PRECISION MECHANICAL MOVE IRRIGATION FOR SMALLHOLDING FARMERS

Jacob LaRue[1]

ABSTRACT

Mechanical move irrigation equipment typically has been designed for square fields 805 m long on each side, as much of the western United States was surveyed and laid out on a township grid system with these field dimensions. Center pivots commonly cover 52.6 hectares out of 64.8 total hectares. Because of this, a common misconception is that mechanical move irrigation equipment such as center pivots and lateral move equipment are only economically viable for large fields. But what about small holding farmers – are there economically viable solutions for them to utilize mechanical move irrigation such as center pivots? What options are commercially available for them to take advantage of the benefits associated with mechanical move irrigation such as precision irrigation, application uniformity, irrigation efficiency and low energy costs? This paper will discuss mechanical move equipment options available for small holding farmers and the infrastructure requirements for this type of equipment. These will be compared to other options a smallholding farmer may be considering for irrigation. Estimated relative costs for project development and operation will be presented for each. Case studies of mechanical move equipment for small fields installed in Asia and Africa will be presented and preliminary results discussed including the 'fit' of this type of equipment into the cultural structure of the area. Based on current data, a proposed economic model to assist with the evaluation of the suitability of mechanical move irrigation for smallholding farmers will be presented. The paper will close with a discussion of future needs and concerns.

INTRODUCTION

When one flies over many parts of the United States, parts of South America and the Middle East, it is common to see large 'circles' on the land below. These are created by mechanized irrigation - specifically the center pivot. Typically these center pivots are about 400 meter in length and cover approximately 50 hectares. The center pivot was invented in the central plains of the United States and by far the largest concentrations of these units are in the southern and central plains of the USA where the land was divided into square blocks of townships, sections and the quarter being the smallest unit – 805 meters x 805 meters. The original center pivot was designed to fit this size of field.

Before the discussion is continued, a summary of the basic components of a center pivot needs to be presented. Typically the center pivot consists of several basic components:

1) Pivot point – which anchors the pivot and about which the center pivot rotates

[1]Manager, Project and Product Support, Valmont Industries International Irrigation, Valley, Nebraska, USA
jlarue@ valmont.com

2) Spans – which carry the water and provide mobility consisting of:
    a. pipeline structure– which carries the water to the water application package
    b. overhang - which extends past the last set of wheels
    c. drive unit/drive train – at the out end of each pipeline section.

3) Water application package – which applies the water in the manner desired by the customer to meet their crop needs

4) Controls – which allow the operator to start, stop, control application depth and control other equipment operations

Every center pivot requires:

1) One pivot point – fixed or towable
2) One control
3) One to twenty two spans
    a. Drive mechanism
4) One water application package

When the center pivot was introduced in the 1950's, the drive train was propelled using water pressure. In the late 1960's three phase electric motors were introduced to provide power to move the drive train. As energy costs rose in the 1970's, the electric drive became the dominate form for providing power.

From the 1950's until the late 1990's the focus continued on center pivots of 400 meters and larger. The center pivot has and continues to bring a variety of significant features to the farmer including uniform application, high efficiency of application, low energy requirements, maximum flexibility of a variety of crops and growing cycles, and minimal filtration requirements. While the general size of 400 meters has worked well in the United States and other countries with large open areas for irrigation, many countries of the world have areas being irrigated by traditional methods which are significantly smaller.

For our discussions, we will consider small holdings farms of one to two hectares.

DISCUSSION

What forms of mechanized irrigation are available to small holding farmers? The same components that are used to make a large center pivot can be used for small holdings.

Equipment options available

A basic drawback for many small fields to utilize center pivots is the lack of three phase power. Three phase power can in many cases prove to be a significant limitation due to the cost and the extensive infrastructure that may be required. To overcome this, center pivot manufacturers offer a number of specific drive train power options for single span center pivots.

Single Span Spinner Drive (Figure 1) –

- Utilizes water pressure to provide the power for the drive train.
- The rest of the drive train is the same as for a conventional center pivot
- Advantage
    - Requires no electric power

- Disadvantages
    - Requires a minimum of 2 bars of water pressure
    - Limited slope capabilities

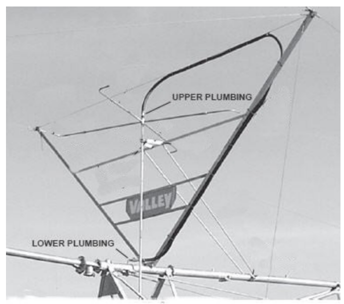

Figure 1. Spinner span drive

Single Span Engine Drive – (Figure 2)

- Utilizes a 4kw internal combustion engine to provide the power for the drive train.
- Advantages
    - Almost no slope limitations
    - Independent of water pressure
    - Easily reversible
- Disadvantages
    - Requires fuel
    - Requires maintenance

Figure 2. Engine span drive

Multi span Electric drive – (Figure 3)

- Utilizes a 0.4kw 480vac motor
- Advantages
    - Almost no slope limitations
    - Operates independently of water pressure
- Disadvantages
    - Requires three phase power source
    - Requires power cable, tower box, collector ring and electric control panel

Figure 3. Electric span drive

Comparison to other irrigation options available for small holdings

Any of these drive options allow the small holding farmer to take advantage of the benefits of center pivots – high application efficiency, high uniformity, flexibility in cropping, and in both of the single span options, simplified infrastructure requirements.

Type	Energy Consumption	Application Uniformity	Cropping Flexibility
Single span mechanical	low	high	high
Surface irrigation	low	low	high
Handmove sprinkler	high	medium	medium
Drip irrigation	low	low	low

Discussion of terms used:

Energy consumption – in general terms it will distinguish if the technology is a high or low user of energy for the amount of irrigation that is used

Application uniformity – in general terms it is the water applied for irrigation that is equally distributed across the entire field

Cropping flexibility – it determines if the type of irrigation has any limitations to the type of crop that can be produced and if the type of irrigation easily allows for a rapid transition between crops

CASE STUDIES – EQUIPMENT AND CULTURAL IMPACT

Case 1 – China

Equipment type used is a Single Span with Spinner drive. The majority use a two wheel EZ Tow pivot point to allow easy movement from one field to the next. A few farms use a fixed pivot point. The span configuration is 60.6m span with a 22.6m overhang covering 2.1ha per set. The machines are towed between two up to six different sets irrigating a total of 4.2 to 12.6ha per unit. The drive train propulsion is water from the impulse arms. There is no control – the unit is either on or off. The water application package is a Senninger I-Wob package.

The crops produced are forage, feed grains and vegetables.

Each machine is shared between three to ten farmers (Figure 4).

The farmers have found the Single Span easy to operate requiring little skill. The Spinner drive provides good uniformity but little control of the depth of water applied per pass. The machine has been simple for them to move from field to field.

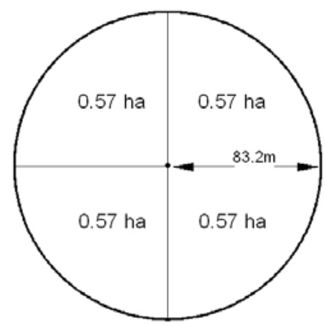

Figure 4

Culturally the Single Span Spinner Drive has fit well and sharing of a single unit by farmers has been readily acceptable.

Case 2 – Pakistan

Equipment type used is a Single Span with Engine drive. The farmers use a two wheel EZ Tow pivot point to allow easy movement from one field to the next. The span configuration is 60.6m span with a 22.6m overhang covering 2.1ha per set. The machines are towed between two up to six different sets irrigating a total of 4.2 to 12.6ha per unit. The drive train propulsion is a 3.7kw gasoline engine. Control is via setting of the throttle of the engine. Water application is provided using a Valley LEN package.

The crops produced are forage and feed grains.

One farmer owns one machine and no units are shared between farmers.

The farmers have found the Single Span Engine Drive easy to operate and allowing control of the depth of water applied per pass. The machine has proved to be simple for them to move from field to field. The Single Span does not require the degree of filtration required for drip systems also used in the area.

Culturally the Single Span Engine Drive has been a good fit and interest exists for a small group of farmers to consider sharing of a unit.

One major issue is the water delivery which impacts all of the precision irrigation solutions. The typical water delivery through the canal system is water is available for seven days and then no water for seven days. This presents a challenge when trying to manage the machine for efficient irrigation.

Case 3 – South Africa

Equipment type used is a Single Span with Spinner drive. The farmers use a two wheel EZ Tow pivot point to allow easy movement from one field to the next. The span configuration is 60.6m span with a 22.6m overhang covering 2.1ha per set. The machines are towed between three to up to eight different sets irrigating a total of 3.6 to 16.8ha per unit. The drive train propulsion is the Spinner impulse arms. No control of water application depth is available since the unit is either on or off. Water application is provided using a Senninger LDN package.

The crops produced are forage, feed grains and vegetables.

One farmer owns one machine and no units are shared between farmers.

The farmers have found the Single Span Spinner Drive simple to operate but does not allow for varying the depth of water applied. Some units are on fields with rolling topography and sufficient water pressure to provide propulsion has been a challenge in some cases.

The Single Span Spinner Drive has seemed to fit well with the culture. Sharing of a unit does appear to be feasible but has not been done at this time.

Economic model of the relationship of initial investment costs to irrigated area

Table 1.
Capital Investment (USD/ha)*

Area (ha)	Spinner	Engine Drive	Drip	Surface	Handmove
2.2	$6,620	$7,265	$5,925	$714	$10,221
4.4	$3,310	$3,633	$4,516	$678	$7,155
6.6	$2,207	$2,422	$4,046	$644	$5,008
8.8	$1,655	$1,816	$3,811	$631	$3,506
11.0	$1,324	$1,453	$3,670	$618	$3,506

Assumptions:

- General assumptions
  - 8.2 liters per second
  - Sufficient pressure for the irrigation package
- Spinner and Engine Drive –
  - Two wheel E-Z Tow pivot point
  - 60.6m, 125mm diameter spans
  - 22.6m overhang
  - 14.9x24 tires
- Drip
  - Drip tape with 34mm spacing
  - Flowrate of 1.5 liters per hour
  - Rows spaced at 1.2 meters
  - Necessary headers but no flush lines
  - Filter system to match flow requirements.
- Surface
  - Assumes some leveling required but not substantial
- Handmove
  - 100mm mainline with 12 meter sprinkler spacing
  - Lines spaced at 18 meters

The Single Span Spinner and Engine Drive are both designed to be easily moved from field to field. With these machines, the initial investment costs decrease as the unit is towed to more fields. There is a limit to the number of fields the units may be effectively towed as determined by the crop water requirements and how quickly one must return to the first field irrigated by the machine. The drip system costs reduce gradually due to the spreading of the filter station costs over more area. Surface irrigation only slightly changes with increased area. Lastly the handmove type of irrigation reduces only to a certain point as it eventually becomes necessary to add more hardware to be able to effectively irrigate the field. For very small areas based strictly on initial investment one sees the least costly would be surface irrigation if one is not water limited. If water is limited, the logical investment would be drip for 2.2 hectare fields.

As field sizes change, so does the capital investment. Surface irrigation will continue to be the least costly initial investment but once one begins to tow a pivot to at least one other set, the

Single Span Spinner or the Single Span Engine Drive become the best choice when water is limited.

The next table presents the annual operating costs associated with each of the forms of irrigation we have discussed.

Table 2.
Annual Operating Expense (USD/ha)

	Spinner	Engine Drive	Drip	Surface	Handmove
Energy Costs	$1,141	$225	$338	$90	$1,217
Maintenance	$82	$118	$139	$178	$160

For the energy costs, pressures are based on typical requirements for the particular type of irrigation. Power is calculated on only the requirement to pressurize the irrigation equipment and a pump efficiency of 75%. Energy costs are assumed to be $ 0.12 per kilowatt.

Maintenance costs are based on estimates for each type of irrigation and experience with each. It includes material and labor. Labor is assumed to be semi skilled and costs $10.00 per day.

When annual operating costs are combined with initial investments the following model emerges.

Table 3.
Combined Annual Cost over a Ten Year Period (USD/ha)

Area (ha)	Spinner	Engine Drive	Drip	Surface	Handmove
2.2	$1,884	$1,070	$957	$340	$2,399
4.4	$1,553	$707	$816	$336	$2,092
6.6	$1,443	$586	$769	$333	$1,878
8.8	$1,388	$526	$745	$332	$1,727
11.0	$1,355	$489	$731	$330	$1,727

Again for the smallest field, the lowest cost solution is surface irrigation if water is not limited. If water is a limiting factor, drip is the best choice. As the area increases, the Single Span Engine Drive becomes the best solution if water is limited and even may approach costs comparable to surface irrigation if one tows the Single Span Engine drive to four different sets.

It is always necessary to continue to improve the products, particularly to better meet the needs of end user. Mechanical move irrigation will continue to provide solutions and innovations to offer the best value to customers of fields of all sizes and a variety of crops. More work needs to be done to utilize alternative fuels in the engine drive package. Maybe ethanol and/or bio-diesel will prove to be viable options. Additionally water delivery system management must be reviewed and understood.

CONCLUSIONS

From the economic model one may draw some conclusions relating to the application of mechanical move irrigation for small holding farmers. One must consider what drives the customer's buying decision. If water is not limited then using traditional surface irrigation methods may be the best economical choice. But if water is limited or could become limited in the future, then one needs to consider other options. These options will be dependent on the field size and to some degree shape. Once one considers towing a mechanical move machine, the costs change quickly and the Single Span Engine Drive becomes the least cost option due to the operating costs of the Single Span Spinner Drive.

In addition one must consider the advantages beyond just the cost for each type of irrigation. The following provides a brief summary.

	Cropping Flexibility	Ability to Manage Soil & Water Chemistry	Application Uniformity
Single span – Spinner	Excellent	Excellent	Excellent
Single span – Engine	Excellent	Excellent	Excellent
Drip irrigation	Fair	Poor	Poor
Surface irrigation	Fair	Fair	Poor
Handmove sprinkler	Good	Good	Fair

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