J. Indian Soc. Coastal Agric. Res. 37(2): 64-71 (2019)

Drip Irrigation for Reducing Soil Salinity and Increasing Cropping Intensity: Case Studies in Indian Sundarbans

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Received: 28.05.2019 Accepted: 14.07.2019

To mitigate the fresh water scarcity and improving productivity, drip irrigation system is the most efficient one. Two types of drip irrigation models to fulfill the motto of more crop per drop, were installed for experimentation at Sonagaon village of Gosaba island, South 24 Pgs, West Bengal, India. Model I was a solar operated with higher cost (₹1.66 lakhs) whereas model II involved low cost (₹45,000) one. Performances of these two models were evaluated for increasing the water use efficiency and cropping intensity. Four mulching treatments *i.e.* T_1: black plastic, T_2: white plastic, T_3: paddy straw and T_4: control, were tested. T_1 resulted in higher yield in three vegetable crops in both the *kharif* and *rabi* seasons. Mean yield of vegetables was 43, 73 and 101% higher in paddy straw, white and black plastic mulching over control. Resource rich farmers or those who can avail Government subsidy could opt for model 1, whereas resource poor farmers can adopt the model 2 for increasing cropping intensity. Besides savings in labour and water, the cropping intensity could be increased to 200-300% by adopting these irrigation models.

(***Key words:*** *Cropping intensity, Drip irrigation, Mulching, Salinity, Solar energy)*

Scarcity of good quality irrigation water is the main constraint for cropping system intensification in the post monsoon period in the Sundarbans region of West Bengal, India. Farmers primarily grow rice during kharif season and much of the land remains fallow during the dry season (Sarangi and Islam, 2019).The salinity of surface water as well as groundwater varies too much spatially and temporally, directly or indirectly coming under the influence of tidal water and inter-connected aquifers.The salinity of coastal saline soil is sometimes high, and with the same ion composition as sea water (Khan *et al*., 1996). Moreover, the groundwater table of this region is quite shallow and the soil salinity changes seasonally (Shi *et al*., 2005).

The salts in the soils are diluted during the rainy season, but again they reappear towards surface during the summer due to evaporation. The tidal surface water sources are brackish (EC may be up to 47.9 dS m^{-1}) and not utilizable for the agriculture (CSSRI, 2018).

Conventional method of irrigation (flooding or pouring) is very cumbersome, laborious and the efficiency of water use is very less and there is lot of wastage of water resources. It necessitates the use of advanced irrigation technologies such as drip irrigation system for conservation of water and improving land productivity. Drip irrigation can be used instead of manual irrigation practices with minimal water losses and a significant reduction in labor, and it has the significant potential to increase crop yield (Singh, 1978). Different technical aspects of the design of drip irrigation systems have been discussed in detail by Keller and Bliesner (1990) and Bucks and Nakayama (1986). Bhatnagar and Srivastava (2003) investigated gravity-fed drip irrigation systems for hilly terraces in which low-pressure emitters were used, but without dividing the irrigated area into sub-units with different pressure ranges. Drip irrigation is considered the most efficient irrigation method because it applies water precisely at the root zone. The water application is more or less uniform and can be operated frequently. It maintainshigh soil matric potential (SMP) in the root zone and thus compensates for the decreased osmotic potential caused by irrigation with saline water(Goldberg *et al*., 1976). By drip irrigation constant high total water potential can be maintained for crop growth (Kang, 1998). Additionally, well-aerated conditions can be maintained under drip irrigation (Keller and Bliesner, 1990). However, most studies

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have concentrated on crops such as tomato (Wan *et al*., 2007), sunflower (Chen *et al*., 2009) and maize (Kang *et al*., 2010), and few studies have considered vegetation rehabilitation under drip irrigation in coastal saline soils. Mahanta (2004) had conducted an experiment on drip irrigation, taking okra as the crop and found that this crop is more resilient to salinity, drought and flooding than other crops.

Keeping these facts in view, a study was conducted at Sonagaon village in Gosaba Island of Indian Sundarbans to assess the performance of different drip irrigation models for increasing cropping intensity and improving productivity of coastal saline zone of West Bengal, India.

MATERIALS AND METHODS

Study area

The Gosaba island of Indian Sundarbans is surrounded by tidal rivers connected with Bay of Bengal, bringing water of high salinity (more than 30 dS m^{-1}), which is not at all suitable for irrigation in agriculture. Good quality ground water is also unavailable for irrigation as it is neither economical to extract this water from very low depths (>600 m below ground level) for use as irrigation nor it is advisable as depletion of water table may cause sea water intrusion. Due to these constraints of soil salinity and scarcity of good quality irrigation water, farmers in this village are unable to grow *rabi* (winter) crops.

Establishment of drip models

Two types of drip irrigation models were introduced in farmers' fields since 2017 at Sonagaon village in Gosaba Island of Indian Sundarbans. First model consisted of a solar lifted gravity fed drip irrigation system, with capacity to cover 1000 m^2 area and the second model was a gravity fed drip system which can cover 500 m^2 area. Total cost of the solar lifted drip irrigation system (Model 1) was about ₹1.66 lakhs (Table 1) with purpose to lift the water during day time with a low cost nano-pump (0.1 hp capacity) and operated whenever required (Fig.1). The uplands (made up by digging out soils from farm pond) were selected for the experiment. The area covered under solar lifted drip irrigation system was 725 m^2 (Farmer 1). The irrigated area was divided in to 4 sub-plots of size in which irrigation of each sub-plot was controlled by individual valve to facilitate optimum crop diversification. The mulching treatments given in each subplot were black plastic (T_1), white plastic (T_2), paddy straw (T_3) and control (T_4) *i.e.* without mulch. In addition a separate plot was kept as a treatment wherein conventional farmer's irrigation practice was followed. The laterals were of 16 mm diameter having inbuilt inline drippers. The dripper discharge rate was 2.4 L hr^{-1} (lph) at 1 kg cm^{-2} pressure. The solar panel was installed near the pond and pump (0.1 hp) was used for lifting water from the farm pond to a tank (1,000 litres capacity) placed at 2.5 m height on a platform. During day time solar pump was operate to lift the water from the pond into the tank and the stored water was applied to high value vegetable crops through drip irrigation system by gravity method whenever irrigation was required.

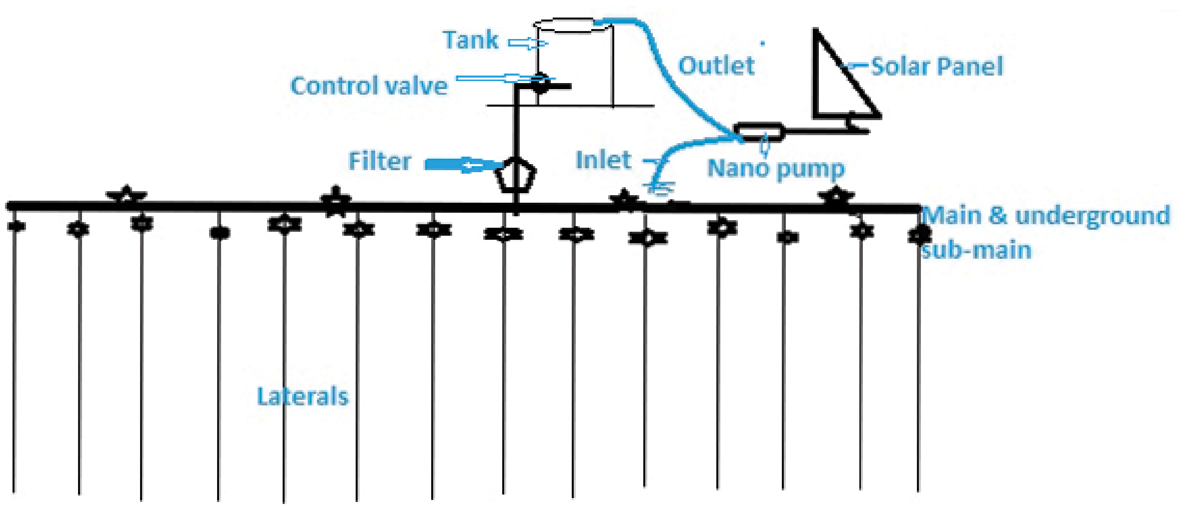

Fig. 1. *Schematic layout of Model 1*

Table 1. *Materials and cost for solar lifted drip irrigation system -Model 1*

Sl. No.	Item	Quantity	Cost (₹)
A	Main, sub-main, lateral & fittings		80, 175
1	Socketted pvc pipe 50 mm , 6 kg cm^{-2}	180m	
2	Socketted pvc pipe 40 mm , 6 kg cm^{-2}	180m	
3	Sup-flow-disc-filter with capacity 7 m^3 h^{-1}	1	
4	Lateral 16mm with drip disc. 2.4 lph, drip spacing 75cm	1500m	
5	Tube outer dia 16 mm Cl2	400m	
6	Barbed poly joiner 16 mm	50	
7	Lateral end stop “8” shape 16 mm	50	
8	Poly grommet take off 16 x 13 mm	50	
9	Control valve 40 mm mold seal plain	16	
10	Flush valve 40 mm	16	
11	Fittings and Accessories		
B	Solar pump (0.1 HP)	1	45,000
C	Mulching materials	1	7,952
1	White plastic mulching	280m	
2	Black plastic mulching	280m	
3	Paddy straw		
D	Tank (1000 litres capacity on platform of 2.5 m height)	1	12000
E	Supply and installation charge		14000
F	Tax		7,256
		Total unit cost of solar drip irrigation system	1,66,383

The Model 2 was electric pump lifted gravity fed drip irrigation system. The cost for purchase and installation of the second model i.e. low-cost drip system was ₹ 45, 000 (Table 2). This system was installed at two farmers' fields. The tanks of 500 litres capacity were placed at 1.8 m high G.I. platform to generate desired pressure. The discharge rate of dripper in the second model was 1.23 lph at tank height of 1.8 m.

The data on solar energy in the Sundarbans region was collected from ICAR-CSSRI, RRS, Canning Town Meteorology Section and used in this experiment for further analysis.

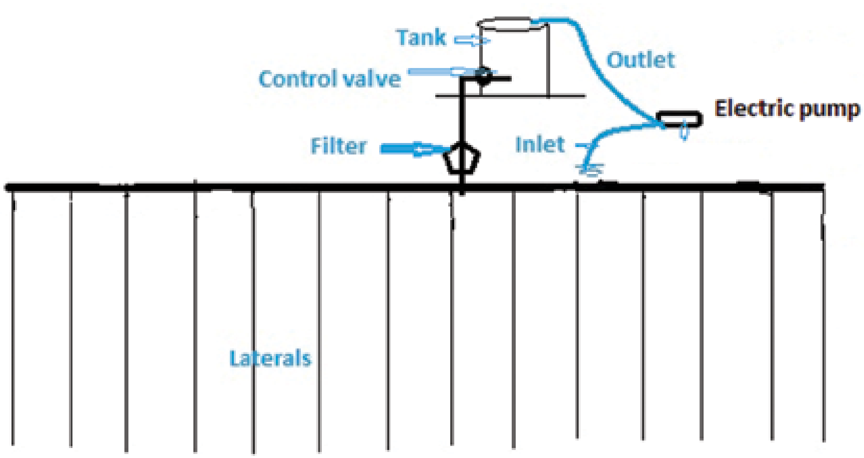

Fig. 2. *Schematic layout of model 2*

Table 2. *Material cost of low cost drip irrigation system for covering 500 m^2 area (model 2)*

Sl. No.	Product specifications	Quantity	Cost (₹)
1	Drip system	1	20,000
a	Adapter 1”	1	
b	Female threaded coupler 1”	1	
c	Single union valve (25 mm x 3/4”)	1	
d	Super flow filter 7 m^3 hr^{-1}”	1	
e	Reducer(1” x 3/4”)	1	
f	Rainport Elbow 3/4” male x 25 mm	1	
g	Tube OD 25 mm Class 2	25m	
h	Rainport elbow 25 mm	1	
i	Rainport tee 25 mm	1	
j	Tool for drip kit (32 mm x 7.5 mm)	1	
k	Lateral end stop ‘8’ shape 25 mm	2	
l	Tube hold stake ‘C’ Clip 12 mm/16 mm	42	
m	Teflon tape	1	
n	Rubber washer 44 x 27 x 5.5 mm	1	
o	Lateral (12 mm) with drip spacing of 30 cm	500m	
p	Take off adapter male 12 x 8 mm	42	
q	Take off adapter female 12 x 8 mm	42	
r	Lateral end stop ‘8’ shape 12 mm	42	
s	Take off plug 12 x 8 mm	20	
2	Tank (500 L)	1	5000
3	Platform of Ht. 6’	1	5000
4	GST		4000
5	Transport & Installation		6000
6	Electrical pump, 1 HP		5000
Grand total			45000

Source of irrigation

In the present study, the conserved rain water in farm ponds were used as source of irrigation. The salinity (EC) of pond water used as irrigation in Model 1 varied from 0.3 to 0.8 dS m^{-1} and in the Model 2 salinity of irrigation water varied from 0.4 to 1.4 dS m^{-1}.

Evaluation of system parameters

Containers were placed all over the experimental plot to collect discharge within a specified time to evaluate the uniformity of water application. Then, Christiansen uniformity coefficient was evaluated by the formula (Michael, 1978):

$$C_u = \left(1 - \frac{\Sigma|x|}{mn}\right) \times 100 \qquad \ldots (1)$$

where, m=average application rate, mm,

n=total no. of points,

x = numerical deviation of individual observations from the av. application rate, mm.

Then efficiency of the system was computed by Michael (1978):

$$\eta = \frac{\text{Actualdischarge}}{\text{Designdischarge}} \qquad \ldots (2)$$

The dry seasons (*rabi* and summer) cropping started in the month of November after the recession of monsoon rain and continued till onset of monsoon. During *rabi* season vegetables like chilli, knol-khol, okra and bitter gourd were cultivated under different mulching treatments. The performance of the experimental crops evaluated based on the costs and return. The okra equivalent yield (OEY) was computed as follows to compare the performance of different crops.

$$OEY = \frac{\text{Yield of crop} \times \text{Price of crop}}{\text{Price of okra}} \quad \ldots (3)$$

Following the demonstration of the solar drip irrigation at first farmer's field, another two farmers of the Sonagaon village adopted the low cost drip model 2. Several vegetables such as okra, bitter gourd, cucumber, cabbage, broccoli, cauliflower, knol-khol and chilli were grown by the farmers due to less irrigation water requirement of crops and ease of irrigation.

RESULTS AND DISCUSSION

Solar power availability

During the *rabi*/summer season, cloud coverage is less in the coastal part of West Bengal. During this period, irrigation requirement of crop is more as days almost remain sunny and hot. The solar energy received in a day was the minimum in the month of July (1.3 MJ) and highest in the month of September (20.1 MJ). When daily average for different months is computed, it was found to be the highest in the month of March and lowest during December (Fig. 3). The post monsoon available solar energy is sufficient to run pumps for irrigation. The average bright sunshine hours (BSH) during the *rabi* season is 7 - 9 hours a day, which is sufficient to harness the solar energy for use in agriculture (Mahanta *et al*., 2018).

Systems parameters evaluation

The containers were placed under the drippers and the amounts collected at different points during specific time were measured. The uniformity coefficient was evaluated to be 87% and 81% respectively for the first and second models computed through equation (1). The uniformity was less in the second model as operating pressure was less and the systems parts were not as robust as Model 1. The efficiency of the models was computed by equation (2) and found to be 85% for Model 1 and 74% for the Model 2.

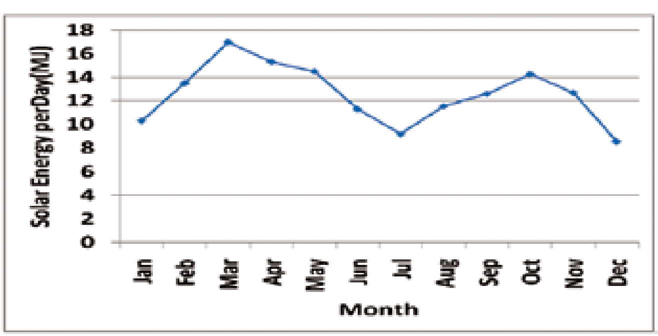

Fig. 3. *The solar energy availability at Canning town in different months*

Effectiveness of mulching

Mulching prevents the evaporation from the surface, thus help retention of soil moisture, checks build up of soil salinity in the root zone and control weeds (Mashingaidze *et al*., 1996).For maximizing production with minimum water mulch plays important role in the water scarce areas (Samant *et al*., 2017). During *rabi* season vegetables like chilli, knol-khol, okra and bitter gourd were cultivated under different mulching treatments. Crops like cucumber, bitter gourd and okra are grown during *kharif* season by providing supplemental irrigation during deficit rainfall period. Out of the four mulching treatments (black, white, paddy straw and control), the highest yield in three vegetable crops (okra, cucumber and bitter gourd) was recorded with black plastic mulching. The black plastic mulching was effective to control weed infestation (Table 3). Mean yield was 43, 73 and 101% higher in paddy straw, white and black plastic mulching over control (CSI4CZ, 2018). During *kharif* season, the mulch was useful to control weeds and in *rabi* season controlled the weeds as well as conserved soil moisture in the root zone.

The yield of chilli under black plastic mulched condition was highest (5.86 t ha^{-1}) whereas 18% and 46 % less yield was obtained under control (only drip) and conventional method.

Table 3. *Effect of mulching on weed biomass and yield of vegetables*

Treatment	OEY* (t ha^{-1})	Weed biomass (t ha^{-1})
Crop		
Okra	9.95	0.73
Cucumber	10.87	0.67
Bitter gourd	5.98	0.77
LSD (P=0.05)	0.22	0.03
Mulching		
Control	5.79	1.75
Black plastic	11.66	0.14
White plastic	10.02	0.18
Paddy straw	8.28	0.81
LSD (P=0.05)	0.27	0.05

*Okra equivalent yield

There was water saving of 40% in only drip and 60% under drip + mulched conditions. The water productivity for most remunerative chilli crop was 20.92, 12.57 and 4.45 kg m^{-3} for drip + mulch, drip and conventional practice respectively. Therefore, with introduction of this technology farmers could take two (vegetable-vegetable) or three (vegetable-vegetable-vegetable) crops in a year to achieve 200~300% cropping intensity.

The economics of the cultivation under solar drip system (Table 4) for an area of 725 m^2 indicated that the system is quite profitable in terms of gross return (₹ 25,679), net return (₹ 13,876) and output-input ratio (2.2). The profitability of the system can be further increased by increasing the area under operation, market based cropping as well as availing the subsidy from the government schemes for installation of drip.

The average system output/input ratio was 4.1 (Table 5), with highest under knol-khol (6.6) and lowest in okra (2.8).

The cost of the Model 2 can be reduced if farmer has assured electrical power supply, in that case the platform and tank can be avoided. The cost of supply and installation of the systems was little bit higher as the village is situated in a remote island. The gain of farmers would be more if they get the drip systems at subsidized rate.

The cost of cultivation of *rabi* season vegetables was reduced due to introduction of solar drip irrigation system as there was savings of about 40% of labour and 40~50% of irrigation water than the conventional method. The production of the vegetables in the drip method increased by 20-50% than the conventional crop cultivation.

Soil salinity

At the begining of the season (November) the soil salinity in the root zone was less than 3 dS m^{-1}. Later the soil salinity further decreased to <2 dS m^{-1} in the top soil layer (0-30 cm) as fresh water of the farm pond was used for the drip irrigation, whereas it increased in the non-irrigated soil at the upper depths (Fig. 4).

Though the drip performance of Model 1 was better than the Model 2, both the drip irrigation models were very much effective for increasing cropping intensity upto 300% in the mono-cropped areas of coastal saline Sundarbans and also economically viable. Chilli was the

Table 4. *Costs and return of crops grown under drip Model 1*

Particulars	Crops*				
	Chilli	Knol-khol	Okra	Bitter gourd	Cucumber
Total production (kg)	325	40	312	250	340
Average selling price (₹ kg^{-1})	35	24	12	18	15
Gross return (₹)	11375	960	3744	4500	5100
Total cost (₹)	2438	636	2675	3610	2444
Net return (₹)	8937	324	1069	890	2656
Output-input ratio	4.67	1.51	1.40	1.25	2.09

*Area under the system is 725 m^2

Table 5. *Cost and return of the crops grown under drip irrigation Model 2*

Particulars	Crops							
	Okra	Bitter gourd	Cucumber	Cabbage	Broccoli	Cauliflower	Knol-khol	Chilli
Total production (kg)	184.5	158.5	226	482	211 (nos.)	170.5	196.5	47
Average selling price (₹ kg^{-1})	14	25	15	10	8	15	14	50
Gross return (₹)	2583	3963	3390	4820	1688	2558	2751	2350
Total cost (₹)	940	1588	1068	871	499	588	417	527
Net return (₹)	1643	2375	2322	3949	1189	1970	2335	1823
Output/ Input ratio	2.8	2.5	3.2	5.5	3.4	4.4	6.6	4.5
Area (m^2)	80	110	111	80	22	27	25	28

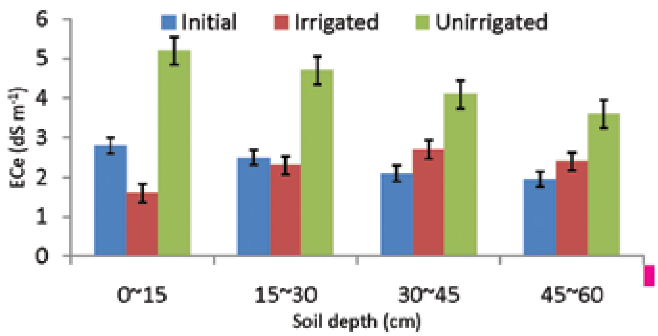

Fig. 4. *The impact of drip irrigation on soil salinity in the root zone (vertical bars show the standard error values)*

most promising crop with highest return. Black plastic mulch was the best for control of weeds and getting high yield. As there was labour and water saving, this drip system can be adopted for higher crop yield. Resource rich farmers or those who avail subsidies can go for Model 1, whereas resource poor farmers may adopt Model 2 for cropping system intensification and crop diversification in Sundarbans region of West Bengal.

ACKNOWLEDGEMENT

This research was funded by the Australian Centre for International Agricultural Research (ACIAR) and Krishi Gobeshona Foundation (KGF) of Bangladesh under the project "Cropping system intensification in the salt-affected coastal zone of Bangladesh and West Bengal, India (CSI4CZ)" (LWR/2014/073).

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