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RESEARCH PAPER

An economic analysis of role of technology in sustaining water resources for enhanced agricultural production

P. ASHA PRIYANKA AND M. CHANDRASEKARAN

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ABSTRACT

Sugar producing regions in India have more than 80 percentage groundwater irrigation through deep-well pumping. Whereas, NASA's gravity recovery and climate experiment satellites have revealed faster depletion of groundwater stocks in India. These areas are cultivating 93 percentage of sugarcane. This research is a comparative study and has attempted to estimate the economic value of irrigation water and the benefits of water and energy that can be saved through adoption of improved irrigation technologies. The economic value of each ha. cm of irrigation water for sugarcane was also worked out. Including additional area under irrigation with the water saved should be recommended only in safe and semi-critical regions to prevent 'rebound' effect.

KEY WORDS : Water saved, Energy saved, Micro irrigation, Rebound effect

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Owing to increasing demand of water for domestic, industrial and energy uses, there is a severe constraint in the availability of water for agriculture. Eventually, water becomes a critical criterion for cultivating high value crops like sugarcane. In India, sugarcane is an irrigated crop; and from 1980 to 2006 irrigation coverage has increased from 80 per cent to 93 per cent of the total sugarcane-cultivated area. According to an estimate by the Ground Water Year Book (2012-13), only 153.66 billion cubic metres (BCM)/yr of groundwater is available for future irrigation, out of which around 63 BCM/yr is available in the sugar-producing states (this groundwater will be utilized for producing other crops as well). Irrigation requirements in arid and semiarid regions are estimated to increase by 10 per cent for every 1°C rise in temperature. NASA's Gravity Recovery and Climate Experiment Satellites have revealed faster depletion of groundwater stocks in India, especially in the North and North-Western parts of the country (18 BCM/yr). These areas having 93 per cent of irrigated sugarcane produc around 60 per cent of sugarcane (Bhattacharya, 2010).

The massive expansion of private sector tube-well irrigation schemes in Bangladesh, India and Pakistan has led to the rapid depletion of groundwater. Sugar-producing regions particularly have more than 80 per cent groundwater irrigation through deep-well pumping (Shrivatsava *et al.*, 2011). Decline in water level of more than 2 meter, which is considered to be significant is seen in parts of Rajasthan, Haryana, Punjab, and western Uttar Pradesh, western Andhra Pradesh and North West part of Tamil Nadu.

Low water use efficiency, poor maintenance of irrigation systems and poor recovery of water charges are some of the major problems associated with the management of water resources in the country (State of Indian Agriculture, 2012-

MEMBERS OF THE RESEARCH FORUM

Correspondence to:
P. ASHA PRIYANKA, Department of Agricultural Economics, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email: tnau.asha53@gmail.com

Authors' affiliations:
M. CHANDRASEKARAN, Department of Agricultural Economics, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

13). Inadequate and sub-optimal pricing of both power and water is promoting the misuse of groundwater. At the current level of water consumption for sugarcane (20,000 kl/ha), the major sugarcane-producing states including Uttar Pradesh, Maharashtra and Karnataka might possibly sustain their production level only up to 2013 (Bhattacharya, 2010).

Many researchers (Magar *et al.*, 1988; Narayanamoorhty, 1997a, 2003; Cuykendall *et al.*, 1999; Qureshi *et al.*, 2001; Dhawan, 2002; Kulecho andWeatherhead, 2005; Namara *et al.*, 2005) have studied the impact of drip irrigation and concluded that drip irrigation technology yielded benefits in terms of resource saving, increased yield and reduced costs of cultivation. A major conclusion is that drip irrigation technology is technically feasible, particularly when farmers depend on groundwater sources (Dhawan, 2000). Hanaa *et al.* (2014), has explored the use of drip and surface irrigation decision support systems to select among furrow, border and drip irrigation systems for cotton, considering water saving and economic priorities. A multicriteria analysis approach was used to analyse and compare the alternatives based upon economic and water saving criteria. Comparing surface and drip irrigation systems, despite low cost, drip alternatives may lead to 28–35 per cent water saving relative to improved graded furrows, and increase water productivity. Macarena and Frank (2012), analyzed the water conservation practices in irrigated agriculture in a sub-basin in North America's Rio Grande. A method is developed to estimate water savings in irrigated agriculture that result from public subsidies to farmers who convert from surface to drip irrigation. They have found that farmers will invest in technologies that reduce water applications when faced with lower financial costs for converting to drip irrigation. Subsidies for drip irrigation increase farm income, raise the value of food production, and reduce the amount of water applied to crops. Negri and John (1989) has attempted to find the irrigation efficiency using various irrigation methods and found that efficiency as highest in drip irrigation, around 80-90 per cent. Dunage *et al.* (2009), has conducted a field experiment at Raichur (Karnataka) on the total water requirements for tomato under nethouse condition using drip. This study revealed that, evapotranspiration (ET) levels of drip irrigation were lower per plant than surface irrigation. The mean application efficiency of the system was 91.75 per cent, while the mean distribution efficiency was 94.27 per cent. Reddy *et al.* (2012), also has conducted a field experiment to assess the response of various drip irrigation regimes and furrow irrigation, in terms of efficiencies and economics on onion. The application efficiency was found highest in 60 per cent ET (94.16 %) using drip irrigation than other treatment. The lowest was found in furrow irrigation. Similarly the water use efficiency was found highest in 80 per cent ET using drip irrigation and the lowest was found in furrow irrigation. The microirrigation technologies such as drip and sprinkler are the key interventions in water saving and improving crop productivity. Evidence shows that up to 40 per cent to 80 per cent of water can be saved and water use efficiency (WUE) can be enhanced up to 100 per cent in a properly designed and managed microirrigation system compared to 30-40 per cent under conventional practice (INCID, 1994 and Sivanappan, 1994). Kumar and Palanisami (2011) have studied the external and private benefits of drip irrigation technology. They have found the external benefit of water saving as Rs. 76943.60 per ha per year and the external benefit of reduced consumption as Rs. 13844.60 per a per year.

The solution to sustain water for crop production is by changing system of irrigation, from surge irrigation to micro-irrigation so that water can be saved instead of wasted. Sustainable Sugarcane Initiative (SSI) is a composite technology that increases the input use efficiency, including water by using micro-irrigation (SSI manual, 2012). In this context, this study concentrates on sustaining available water for irrigation under depleting natural resource and changing climate with the help of improved technologies *viz.*, SSI and drip system. The objectives of the study are :

– To estimate the economic value of irrigation water in sugarcane cultivation,

– To assess the benefits of water that can be saved through improved technologies.

METHODOLOGY

Sampling and data collection :

The study area chosen, covered Coimbatore and Erode districts located in the western part of Tamil Nadu. In Erode district around 47 per cent of gross area irrigated was from groundwater whereas around 80 per cent of gross area irrigated was from groundwater in Coimbatore district. Sugarcane forms one of the major crops under irrigated situation in both the districts (Statistical Handbook, 2011-12). One taluka in each district was taken with Drip system and SSI as improved technologies to compare with conventional irrigation methods.

Drip irrigation is a technology widely used in agriculture to apply water directly where it is needed. It minimises the use of water and enables the injection of fertilizer through drip irrigation system growing healthier plants with less diseases. Though Sustainable Sugarcane Initiative (SSI) includes drip system it also has features such as; use of less seeds, less water and optimum utilization of fertilizers and land to achieve more yields. Driven by farmers, SSI is an alternative to conventional seed, water and space intensive sugarcane cultivation. Though Sustainable sugarcane initiative (SSI) includes drip system it also has features that makes it to differ from simple drip system such as; raising nursery using single budded chips, transplanting young seedlings (25-35 days old) and maintaining wider spacing (5 x 2 feet) in the main field.

Drip is a technology whereas SSI is a composite technology called method of farming. Thus, the study is designed to compare the conventional surge irrigation method with improved irrigation methods.

Annur taluka in Coimbatore and Sathyamangalam taluka in Erode was chosen for the study. Thirty sample farmers each from the three sugarcane farming situations namely; conventional (surface irrigation), Drip system and SSI were selected for the study. Data were collected by survey through direct interview method. In Coimbatore District, water is to be found between 26.5 to 304 metres (District Groundwater Brochure on Coimbatore District, 2008). Both Sathyamangalam and Annur have a tropical climate. The mean annual rainfall of Annur was 707 mm. North-East monsoon showers the highest of 46.52 per cent of mean annual rainfall (Statistical Handbook, 2011-12). In Annur, the water level had dropped six meter – from 22 meter BGL in 2012 January to 28.10 m in 2013 January (The Hindu). It comes under over-exploited groundwater potential region (TWAD Board). Groundwater is the main source of irrigation in both the talukas. The groundwater available for future irrigation in Annur is -2505.13 as on 2004, (District Groundwater Brochure on Coimbatore District, 2008).

Sathyamangalam taluka is located in Erode district. In Erode District, water is found to be between 25 to 300 meteres, (District Groundwater Brochure on Erode District, 2008). The mean annual rainfall happened to be 762.60 mm. North-East monsoon showers the highest of 53.63 per cent of mean annual rainfall (Statistical Handbook, 2011-12). It comes under the category 'critical-exploited' (between 90-100 % of extraction) groundwater potential region (TWAD Board). Around 43 per cent of net area irrigated is from groundwater. CGWB states that, in recent years, the declining water levels and reduction in yields of wells are being observed due to increased extraction of ground water through large number of bore wells for irrigation purposes.

Analytical tools determining the economic value of irrigation water :

The economic value of irrigation water was determined by employing production function approach (Gibbions, 1987). The Marginal Value Product (MVP) of water (ha. cm) is the marginal physical product times the output price. A quadratic production function was estimated with yield (tonnes / ha) as dependent variable and volume of irrigation water used (ha. cm of water) as independent variable. The production function is specified as follows:

$$\ln \text{Yield} = \ln a_1 + b_1 \ln (\text{water})$$

Karthikeyan *et al.* (2009), had done a similar study in assessing the economic value of irrigation water for paddy.

Direct benefits of water saved :

It is apparent that the adoption of drip irrigation generates various positive externalities. These include increased water availability for irrigation purposes, reduced cost of electricity consumption, and reduction in the cost of well deepening, a reduction in the cost of drilling new wells/ bore wells, and a reduction in well failure.

The external benefit of water saved is the product of difference between the water used in the surge method and improved method, multiplied by the MVP of irrigation water used.

Water saving through SSI in sample farms :

$$(W_C\text{-}W_{SSI}) * {}^{-} = VW_S$$

where,

VW_S = Value of water saved in (Rs. per hectare),

W_C = Water use in conventional surge irrigation (in ha. cm).

W_{SSI} = Water use in SSI method of farming (in ha. cm).

θ = value marginal product of water (Rs. / ha. cm).

Water saving through drip system in sample farms :

$$(W_C\text{-}W_D) * {}^{-} = VW_S$$

where,

VW_S = Value of water saved in (Rs. per ha).

W_C = Water use in conventional surge irrigation (in cm/ ha).

W_D = Water use in drip irrigation (in cm/ ha).

θ = value marginal product of water (Rs. / ha. cm).

Indirect benefit (energy saved) :

According to the Central electricity authority (CEA), the energy deficit of the State in FY 2013 was around 17.5 per cent as compared to 2.8 per cent in FY 2008. Hence an attempt was made to ascertain the external benefits of improved technologies in the form of reduced consumption of power (energy).

Energy saving through SSI in sample farms :

$$(E_C\text{-}E_{SSI}) * \cdot = VE_S$$

where,

VW_S = Value of energy saved in (Rs. per hectare)

E_C = Energy use in conventional surge irrigation (in kwh / ha)

E_{SSI} = Energy use in SSI method of farming (in kwh/ ha)

ψ = Tariff rate of energy in Rs./kwh.

Energy saving through drip system in sample farms :

$$(E_C\text{-}E_{SSI}) * \cdot = VE_S$$

where,

VW_S = Value of energy saved in (Rs. per hectare)

W_C = Energy use in conventional surge irrigation (in kwh/ ha)

W_D = Energy use in drip irrigation (in kwh/ ha)

ψ = Tariff rate of energy in Rs./kwh.

A one HP pump running for one hour consumes 0.746 kwh of power. Accordingly, the electricity consumption for each crop was computed as: kwh for each crop = (HP of pump)*(0.746 kwh)*(number hours of irrigation)*(number irrigations). The value of energy is Rs. 5.5/ kwh, which is the unit cost of supply of electricity in Rs./kwh(TNERC, 2013).

ANALYSIS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

The economic value of irrigation water :

The estimated equation is :

ln Yield = - ln 0.7342 + 0.7465 ln water
Std. Error: (0.4738) (0.0889)
Adjusted R Square: 0.7130
F value: 70.57; Significance F: 5.18E-09

The price of output of sugarcane is Rs. 2000 / tonne. The marginal value product of water (MVP) is evaluated at mean values of water use. Marginal Value Product = Marginal Physical Product * Price of one unit of Sugarcane (Rs. / ton). The Average Physical Product(APP) is 0.53 tonnes per ha. cm of water being irrigated.

MPP = (0.7465*0.53) = 0.3956

MVP = (0.3956 * 2000) = Rs. 791.35/ ha.cm of water

It is evident that the marginal value product of each ha. cm of water worked out to Rs. 791.35. The average quantity of water used is 207.91 ha.cm per hectare in conventional surge irrigated farm. The average quantity of water used in case of SSI is 143.59 ha.cm per hectare and in case of drip system is 166.23 ha. cm per hectare. Around, 40 per cent of water can be saved through adoption of SSI method of farming and around 20 per cent of water can be saved through adoption of drip system in conventional farms than convention farming with surge irrigation.

Direct benefits of water saved :

The adoption of drip irrigation generates positive externality of increased water availability for irrigation purposes. The quantity of water pumped depends on the well yield (discharge rate), frequency of irrigation, hp of motor pump and the hours of pumping. The drip irrigation method generally requires less pumping hours but the frequency of irrigation under the drip method is higher. For sugarcane crop under the drip method, farmers tend to irrigate every two to three days. Under the conventional surface irrigation, farmers tend to irrigate for every four to seven days. The average number of irrigations for sugarcane crop in the sample farms under drip method was 118; under

Table 1 : Value of water used for irrigation (Rs./ha)

Farming situation	Average quantity of water (ha.cm/ ha)	Value of water (Rs. / ha)
Conventional farming without drip	207.91	1,64,529.58
Conventional farming with drip	166.23	1,31,546.11
SSI	143.59	1,13,629.95

Table 2 : Total crop water requirement (in ha.cm)

Other irrigated crops in sample farms	Total water requirement (in ha.cm) *	Additional area that can be irrigated by water saving through SSI in sugarcane (in ha)	Additional area that can be irrigated by water saving through drip system in sugarcane (in ha)
Sorghum	50	1.29	0.83
Tomato	70	0.92	0.60
Onion	45	1.43	0.93

* source: *www.agritech.tnau.ac.in*

Table 3 : Categorisation based on groundwater development

Stage of ground water development	Significant long term decline		Categorisation
	Pre-monsoon	Post-monsoon	
<= 70%	No	No	Safe
>70% and <=90%	No	No	Safe
	Yes/No	No/Yes	Semi-critical
>90% and <=100%	Yes/No	No/ Yes	Semi-critical
	Yes	Yes	Critical
>100%	Yes/No	No/Yes	Over-exploited
	Yes	Yes	Over-exploited

Source: *cgwb.gov.in/faq.html*

SSI method of farming it was 105 and under conventional surge irrigation it was 78.

The external benefits of water saving can be evaluated as:

From Table 1, the water that can be saved through improved technologies can be calculated as follows:

Water saving through SSI in sample farms :

1,64,529.58 - 1,13,629.95 = Rs. 50,899.63/ ha

Water saving through drip system in sample farms :

1,64,529.58 - 1,31,546.11 = Rs. 32983.47/ ha

The area under SSI in sample farms is 26.80 hectare and area under Drip system in sample farms is 23.25 hectare. The economic value of the water saved through SSI in sugarcane is Rs. 50,899.63/ hectare in the sample farms. The economic value of the water saved through drip system of irrigation in sugarcane is Rs. 32983.47/ hectare in the sample farms. The area under sugarcane in Coimbatore and Erode districts are 1484 ha and 31540 ha. While generalising for districts, the value of water saved through adoption of SSI in Coimbatore and Erode districts are Rs. 75.53 million and Rs. 1605.37 million, respectively. Similarly, the value of water saved through adoption of drip system in Coimbatore and Erode districts are Rs. 48.94 million and Rs. 1040.29 million, respectively Thus, the water saving can be treated as real. Hence, improved technologies both drip and SSI give more external benefits in the form of water saving.

Indirect benefit (energy saved) :

An indirect or external benefit of improved technology like drip system is energy saving. Hence, the study has attempted to estimate the value of energy saved. The energy required for irrigating under SSI farming system is 12274.03 kwh /hectare and under drip system is 13218.19 kwh/hectare which is around 29 per cent and around 23 per cent lesser than energy required for conventional surge irrigation (17285.5 kwh/hectare), respectively.

Energy saving through SSI in sample farms :

(17285.50 - 12274.03)* 5.5 = Rs. 27563.08 / ha

Energy saving through drip system in sample farms :

(17285.5 - 12274.03) * 5.5 =Rs. 22370.21 / ha

It is evident that at monetary terms the energy used can be reduced by around 23 per cent by adopting drip system in farms and around 31 per cent through SSI method of farming when compared conventional surge irrigation.

Conclusion :

Water saved through one ha of SSI in sugarcane is 64.32 ha.cm and the water saved from one ha of drip system in sugarcane is 41.68 ha.cm. Sorghum, tomato and onion are the other irrigated crops in the sample farms. Hence, the study has sought to find the additional area that can be irrigated with the water saved from a hectare by adopting improved technologies in sample farms.

The water requirement of sorghum, onion and tomato-other irrigated crops in the sample farm are given in Table 2. The results indicate that an additional area of 1.29 hectare of sorghum or 0.92 hectare of tomato or 1.43 hectare of onion can be irrigated from 64.32 ha.cm of water saved from a hectare by following SSI system in sugarcane. Similarly, an additional area of 0.83 hectare of sorghum or 0.60 hectare of tomato or 0.93 hectare of onion can be irrigated from 41.68 ha.cm of water saved from a hectare by following Drip system in sugarcane. Through the water saved we can irrigate additional areas of other crops (in cropping pattern) in the sample farms. Thereby, the increase in area under cultivation of a cash crop like sugarcane can be replaced with other food crops of the region. But, there must be a consideration in including additional areas, about the groundwater development in the region. For a 'critical-exploited' and 'over exploited' region including additional area into farming with water saved through improved technologies may lead to 'rebound effect' as it is widely concerned. Instead, including additional area into farming with water saved through improved technologies can be recommended in 'safe' and 'semi-critical' regions. Thus the future of food security system as well as the quality of life and livelihood of millions of people to a large extent depend on our ability to conserve and utilize ground water resources in an environment friendly, economically efficient and socially equitable manner.

Note :

The ground water development depends upon, stage of groundwater development and long term pre and post monsoon water levels. The details on the categorisation of regions based on groundwater development are given in Table 3.

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