system can irrigate about 5 to 10 acres with one or two moves a day. The system can be moved by pulling the line, with pods attached, with an all-terrain vehicle (ATV), tractor or utility vehicle. Systems are typically moved once or twice daily depending on how much water you want to apply, and passes are repeated on a seven- to 14-day rotation as needed.

The primary advantage of this system is its flexibility. It can be used on many field sizes and slopes. Pod-line irrigation systems can be customized (number of pods and nozzle types per system) to match the water source capabilities, and separate lines can be added to increase the acres covered. Pod-line systems have low capital investment costs when compared to other systems and low maintenance requirements.

A disadvantage of pod-line irrigation is that it is a manual system that must be moved to another area once or twice a day. Also, it covers a limited number of acres per pod line. Its coverage can be scaled up with the purchase of additional pod-line systems, but each additional pod line increases daily labor needs. Further, some tall-growing crops are difficult to irrigate with pod-line systems due to the mashing that occurs during moving.

Figure 3. Pod-line irrigation system.

Figure 4. Low-pressure traveling irrigator.

Figure 5. Hose-pull traveler irrigation system.

Figure 6. Center-pivot irrigation system.

Traveling irrigator (low pressure)

The low-pressure traveling irrigation system is a wheeled system used to spread effluent or to irrigate pasture (Figure 4). Nozzles spray water while being constantly spun in a circle. The irrigator is attached by a cable to an anchored endpoint, along with a hose that supplies the water. The spinning causes a series of gears to move, reeling the irrigator in with the cable toward the endpoint. Optimal pressure needs for this sprinkler system will vary from 20 to 50 psi. A typical system will irrigate 20 to 40 acres.

Some benefits of this traveling irrigator include adjustable speeds, low cost, low pressure needs, light weight, and ease of use in comparison to other irrigation systems. This system can effectively irrigate a variety of field sizes and shapes in straight lines.

A disadvantage of this system is the daily labor requirement. The system must be reset for each path, and the travel distance is limited by the cable length, which ranges from 820 to 1,300 feet.

Traveling gun (high pressure)

A high-pressure traveling gun irrigation system is made up of a large sprinkler gun on a wheeled cart and a reel system (Figure 5). Traveling guns require pressure ranging from 60 to 120 psi and can irrigate 0.2 to 0.9 acres for every 100 feet of travel length. The reel system is available in either a cable-tow (flexible hose) or hose-pull (hard hose) configuration. Cable-tow systems are anchored at a point at the end of the field and use a winch, powered by an engine or a water drive, on the cart to pull itself across the field. A hose-pull system uses the hose to pull itself across the field and has a reel powered by either an engine or a water drive. Most traveling guns will cover a maximum of 80 to 100 acres per gun.

A major advantage of the traveling gun system is its flexibility. It can accommodate fields of many sizes and shapes. Additionally, it can put on more water and cover larger acreages than low-pressure traveling irrigator or pod-line systems.

Disadvantages of a traveling gun system are that the operating costs and energy requirements tend to be high. Additionally, daily labor needs are high as the system requires a new setup after each path is completed.

Center pivot (low or high pressure)

A center pivot consists of a series of sprinklers on a self-propelled system that rotates around a pivot point (Figure 6). Depending on how many acres are being irrigated, several towers are linked together to make up the system. Typically the length of the system is 10 towers, which would equal 1,320 feet, or a quarter mile. With each additional tower added on, the number of acres irrigated and total travel distance begins to increase at an accelerated rate. Center-pivot systems are available in towable or nontowable (fixed at the pivot point) units. Electric or hydraulic drive systems can be used to propel the center pivot. Sprinklers can be adjusted for low or high operating pressures. In addition, the pivot system can be outfitted with additional lines and sprinklers to spread liquid effluent or to mist cows to alleviate heat stress in the pasture. Such dual irrigation/cow-cooling systems are typical in center-pivot-irrigated, pasture-based dairies.

The advantages of the center-pivot system contribute to its wide usage. The system can be adjusted to be as large or as small as needed by changing the number of towers. Control systems can be sophisticated or simple and can even be operated remotely by wireless communications. These systems have low labor and maintenance requirements and are easy to operate. In addition, pivot systems can be used to cool cows and to spread effluent by either using the same irrigation line or hanging additional lines on the system.

Disadvantages of a center-pivot system include that not all fields are conducive to their use, and total capital investments may be higher than with other systems. Land with slopes greater than 10 percent or a field shape that limits the circular rotation are the primary concerns with center pivots. Because of the system's circular rotation, corner areas do not receive water irrigation unless you invest in a corner system. Also, retrofitting a center pivot into an existing grazing system with fencing and other existing infrastructure can be challenging. Additionally, capital investments for the system tend to be higher on a per acre basis for small pivot systems than those for pod-line and traveling irrigator or gun systems.

Economics

The decision to invest in a forage irrigation system should be carefully considered from a financial standpoint. For beef and dairy producers, investing in additional storage for harvested forages and continually carrying additional hay or silage inventory as drought insurance may be cheaper than developing irrigation as a means of drought mitigation. Still, many farmers see irrigation as a better way to assure normal operations during rainfall shortages.

Generally, larger irrigation systems lead to lower irrigation investment per acre and have lower operating costs per acre than smaller systems. For many farmers, the choice of irrigation system depends on the capability of the water system, the time they are willing to spend irrigating, and the field size and shape.

When deciding whether to invest in a forage irrigation system, you should consider both the ownership and the operating costs.

Ownership costs

Ownerships costs for an irrigation system include depreciation, interest on the investment, property taxes and insurance.

Capital investments include equipment, piping, pumps, storage, and system installation. All assets decrease in value over time. Economic depreciation is a method of recognizing the annual cost of the one-time investment in those assets. Each investment has an expected useful life, in years, and an anticipated salvage value at the end of its useful life. Economic depreciation is calculated by subtracting the salvage value from the purchase price, and dividing the balance by the assumed years of life.

Interest is considered on a capital investment. Producers may purchase equipment with equity or use debt financing. Even if assets are purchased with equity, there still remains the opportunity cost of not using those funds on another alternative. One method for calculating interest costs would be to multiply the average capital investment (purchase price plus salvage value, divided by two) by an annual interest rate.

Missouri collects personal property tax on farm equipment. Market value of equipment is multiplied by an assessment level — 12 percent for farm equipment — to arrive at an assessed value. Assessed value is then multiplied by the local tax rate, which varies by county or jurisdiction, to derive the property tax owed.

Finally, insurance premiums will vary by the insurance carrier and policy chosen.

Operating costs

Operating costs for an irrigation system include power, labor, and equipment repair and maintenance.

Irrigation power units require energy to pump water and pressurize the whole system. Power units may be electric motors or diesel or propane engines. In general, electricity tends to have advantages over liquid fuels in cost, maintenance and automation. But in some cases, getting access to electricity if it is not readily available at the location needed can be cost-prohibitive. Major factors that will affect the pumping cost include the price of fuel, operating pressure (psi), pumping lift (depth), and volume of water applied.

Labor is needed for the setup and operation of irrigation equipment. Producers should factor in the labor rate — including wages, social security, Medicare, workers compensation, etc. — necessary to pay for labor to perform irrigation duties in setting and operating the irrigation system.

Repairs and maintenance are required to keep irrigation equipment and power units set, tuned and operational. The expected costs will vary by component (pump, engine, well, pipe, etc.) and its usage and age. Estimated annual maintenance costs for irrigation system and its components will typically range from 0.5 to 5 percent of average capital investment.

Economic examples of irrigation systems

The economics of various irrigation systems are presented below in examples (Tables 2, 3, 4, and 5) that could be applied in Missouri. Assumptions and costs were generalized and can be customized to be specific to any farmer's situation. To simplify the examples, they assume that you already have access to a lake, river or well that can provide the sufficient water quantity and rate, and the forage response from irrigation is 600 pounds of dry matter per acre-inch water.

Table 2. Pod-line irrigation system (10 acres).

Type of cost/assumption		Annual cost ($)	Per acre ($)
Depreciation	15 years of useful life	380.00	38.00
Interest	5.50% of avg. investment	156.75	15.68
Taxes	0.25% of avg. investment	7.13	0.71
Insurance	0.50% of avg. investment	14.25	1.43
Labor	60 hours of irrigation (6 hours per run)	960.00	96.00
Repair	3% of avg. investment	85.50	8.55
Power	Electric @ $0.11 per kilowatt hour, 2.3 hp	245.14	24.51
	Total annual costs	1,848.77	184.88
	Irrigation cost per ton of dry matter	61.63 per ton	

Notes: Water volume applied was 2,715,400 gallons per year based on 10 application periods and 1 acre-inch per irrigation. Water source is assumed a nearby river, lake or lagoon. Total capital investment was $5,700 for pod-line system, source pump/power unit and distribution pipe, connections and intake. Additional dry matter expected for irrigation is 30 tons per year.

Table 3. Traveling irrigator (low pressure) (30 acres).

Type of cost/assumption		Annual cost ($)	Per acre ($)
Depreciation	15 years of useful life	860.00	28.67
Interest	5.50% of avg. investment	354.75	11.83
Taxes	0.25% of avg. investment	16.13	0.54
Insurance	0.50% of avg. investment	32.25	1.08
Labor	90 hours of irrigation (9 hours per irrigation)	1,440.00	48.00
Repair	3% of avg. investment	193.50	6.45
Power	Electric @ $0.11 per kilowatt hour, 7.8 hp	1,103.15	36.77
	Total annual costs	3,999.78	133.33
	Irrigation cost per ton of dry matter	29.63 per ton	

Notes: Water volume applied was 12,219,300 gallons per year based on 10 application periods and 1.5 acre-inch per irrigation. Water source is assumed a nearby river, lake or lagoon. Total capital investment was $12,900 for the traveling irrigator, a source pump/power unit and distribution pipe, connections and intake. Additional dry matter expected for irrigation is 135 tons per year.

Table 4. Traveling gun (high pressure) (60 acres).

Assumptions		Annual cost ($)	Per acre ($)
Depreciation	15 years of useful life	3,833.33	63.89
Interest	5.50% of avg. investment	1,581.25	26.35
Taxes	0.25% of avg. investment	71.88	1.20
Insurance	0.50% of avg. investment	143.75	2.40
Labor	180 hours of irrigation (18 hours per irrigation)	2,880.00	48.00
Repair	3% of avg. investment	862.50	14.38
Power	Electric @ $0.11 per kilowatt hour, 34.6 hp	3,364.98	56.08
	Total annual costs	12,737.69	212.29
	Irrigation cost per ton of dry matter	47.18 per ton	

Notes: Water volume applied equaled 24,438,600 gallons per year based on 10 application periods and 1.5 acre-inch per irrigation. Water source is assumed a nearby river, lake or lagoon. Total capital investment was $57,500 for the traveling gun/cart, a source pump/power unit and distribution pipe, connections and intake. Additional dry matter expected for irrigation is 270 tons per year.

Table 5. Center pivot (low pressure) (134 acres).

Assumptions		Annual cost ($)	Per acre ($)
Depreciation	25 years of useful life	5,076.00	37.88
Interest	5.50% of avg. investment	3,489.75	26.04
Taxes	0.25% of avg. investment	158.63	1.18
Insurance	0.50% of avg. investment	317.25	2.37
Labor	20 hours (2.0 hours per irrigation)	320.00	2.39
Repair	3% of avg. investment	1,903.50	14.21
Power	Diesel @ $2.15 per gallon, 179.3 hp	19,782.22	147.63
	Total annual costs	31,047.34	231.70
	Irrigation cost per ton of dry matter	51.49 per ton	

Notes: Water volume applied equaled 54,579,540 gallons per year based on 10 application periods and 1.5 acre-inch per irrigation. Water source is assumed a well. Total capital investment was $126,900 for the pivot machine, electric generator, concrete pad, source pump/power unit, fuel tank and 500 foot well.Additional dry matter expected for irrigation is 603 tons per year.

Decision support tool

The Forage Irrigation System Cost Analyzer (https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pro/Beef/Docs/ForageIrrigationSystemCostAnalyzer.xlsx)is a spreadsheet tool that helps producers estimate the cost of using forage irrigation. You can use it to develop an irrigation system based on time and water needs, estimate an irrigated forage response, and detail irrigation costs to get an economic summary of a system. Additionally, it can help plan pipe and pump sizing for your situation.

For more information

For more information about irrigation systems, contact a local irrigation company or dealer. They can help customize irrigation systems around your farming situation and provide irrigation technical assistance and specific cost information.

Sources

Henggeler, J.C. 1988. Irrigation systems for forage crops. Guide B-1611. Texas Agricultural Extension Service.

Henggeler, J.C. 2012. Irrigation systems, wells, and pumps of the Mississippi River Alluvium Aquifer of Southeast Missouri. Columbia: University of Missouri Extension.

Hoffman, T. R. and G. S. Willet. 1998. The economics of alternative irrigation systems in the Kittitas Valley of Washington state. Farm Business Management Reports EB1875. Washington State University Cooperative Extension.

Scherer, Thomas, et al. 1999. Sprinkler irrigation systems. Ames, IA: MidWest Plan Service.

Scherer, Thomas. 2018. Selecting a sprinkler irrigation system. AE-91 Guide. North Dakota State University Extension Service.

Volesky, J. D. and A. L. Berger. 2010. Forage production with limited irrigation. Neb Guide G2012. Lincoln: University of Nebraska-Lincoln Extension.

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