Leveraging Renewable Small-Plot Pumping Energy with Drip Irrigation

by

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Some Beginning Thought

- I am guessing, but believe:
  - Roughly 80% of our agricultural produce is produced by 20% of the farm enterprises on large farms, from 50 up to 10,000 ha or more
  - But roughly 80% of the worlds farmer households make their living from small farms, between 0.2 and 2.0 ha
- Unfortunately we are nearing “Peak Oil” and we must be cautious because:
  - Large scale farming depended on more and more complex systems and large inputs of mobile forms of energy
  - Our food chain from farm to table is also complex and the average transport distance for food in the USA and Europe is over 1000 Km from the farm to the table

Background

- We worked as an International Development Enterprises (IDE) team developing affordable small-plot irrigation products (SIPs) using donor funds
- Donor funds are also used to socially market the SIPs, but farmers pay the costs of making and merchandizing the SIPs
- Thus the SIPs are low-cost and affordable, but smallholder farmers (and we) need field plot studies to evaluate their profitability.

Pumping Energy Study Overview

1. The amount of water members of a typical smallholder household can manually pump using a suction treadle pump
2. The field plot setup and the comparative production of plots with an eatable gourd irrigated with a traditional furrow and two types of SIP drip irrigation systems
3. The evaluation of the costs and returns under traditional row and SIP drip irrigation systems

Nepalese woman operating suction treadle pump.

Suction Treadle Pumping

- Smallholder farmers use treadle pumps to irrigate small-plots where reliable electric power is not available
- Assuming an average dynamic pumping head of 6 meters, the average pump discharge is in the neighborhood of 2800 liters/hour.
- When all household members participate in manual pumping, they typically produce 11,000 to 17,000 liters of irrigation water per day.

Typical Treadle Pump Discharge Rates for Different Suction Lifts and Discharge Pressure Heads

Type of Treadle Pump and Discharge Pressure Head Above Ground Surface	Discharge Rate - L/hr with Different Total Suction Lift			
	2 m	4 m	6 m	8 m
Suction Pump with outlet 0.35 m above the ground surface	3600	3000	2800	1800
Pressure Pump with 3 m Discharge Pressure Head	3000	2800	2000	1600
Pressure Pump with 6 m Discharge Pressure Head	2800	2000	1800	1200
Pressure Pump with 9 m Discharge Pressure Head	1800	1200	900	-------

Estimates of the pumping durations every day (7 days per week)

- Household sharing the pumping labor:
  Maximum – 6 hr/day Average – 4 hr/day
- Typical adult males alone:
  Maximum – 4 hr/day Average – 2 hr/day
- Typical adult females alone:
  Maximum – 3 hr/day Average – 2 hr/day

Solar Voltaic

- Affordable PV powered pumping is attractive because manual pumping is so laborious
- But simple suction treadle pumps only cost between 15 and 40 USD
- PV powered pump with a similar capacity would probably cost well over 300 USD
- Thus it is important to increase the returns by increasing irrigation water use efficiency and/or the yields

Main Field Study Objectives

- To compare the water saving and productivity of pre-punch and button emitter drip systems with typical surface irrigation practiced by Indian farmers
- To test a convenient small plot farmer-friendly way for scheduling irrigation applications.
- To estimate the water saving/loss and application uniformity with respect to drip lateral length.

Simple cup used to estimate ET_O which we called the Cup Evaporation, CE

Based on practical ET_O monitoring suggestions from David Seckler (±10 cm diameter by ±10 cm deep)

David Seckler's ET Monitoring Innovation

David Seckler's Natural Irrigation Monitor

Irrigation Application Scheduling

- Gross Irrigation applications depths were based on the crop coefficient representing the growth stage, K_C times the given % of CE
- Water deliveries for each irrigation application were calculated and volumetrically measured:

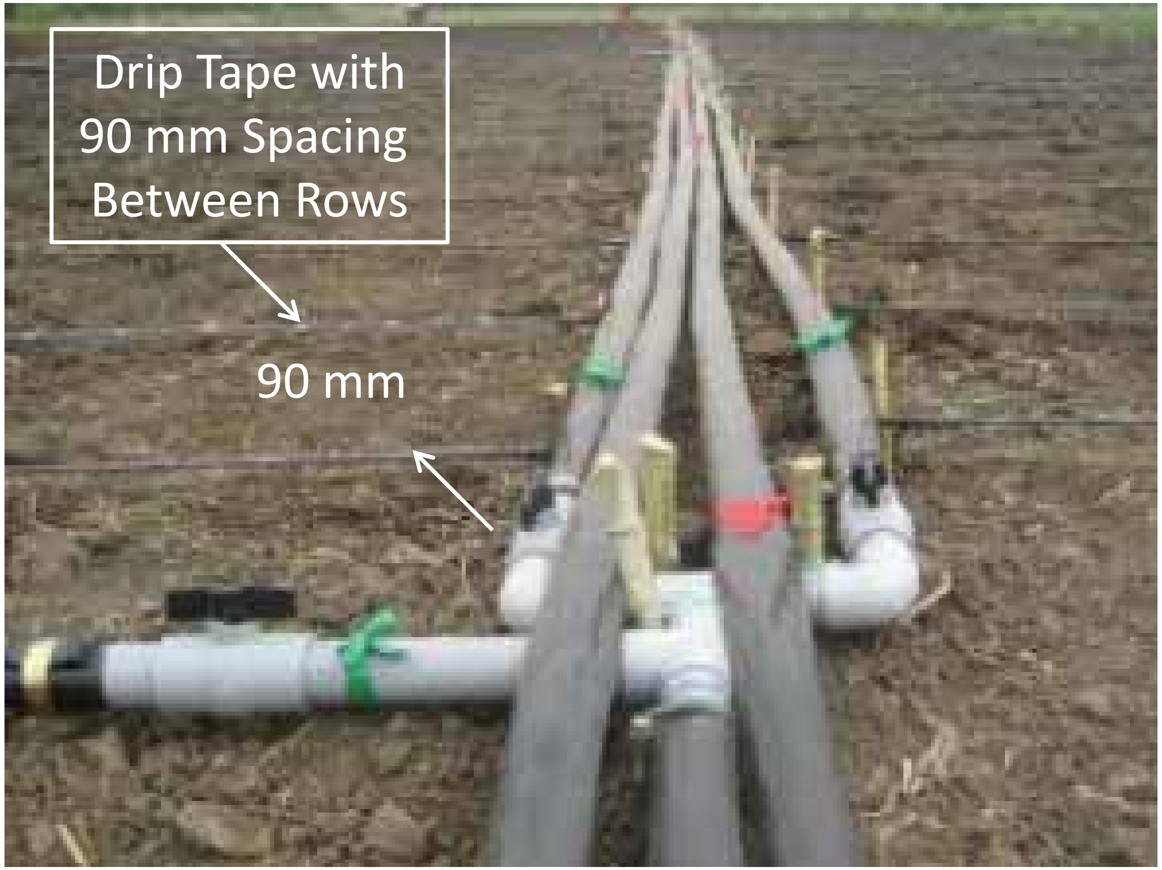
$$\text{Volume} = K_C \times \%\ \text{CE} \times (\text{Sub-Plot Area})$$

Field Plot Layout

- Traditional surface row irrigated sub-plots:
  - There were two 7.5 m wide by 36 m long
  - Two levels of irrigation intensity, based on 100% and 125% of CE every six days (the accumulated two-day CEs over the six day period) multiplied by the crop growth coefficient
- Drip irrigated sub-plots:
  - There were three 12 m wide by 15 m long sub-plots for each drip technology
  - Three levels of irrigation water intensity, based on 50%, 75% and 100% of the two-day CE multiplied by the crop growth coefficient

Water Meters Used for Measured Deliveries to the Sub-Plots

Color codes were used for each type of sub-plot: Green for Traditional Row; Red for Pre-Punched Drip; Orange for Button Emitter Drip; and Blue for Sub-surface Drip



Layflat Tubing Supply Lines Between the Water Meters and the Individual Sub-Plots

Water levels were controlled with valves by starting with sub-plots with 50% of CE and turning their valves off and progressing to the plots with 75% CE, the to 100% CE and ending with the surface plot with 125% CE

Editable Gourds Produced at the Field Site

Gourd Yields for Different Irrigation Systems and Water Application levels

Irrigation System	Gross Water Application		Yield, Kg/1000m²	Yield Increase Over Surface @100% CE
	Based on % of Cup Evap.	Total Season mm		
Surface row	100	455	75.2	0
	125	568	105.0	39.6
Pre-punched Tubing	50	227	66.3	-11.8
	75	341	152.2	102.3
	100	455	201.3	167.6
Button Emitter	50	227	83.6	11.1
	75	341	181.0	140.6
	100	455	206.5	174.6

Treadle Pumping Area and Time

- Depth of water with applied based on 100% CE for the 77 day growing season was 455 mm (see Table 3) and the peak daily CE was 11 mm
- Production with applications based on 100% of CE was:
  - 206 Kg/1000 m^2 with button drip versus
  - 75 Kg/1000 m^2 with surface irrigation.
- With water of 6 m lift and maximum treadle pumping for 6 hours per day the sater pumped would be: (2800 x 6) = 16,800 liters/day
- Based on a gross water application of 11 mm/day this would irrigate a: (16,800/11) ≈ 1,500 m^2 plot.
- Based on a seasonal water requirement of 455 mm, it would require a total of: (455 x 1500)/2800 = 244 hrs (or about 3 hrs/day during the 77 day growing season) of household pumping labor to irrigate the 1,500 m^2 plot.

Average Cost, Crop Season Fixed Cost, and the Typical Required System Inlet Pressure Head for Various Types of SIP Irrigation Application Systems.

Type of SIP Application System	System Durability: Most	System Durability: Least	System Cost*	Fixed Cost Per Crop**	System Pressure Head
	% of System & # of Crop Seasons		USD per 100 m²		M
Drip Kits with Head Tank and Button emitters – 100 to 1,000 m² systems	100% & 6 Seasons		13.00	1.75	1
Button (emitter) Drip System – 2,000 to 20,000 m² (2 ha or 5 ac)	**40% & 10S**	**60% & 4S**	**6.00**	**1.50**	**3**
Pre-punched Drip System – 2,000 to 20,000 m² (2 ha or 5 ac)	**50% & 10S**	**50% & 4S**	**5.00**	**1.10**	**3**
Portable Impact-Sprinkler System – 2,000 to 20,000 m² (2 ha or 5 ac)	80% & 10S	20% & 4S	5.00	0.80	8 to 15
Fixed Mini-Sprinkler System – 2,000 to 20,000 m² (2 ha or 5 ac)	60% & 10S	40% & 4S	5.00	1.00	7 to 13
Shifted Mini-Sprinkler System for Pressure Treadle Pumps – 1,000 to 2,000 m²	30% & 10S	70% & 4S	4.00	1.05	8 to 9
Piped Row or Basin System for Suction Treadle Pumps – 1,000 to 2,000 m²	100% & 8 Seasons		1.25	0.20	0.3 to 0.4

* Costs are based on delivered prices in India, application system prices in Africa and the Americas are usually more than 1½ to 2 times higher.

** Based on India cost weighted average of most and least durable system components sets; 1-year of interest at 25%; and uniformly prorated over the number of crop seasons shown in System Life column.

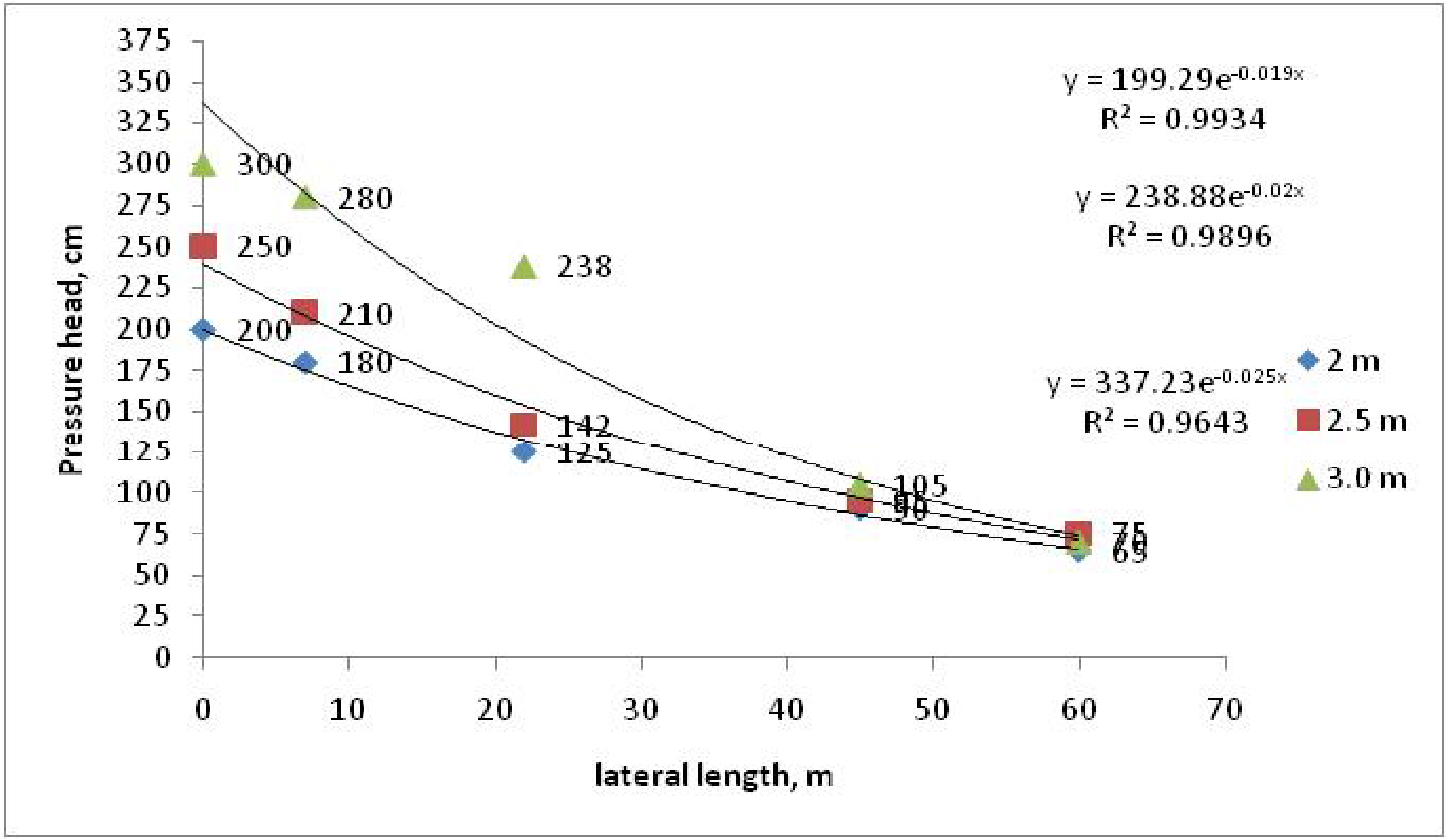
Treadle Pumping Economics

- The sponge gourds sold for 42 INR (0.93 USD) per Kg, so even with the late planting resulting in low yields, the gross return from a 1,500 m^2 plot:
  - With a button drip SIP system would be 288 USD
  - but only 105 USD with traditional surface irrigation.
- SIP drip irrigation systems cost roughly 6.00 USD per 100 m^2
- Thus the 90 USD cost of a 1,500 m^2 button drip system (see Table 2) would be easily covered by the increased yield during its first crop season.

A Second Part of the Study an Analysis of Uniformity and Productivity Along 60 m Long Drip Laterals

- Comparison for pre-punched with button emitter drip 16 mm diameter laterals with emitters spaced at 45 mm along the laterals
- Operating at inlet pressure heads of 2.0, 2.5, and 3.0 m
- All laterals received an irrigation application based on 100% of CE.

Pressure Head Along 60-meter Long 16-mm Diameter Lateral with Button Emitters Spaced at 45 cm (Emitter discharge = 4.5 lph @ H = 1.0 m)



Lateral Hydraulic Analysis

- For SIP button-drip at 2.0 m inlet pressure the measured friction **head loss with was 1.35 m**
- These values confirm the lateral friction head loss equation recommended by Keller and Bliesner, 1990 for use with small diameter plastic pipe:

$$H_f = [L + f_e \cdot (L/S_e)] \cdot 0.47 \cdot (Q^{1.75})/(ID^{4.75})$$

- Where: H_f = friction head loss in the pipe or tubing, m; L = length of the pipe or tubing, m; f_e = connection loss equivalent for each emitter or outlet connection, m; S_e = emitter or outlet spacing on the lateral or sub-main, m; Q = flowrate in the pipe, lps; and ID = inside diameter of the pipe or tubing, mm
- An analysis using an excel spreadsheet program based on this equation for button emitters, where the emitter flow rate is: $q = 4.5 \times H^{0.5}$; and f_e = 0.05 m the **computed friction head losses is 1.33 m**

Application Uniformity Analysis

- Keller et. al. 2003, recommend using CvU_d to evaluate drip system uniformity for design purposes and targeting a design value close to 80% or higher for smallholder irrigation systems based on this equation:

$$CvU_d = 100\{1.0 - [(v_m/\sqrt{N_p})^2 + (v_p)^2]^{0.5}\}$$

- Where: CvU_d = design Coefficient of variation Uniformity, percent; v_m = coefficient of emitter discharges due to manufacturing variations; N_p = number of emitters each plant can obtain water from; and v_p = coefficient of emitter discharges due to pressure variations along lateral
- The coefficients of emitter discharges due to manufacturing variations used for the pre-punched drip laterals was v_m = 0.19 and v_m = 0.15 for the laterals with button emitters as mentioned above

Design Coefficient of Variation Uniformity (Cvu_d) for Various Lengths with an Inlet Pressure Head of 2 m On Level Fields

Lateral Length m	Discharge Uniformity, CvU_d, %		Lateral Length m	Discharge Uniformity, CvU_d, %	
	Pre-punch	Button Emitter		Pre-punch	Button Emitter
0	81	85	30	80	85
5			35	79	84
10			40	78	84
15			45	75	83
20			50	72	81
25			55	69	79
30	80		60	64	77

Conclusions

- In the mid-sections of the 60 m long laterals where the water applied was rough roughly equal to 100% CE
- The gourd yields were 245 for SIP pre-punch drip and 340 Kg/1000 m^2 for SIP button drip
- Based on a return of 42 INR/Kg and 45 INR/USD, the gross return to cover input costs, land, water and labor would be: 0.23 USD/m^2 for pre-punch and 0.32 USD/m^2 for the button emitter drip systems
- For the 1,500 m^2 treadle pump irrigated plot this would be 345 USD for the SIP pre-punch drip and 480 USD for the SIP button drip systems

Good By

J.N. Ray and K Singla and I thank you for your attention and hope a few of you will join us in addressing the needs of the other 80% of the farm households.