DRIPPING WATER TO A WATER GUZZLER: TECHNOECONOMIC EVALUATION OF DRIP IRRIGATION OF ALFALFA IN NORTH GUJARAT, INDIA

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Alfalfa is a highly water intensive forage crop grown in the region using groundwater from deep aquifers, and account for 13% of the total water diverted according to some estimates. In India, past research on techno-economic aspects of drip irrigation has only focused on horticultural crops, sugarcane, cotton and vegetables. A study was undertaken on the use of Family Drip System (FDS) of Netafim, India on alfalfa to analyse its performance vis-à-vis water application rate, crop yield and water productivity in alfalfa against traditional irrigation practice; and to work out its economics. Irrigation scheduling for drip irrigated plots was daily irrigation with suggested depths of 4mm/day and 8mm/day for winter and summer, respectively, on the basis of average daily evapotranspiration for the nearest region and field application losses.

Analysis showed that water-saving from FDS could be as high as 43% at 0.30m *0.30 spacing of emitters. The increase in yield is 7.4 to 10.8%. The overall increase in yield per unit of applied water ranged from 17.5% to 94%. As regards economic performance, the private gains from using the drip system (B/C ratio: 1.05 to 1.29) were just sufficient to cover installation costs. Drip irrigation of alfalfa is economically viable (B/C ratio: 1.18 to 1.83) from a macro perspective, if we consider the cost of producing the electricity used for groundwater pumping. Economic viability improves (B/C ratio: 1.28 to 2.78) when one considers the price at which water is traded as the economic value of the resource. For water buyers, gains from drip system would exceed the annualized over cost of the system, if they manage the system properly.

INTRODUCTION

Irrigation water use efficiencies are very poor in India, though efficiencies are better in well irrigation [4]. Given India’s food policy, the Nation’s ability to produce food for the growing population in the coming decades would heavily depend on improving the efficiency of use of irrigation water [6]. This approach can make significant headway if technologies like drip irrigation become more versatile and get adopted for some of the water intensive conventional field crops. Worldwide, drip irrigation normally is used for higher yields and better quality farm produce, enhancing water use efficiency, irrigation labour saving and saving of other inputs such as fertilizer and energy. It is normally used for orchards and row crops, with limited adoption in field crops. The reasons for its limited adoption for field crops are high capital investment due to small emitter and
lateral spacing and lack of versatility of installations vis-à-vis crops of different row spacing, and restricted plant root development [9].

The past research on drip irrigation in India focused heavily on high valued fruit and row crops and large farmers [3]. An important reason for little research on field crops is that the systems being capital intensive, it has been pushed as a precision irrigation technology for sensitive crops that are also high-valued, rather than a general water saving technology for all crops. Part of the reason is economic viability. It would be generally sound for horticultural and row crops where the lateral and emitter spacing are considerably large, which reduces the system costs. Also, horticultural crops being high-valued, a marginal increase in yield results in significant rise in value of crop output [3]. Its economic viability is generally not sound for field crops where in the laterals and emitters have to be spaced closely, increasing the system cost [9]. Further, water saving does not result in income gains for most Indian farmers. Given the fact that marginal cost of pumping groundwater for agricultural purpose is close to zero in many Indian states due to heavy electricity subsidies or flat rate system of pricing [10] and canal water is not charged on volumetric basis, the opportunity cost of using water is almost nil unless there is physical shortage of water.

In the United States, there has been research in the past which showed suitability of sub-surface drip irrigation (SDI) for field crops like alfalfa [1]. Study by Lamm and Trooien showed that it is possible to save up to 25% of total water used in a season by using SDI [8]. Study by Ayars and others showed an increase in alfalfa yield of 22% while irrigation water requirement reduced by 6% [1]. Another research study carried out in Kansas looked at the impact of drip tap spacing and depth (below ground) on the dry matter yield of alfalfa and soil moisture distribution [11]. In north Gujarat region of western India, agricultural water use accounts for 92% of the total water use in the region. A lion’s share of irrigation comes from groundwater [5]. Due to intensive use of groundwater for agriculture, the region has been experiencing serious problems of overdraft. The water levels are falling at an average rate of 0.95m to 6.02m per year in Mehsana [2], an intensively irrigated district in north Gujarat. In order to address depletion problems and to sustain livelihoods of the rural communities, International Water Management Institute (IWMI) initiated an action research project on sustainable groundwater management in Banaskantha district.

North Gujarat is a semi-arid region with moderate to low rainfalls and high potential evapo-transpiration [5]. Aridity prevails in some parts of the region, especially in the Banaskantha district. The fountainhead of the IWMI strategy has been to manipulate the demand for water in agriculture without compromising on its net returns, so as to cut down groundwater pumping. Facilitating large scale adoption of water saving irrigation devices has been accepted as the most important operational strategy for IWMI. Alfalfa, a fodder crop, is the most water intensive crop grown extensively in the region with large water loss resulting from border irrigation practised throughout the region for irrigating this crop [7].

A major constraint in promoting large-scale adoption of conventional micro irrigation systems is the absence of independent water sources and pressuring unit with most of the irrigators. The Netafim India ltd. has launched a product, named, Family Drip System, which consists of inline drippers, designed for small plots of size 500 m². This system requires very little pressure (0.4 kg/cm²) to provide an emitter discharge of 1.6 litres per hour. The system includes an overhead tank, a valve, a filter, a connector pipe
and lateral pipes having inline drippers. The laterals are available in different diameters ranging from 8 mm to 16 mm. But the FDS system has never been used in India for field crops.

**STUDY OBJECTIVES, METHODS, LOCATION AND MATERIALS**

The objectives of the research study were: 1) to analyse the performance of FDS on water application rates and crop yield in selected demonstration plots of alfalfa against flood irrigated alfalfa plots; 2) to analyse the water productivity impacts of FDS in alfalfa; and 3) to carry out economic evaluation of this irrigation device by comparing the value of incremental benefits due to drip system against its costs. The study compared irrigation water applied and biomass yield of FDS plots and plots with small border irrigation. Estimated average daily water application rates (mm/day) were used to analyze the impact of FDS on irrigation water use. The extent of water saving and yield increase due to FDS were estimated by taking irrigation water use and yield, respectively, in small border-irrigated plot as the benchmark. Estimated average daily yield per unit area (gram/sq. m/day) was used to analyze the yield impact of FDS. A total of four plots were selected as sample plots for FDS system, and for each sample plot, a control plot with small border irrigation was selected. One of the experimental fields was located in Danta taluka and the rest three were located in Palanpur taluka.

Analysis of weekly rainfall based on historical data for two locations in Banaskantha district, namely, Danta and Palanpur, for the periods 1958-90, 1958-90 and 1901-90 respectively shows that rainfall is quite insignificant during January and June and then during November and December. The mean annual rainfall values for these two locations are 682mm for Palanpur and 795mm for Danta (source: authors’ own analysis based on data provided by Gujarat Agriculture University, Anand). The annual potential evapo-transpiration (PET) for the nearest location (Radhanpur) was estimated to be 1750mm. Thirty two per cent (32%) of this evapo-transpirative demand is during the four months of July-October when the region receives monsoon rains (source: Indian Meteorological Department, Ahmedabad). The average PET is 3.5mm/day in winter and 7.4mm/day in summer. The soil type in the area varies from sandy (1st plot) to sandy loam (2nd and 3rd) and loamy sand (4th plot).

Farmers have prepared small borders of width 1-1.5 m and length 15-20m. Both in the case of sample plots and control plots, a few initial irrigations were practiced using conventional method before irrigation using FDS was started. This was to prevent the chances of poor germination. In the sample plots, drip irrigation was actually started after one month of irrigation and when the roots system developed. The laterals and emitters were kept at spacing of 0.30m + 0.30m. This spacing was chosen after field trials on wetting with different spacing (0.3m, 0.35m and 0.40m). The diameter of the laterals was 8 mm. The tank capacity was 1000 litres.

The water application rate recommended was 4mm/day in winter and 8.0mm/day in summer with daily application for drip-irrigated plots. The water application rates were kept slightly above the ET values to cover application losses. From these figures and from the data on number of drippers and emitter discharge, the duration of water delivery was worked out. For small border-irrigated plots, the schedule normally followed by the farmers in the region, i.e., once in 10 days during winter and once in a week during summer was recommended.
Field measurements showed that discharge variation between the first dripper of first lateral and last dripper of last lateral is less than 10% in plot 1, 2 and 3 and 20% in plot 4. Also, the central dripper of middle lateral had discharge very close to the mean of highest and lowest discharge. In order to measure water applied to the alfalfa fields irrigated with FDS, a bucket with a cover was kept approximately in the central border in buried condition to collect water from one of the drippers. The bucket was emptied in regular intervals and volume of water measured. The total volume of water applied in the field during the time span between two intervals was estimated by multiplying the number of drippers and the volume of water collected in the bucket. In the case of control plots, the same was measured each time through measurement of discharge using a water meter and time of water delivery using a stop watch. In order to measure fodder yield, a 1 m* 1 m plot was selected from the centre of one of the borders in each plot and fodder was cut and weighed and each time the same plot was chosen for sample collection.

RESULTS AND DISCUSSION

Water-saving, yield and water productivity impacts of drip irrigation in alfalfa

The performance of a drip irrigation system can be assessed by comparing the amount of water that is available to the crop root zone to meet the consumptive requirements against the total amount of water delivered to the field. If one assumes that with drip method, the same amount of water is available to the crop root zone as with traditional method and with no adverse impact on yield, the performance of the drip irrigation system can be assessed as a direct function of the reduction in irrigation water applied. Table 1 shows water application rates for four sample (drip-irrigated) and control (small border-irrigated) plots. The absolute and percentage reduction in water use varies from case to case. The highest reduction in water use is 5.5mm/day (1st case) and lowest 0.63 mm/day (3rd case). The highest extent of reduction obtained is 43% (4th case) and the lowest is 7.2% (second case).

That said yield figures for drip-irrigated plots showed some improvements against traditionally irrigated plots in all the four cases. Hence, the reduction in irrigation water use achieved here can be termed as actual water saving at farm level. The yield figures are expressed in terms of yield per day and are given in Table 2. The “yield per day” was estimated by dividing the total yield per square metre by the number of days of observation. Table 3 show that the drip irrigated plots yield slightly higher quantities of alfalfa. But, the highest yield enhancement obtained was only 10.8% (second farmer), immediately followed by 10% (3rd farmer). The lowest yield enhancement was in the case of 1st farmer, who got large water-saving. The number of harvest made was seven, eight, eight and six for field 1, 2, 3 and 4, respectively. In most of the harvests, the measured yield was consistently higher for drip-irrigated plot, across the four experimental fields, while equal in rest of the harvests. The water saving essentially comes from prevention of deep percolation losses, which is common in flood irrigation.

Water productivity is the ratio of the total volume of applied water (WP =Y/AW). Water productivity is often used as an ultimate indicator for assessing comparative performance of two different types of irrigation systems operating in the same agro ecology, like the cases we have. As last column in Table 2 shows, the water productivity impact is in the range of 17.5% to 94%. The highest water productivity enhancement was
achieved by the fourth farmer with 94% increase, followed by the first farmer with 76.1% increase.

**Economics of drip irrigation in alfalfa**

The economics of drip irrigation for alfalfa is worked out as the ratio of the net incremental benefit accrued from drip irrigation over the entire life of the system (10 years) and the incremental costs associated with the system. Following are the incremental benefits: benefit due to rise in yield; benefit due to saving of labour required for irrigation; and any benefit arising out of saving in water and or electricity used for groundwater pumping. All the four farmers used water from their independently owned tube wells for irrigating alfalfa and hence there are no direct benefits due to water-saving.

As regards benefit due to energy saving, well-owning farmers of this region are not confronted with marginal cost of using energy due to flat rate system of pricing electricity in agriculture, and hence for them energy saving does not result in any income gain. But, from a macro economic perspective, if one wants to evaluate the economics of the system, it is important to consider the cost of supplying electricity to the farms, which would be saved due to drips. Also, if we consider the price at which groundwater is traded in the market for irrigation (3-5 cents/m$^3$) as the economic value of water, then any saving in water resulting from drip use could be treated as an economic gain.

The private income benefit due to water saving is applicable to only those who purchase water on hourly basis. Here, the income gain from the use of drip system depends on the unit volumetric price at which water is purchased and the volumetric reduction in irrigation water use achieved. Keeping in view these perspectives and situations, economics of drip irrigation was worked out for four different situations.

In the first situation, the analysis is limited to a private cost and benefits from drip irrigation (level 1). The annual yield benefit was estimated by taking calculated daily yield increase (col. 3- col. 5 in Table 3) and multiplying by 240, which is the approximate number of days for which the fodder field yields in a year. The irrigation labour saving benefit was estimated by taking the irrigation equivalent (in daily terms) of total water saved (total volume of water saved/discharge of pump in 8 hours) and multiplying it by the daily wage. In the second situation, the actual economic cost of using every unit of electricity is considered as a benefit from saving every unit of the energy (level 2). Here, the energy saving benefit depends on two factors: electricity required pumping unit volume of groundwater, which is a factor of the geo-hydrological environment; and the total volume of water saved. The energy saving benefit was estimated by taking the pump horse power, and the pump discharge and the total volume of water saved. The energy saving benefit was estimated by taking the pump horse power, and the pump discharge and the total volume of water saved. In the third situation, the unit price of water in the market was treated as economic gain from “actual saving” of every unit of water and was added to the energy saving benefit due to every unit of “saved water”. This was multiplied by the total volume of water saved to obtain the total economic gain in excess of the gain from yield increase and labour saving (level 3). In the fourth situation, all farmers are assumed to be irrigating with purchased water. Therefore, the unit price of water was considered as a private gain from saving every unit of water (level 4). Here, the cost of construction of a storage tank and a 0.5 HP pump are added to the cost of installation of the system. The results are presented in Table 5.

For estimating B/C ratio, the cost of electricity was assumed as 10 cents/KWhr; cost of labour is assumed as US$ 1.05 per person day; price of alfalfa was taken as 4 cent/kg, which is the prevailing market price; the price of water was taken as 4 cents/m$^3$ while the
prevailing market price is found to be varying from 3 cents/m³ to 5 cents/m³. In order to estimate the present value of annuity, the life of the system was taken as 10 years; the discount rate was taken as 6%. The present value of an annuity was estimated as 7.36. The cost of tank and motor needed to run the system (only in the case of water buyers) was assumed as US$ 74.5. As Table 3 shows, the highest private benefit/cost ratio is 1.29, and lowest is 1.05. The economic benefit/cost ratios (level 2 and level 3) are highest for the first farmer (1.83 and 2.78 respectively), followed by the fourth farmer (1.73 and 2.79 respectively), owing to the large extent of water and energy saving obtained. The private benefit/cost (level 4) is also highest in the case of first farmer (1.39) and lowest for the third farmer (0.88).

Summary of Findings
The extent of water saving achieved through the use of drip system ranged from 7.2% to 43.0%. A highest reduction of 5.56 mm/day in water use was achieved by the first farmer, in whose case the extent of reduction is 40.7%. The farmers who properly ran the system regularly could achieve higher water-saving. The extent of yield enhancement obtained through FDS is in the range of 7.4% to 10.80%. The water productivity impact of drip irrigation is in the range of 17.5% to 94%. Drip irrigation is not an economically sound proposition for alfalfa growers. The B/C ratio ranged from 1.09 to 1.29. But from a macro perspective, it would be viable, owing to the economic gains coming from saving in energy used for pumping groundwater. The B/C ratio in that case ranged from 1.18 to 1.83. The B/C ratio would improve (1.28 to 2.78) if the price at which groundwater is traded in the region for irrigation is treated as its economic value. Further, income gains from drip irrigation would exceed the costs for water buyers, provided they manage the system well and save substantial amount of water.

CONCLUSIONS AND POLICY IMPLICATIONS
The exploratory study shows that use of FDS in alfalfa helps save irrigation water without affecting yield. Yield benefits are promising, though not fully validated. The study shows FDS could help more crops per every unit of irrigation water. But, the water productivity enhancement depends on how judiciously farmers manage the drip system. Under the current electricity pricing regime, for well owning farmers returns from FDS do not appear to be high enough to exceed the investment significantly. Hence, they are less likely to have strong incentive to use drip irrigation in alfalfa unless they face acute physical water shortage that induces opportunity costs of wasting water. Finally, in view of the fact that water and electricity are scarce, the economic benefits that can be accrued from drip systems such as the one discussed above would be enormous owing to the large saving in water, and electricity used for groundwater pumping. Given these scenarios, it would make strong sense, from macro economic perspective to subsidise this drip system for alfalfa cultivation.
### Table 1. Water Saving Impact of Drip Irrigation in Alfalfa

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Water Application in Drip</th>
<th>Water Application in Flooding</th>
<th>Reduction in water application rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration of application (days)</td>
<td>Water application rate (mm/day)</td>
<td>Duration of application</td>
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<tr>
<td>1</td>
<td>200</td>
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<td>224</td>
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<tr>
<td>2</td>
<td>200</td>
<td>6.54</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>208</td>
<td>8.07</td>
<td>208</td>
</tr>
<tr>
<td>4</td>
<td>203</td>
<td>6.60</td>
<td>203</td>
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</tbody>
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### Table 2. Yield Impact of Drip Irrigation in Alfalfa Field

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Yield of alfalfa in Drip-irrigated Field (one sq. m)</th>
<th>Yield of alfalfa in Flood-irrigated Field (one sq. m)</th>
<th>% Increase in Yield</th>
<th>% Increase in Water Productivity</th>
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<tbody>
<tr>
<td></td>
<td>Duration of observation (days)</td>
<td>Average Yield (gram/day)</td>
<td>Duration of observation</td>
<td>Average Yield (gram/day)</td>
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<td>234</td>
<td>67.09</td>
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<tr>
<td>2</td>
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<td>68.00</td>
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<td>4</td>
<td>203</td>
<td>45.30</td>
<td>203</td>
<td>40.88</td>
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</table>

### Table 3. Economics of Drip Irrigation in Alfalfa Economic Benefit/Cost for Four Different Situations

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Initial Cost of the System (US $)</th>
<th>Total Water Saving/Year (M³)</th>
<th>Equivalent Energy Saving/Year (K.W.hr)</th>
<th>Labour Saving/Year (person days)</th>
<th>Yield Increase From the entire plot (Kg)</th>
<th>Private Benefit/ Cost Ratio (Level 1)</th>
<th>Economic Benefit/ Cost Ratio (Level 2)</th>
<th>Economic Benefit/ Cost Ratio (Level 3)</th>
<th>Private Benefit/ Cost Ratio (for water buyers) (Level 4)</th>
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<td>1</td>
<td>157.0</td>
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<td>149.00</td>
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<td>1.09</td>
<td>1.83</td>
<td>2.78</td>
<td>1.39</td>
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<td>136.0</td>
<td>111.30</td>
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### REFERENCES


