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# Accounting Cost of Irrigation in Sugarcane Production: A PAM Approach to Conventional, DRIP and SSI Methods in Tamilnadu, India

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author PAP designed the study, performed the statistical analysis, wrote the protocol and wrote the manuscript under the guidance of author MC. Author EN has helped in data collection and analysis. All authors read and approved the final manuscript.*

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## ABSTRACT

India has a comparative advantage in producing sugarcane. Sugarcane being a highly water consuming crop, more than 80 percentage of groundwater irrigation is done through deep-well pumping. Whereas faster depletion of groundwater stocks in 93 percentage of sugarcane cultivating area in India is revealed. Drip and Sustainable Sugarcane Initiative (SSI) are two cultivation methods reducing water consumption. The study was conducted in Tamil Nadu, a major contributing State to production in India. This research is a comparative study on various sugarcane cultivation methods, iterating the comparative advantage of the State by accounting the cost of irrigation water thru Policy Analysis Matrix (PAM) from which trade indicators could be derived. The indicators from

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PAM have shown that a developing country like India could be in a disadvantageous position when cost of irrigation water is accounted and urges the need to disseminate improved technologies such as drip system and SSI in sugarcane production.

*Keywords: PAM; SSI; ground water; sugarcane; comparative advantage.*

## 1. INTRODUCTION

India is the second largest producer of sugarcane and sugar in the world next to Brazil. Sugarcane is the second most important industrial crop in the country grown in over 5 million hectares and supporting millions of cane farmers in the rural areas. The estimated cane and sugar production in 2014-15 was 336.70 million Metric Ton (MT) and 25 million MT, respectively [1].

In India, sugarcane is an irrigated crop; and from 1980 to 2006 irrigation coverage has increased from 80 to 93 percent of the total sugarcane-cultivated area. According to an estimate 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) [2]. 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 contributing 93 percent of irrigated sugarcane produce around 60 percent of sugarcane. Sugar producing regions in India have more than 80 percentage groundwater irrigation through deep-well pumping [3]. 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 [4]. Inadequate and sub-optimal pricing of both power and water is promoting the misuse of groundwater [3].

The methods in which sugarcane is cultivated in India can be classified as, conventional, conventional method with drip system and Sustainable Sugarcane Initiative (SSI). SSI and drip system are water efficient cultivation methods. In this context the objectives of the study were to estimate the cost of irrigation water required in the above cultivation methods and to account it into Policy Analysis Matrix (PAM). Thru PAM, meaningful trade indicators could be derived to understand the comparative advantageous position of the study area in sugarcane production even after including cost of irrigation water.

## 2. METHODOLOGY

The primary data on cost of production sugarcane was collected from sample respondents (45 from each of the three production methods) in Western Zone of Tamil Nadu (27.74% of area under sugarcane production). The present study has calculated the cost of production of sugarcane as fixed and variable costs. The fixed cost constituted rental value of owned land, land revenue, cess and taxes. The amortised cost of drip system was included as fixed cost in case of conventional production with drip system and SSI method of production. The operational cost or variable cost included; cost of human labour, cost of machine power, seed (planting material), fertilizer, manure, insecticide and irrigation. The gross return is computed as a product of total production of main product (MT per hectare of sugarcane) and the average price paid by the sugar mill in the study area based on State Advised Price (SAP). During the year 2013-14, the SAP for sugarcane was $43.80 per MT. Profit was estimated as the difference between the cost of cultivation per hectare and the gross return per hectare.

To find the profitability and efficiency of sugarcane production in the study area, the study has applied Policy Analysis Matrix (PAM). PAM approach was first developed in 1981 to study the changes in agricultural policies in Portugal and later augmented by Masters and Winter-Nelson in 1995 [5,6]. The central purpose of PAM analysis is to measure the impact of government policy on the private profitability of agricultural systems and on the efficiency of resource use [7]. The canonical steps in using the PAM method are identifying the commodity system, assembling representative budgets for each activity in the system, calculating social values, aggregating the budgetary data into a matrix, analyzing the matrix, and simulating policy changes [8]. The basic of working in PAM is discussed below with the help of Table 1.

**Table 1. Policy analysis matrix**

| | Value of output | Value of input | | Profit |
|---|---|---|---|---|
| | | Tradable | Domestic factor | |
| Private prices | A | B | C | N |
| Social prices | D | E | F | O |
| Policy transfer | G | H | I | P |

*Private profit: N= A−(B+C)*
*Social profit: O= D−(E+F)*
*Output transfer: G= A−D*
*Input transfer: H= B−E*
*Factor transfer: I= C−F*
*Net policy transfer: P= N−O*

*DRC = F/ (D - E)*
*EPC = (A – B)/ (D – E)*
*SBC = D/ (E + F)*
*PSE = P/ A*
*SRP = P/ D*

In the table above, 'A' is the value of output in private prices, 'D' is the value of output in social prices, 'G' is the output transfer, 'B' is the value of tradable input in private prices, 'E' is the value of tradable input in social prices, 'C' is the value of domestic input in private prices, 'F' is the value of domestic input in social prices, 'H' is the tradable input transfer, 'I' is the domestic input transfer, 'N' is the profit in private prices, 'O' is the profit in private prices and 'P' is the net policy transfer.

Domestic Resource Cost (DRC) Ratio, Social Benefit Cost (SBC) Ratio, Effective Protection Coefficient (EPC), Producer Subsidy Equivalent (PSE) and Subsidy Ratio to Producers (SRP) are the trade indicators derived from PAM. A DRC value nearing one indicates comparative disadvantage and that nearing zero indicates comparative advantage. An EPC value above one indicates producers are subsidised and that below one indicates producers are taxed. A SBC value above one indicates social profit and that below one indicates social loss. A PSE value above zero indicates producers are subsidised and that below zero indicates producers are taxed. A SRP value above zero indicates producers are subsidised and that below zero indicates producers are taxed.

The general model solution for social factor prices is based on the assumption that all commodities have world market prices *i.e.,* Free on Board (FOB) for exports and Cost, Insurance and Freight (CIF) for imports were used. For tradable items for which international prices are not directly available and for non tradable items, Social Conversion Factor (SCF s') of partial Little-Mirlees method could be used to convert actual rupee cost into social cost [9,10]. Conversion factors are obtained from previous studies of the economy [11]. In the partial Little-Mirlees method, for some components SCF are provided directly but for some components only 'proportions for tradable (T), labour (L) and residual (R) are given. To convert proportions to SCF, the proportion of tradable component must be multiplied with a factor 0.67; similarly, the proportion of labour component must be multiplied with a factor 0.50 (as the shadow price of labour is considered to be 50 percent of the actual) and the proportion of residual component must be multiplied with a factor 0.50.

The factor prices at the absence of government policy are also a measure of social values, hence the social values of fertilizer and drip system was assessed by subtracting the respective subsidies. The private and social cost of fertilizer subsidy was computed as per the nutrient based subsidy rates prevailed during 2013-14.

The cost of drip installation and maintenance incurred by the farmer is the private cost and the cost of drip installation incurred by the Government is the external cost incurred by the government. The social cost of installing drip system is therefore the sum of both the private and the external costs. The cost of installing drip was amortised for a year [12]. The amortisation of irrigation structures was computed as follows:

$$\text{Amortized cost of drip} = [(\text{Compounded cost of drip}) * (1+i)^{AL} * i] \div [(1+i)^{AL} - 1]$$

$$\text{Compounded cost of drip} = (\text{Initial investment on drip}) * (1+i)^{(2014\text{-year of installation})}$$

Where AL is average life of drip irrigation equipment *i.e.,* 10 years and 'i' is the discount rate which is five percent.

The PAM on sugarcane production which does not consider the environmental impacts is called unsustainable PAM. To estimate the environmental PAM on sugarcane production, the environmental impacts of sugarcane production should be enumerated in detail. Ground water utilization and pollution due to post-harvest burning are notable environmental impacts of sugarcane production.

The value of water utilised for production of sugarcane was calculated to estimate the environmental PAM for sugarcane production. Quantity of water used for irrigation was calculated as per the formula [13] as stated below.

Quantity of Water Used for Irrigation in gallons per minute = (WHP x C x H x d x 60) /D

Where,

WHP = Water Horse Power which can be calculated as a product of horse power of the pump and efficiency. The data on horse power of the pump was obtained through survey from sugarcane producers. The efficiency of submerged and open pump was assumed to be 80 percent and 65 percent, respectively.
C = Constant in the formula = 3960
H = Hours of operation of motor to irrigate sugarcane field per hectare
D = Number of days sugarcane field was irrigated. The hours of operation of motor throughout the duration of sugarcane production was converted to minutes by multiplying with 60.
D is the depth of water in meter or total head

To incorporate the value of irrigation water in PAM, the economic value of irrigation water has to be determined. The economic value or marginal value product of irrigation water was determined by employing production function approach [14]. Marginal value product (MVP) of irrigation is a more appropriate measure of the economic value of water [15]. The MVP of water ($m^3$) is the marginal physical product times the output price. A Cobb-Douglas production function was estimated with Yield (MT per ha.) as dependent variable and volume of irrigation water used ($m^3$) as independent variable. [16] a similar study in assessing the economic value of irrigation water for paddy had also done.

In India, most of the sugarcane residues are usually burnt in the field only after harvest due to lack of proper composting techniques [17]. In the study area, most of the sugarcane left over trashes was burnt on-field. In case of intercropping or drip system installed on field, the trashes were manually collected and burnt off-field. The excess crop biomass that arises from the leaves, small tillers and stalk tips (called trash) whose fraction makes up about 14 percent of the sugarcane crop weight [18]. A research has used 0.40 as the conversion factor for sugarcane trash to carbon content [19]. A study has estimated the social cost (include uncertainty, risk aversion and equity weighting) of $CO_2$ emitted for the year 2015 as US$12 per MT in 2005 US$ prices [20]. Therefore, the social cost of $CO_2$ emitted by burning sugarcane trash can be estimated as the product of quantity of trash produced, $CO_2$ conversion factor (*i.e.,* 0.40) and social cost of $CO_2$.

## 3. RESULTS AND DISCUSSION

### 3.1 Policy Analysis Matrix on Sugarcane Production

#### 3.1.1 Unsustainable PAM

The private and social cost of production of sugarcane which is the prelude for constructing PAM was calculated for all the three production systems and presented in Tables 2-4. The profit per hectare in conventional production in private and social prices was $839.40 and $2279.61, respectively. The profit per hectare in conventional production with drip system in private and social prices was $1512.27 and $2746.62, respectively. The profit per hectare in SSI method of production in private and social prices was $1906.75 and $2823.07, respectively.

**Table 2. Result of unsustainable PAM on conventional sugarcane production**

**($ per hectare)**

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic factor | | |
| Private prices | 4542.98 | 290.02 | 3413.55 | 3703.58 | 839.40 |
| Social prices | 4835.87 | 498.94 | 2057.33 | 2556.27 | 2279.61 |
| Policy transfer | -292.90 | -208.91 | 1356.22 | 1147.31 | -1440.21 |

**Table 3. Result of unsustainable PAM on conventional sugarcane production with drip system**

($ per hectare)

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic factor | | |
| Private Prices | 5094.69 | 283.80 | 3298.62 | 3582.42 | 1512.27 |
| Social prices | 5423.15 | 485.68 | 2190.85 | 2676.54 | 2746.62 |
| Policy transfer | -328.47 | -201.89 | 1107.77 | 905.88 | -1234.35 |

**Table 4. Result of unsustainable PAM on SSI method of sugarcane production**

($ per hectare)

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic Factor | | |
| Private prices | 5450.16 | 277.94 | 3265.47 | 3543.41 | 1906.75 |
| Social prices | 5580.26 | 482.59 | 2274.61 | 2757.20 | 2823.07 |
| Policy transfer | -130.11 | -204.65 | 990.86 | 786.21 | -916.32 |

**Table 5. Trade indicators for unsustainable PAM**

| Trade indicators | Conventional production | Conventional production with drip system | SSI method of production |
|---|---|---|---|
| DRC | 0.474 | 0.444 | 0.446 |
| EPC | 0.981 | 0.974 | 1.015 |
| SBC | 1.892 | 2.026 | 2.024 |
| PSE | -0.317 | -0.242 | -0.168 |
| SRP | -0.298 | -0.228 | -0.164 |

**Table 6. Result of environmental PAM on conventional sugarcane production**

($ per hectare)

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic factor | | |
| Private prices | 4542.98 | 290.02 | 3413.55 | 3703.58 | 839.40 |
| Social prices | 4835.87 | 498.94 | 5409.30 | 5908.23 | -1072.36 |
| Policy transfer | -292.90 | -208.91 | -1995.74 | -2204.66 | 1911.76 |

**Table 7. Result of environmental PAM on conventional sugarcane production with drip system**

($ per hectare)

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic factor | | |
| Private prices | 5094.69 | 283.80 | 3298.62 | 3582.42 | 1512.27 |
| Social prices | 5423.15 | 485.68 | 4890.87 | 5376.55 | 46.60 |
| Policy transfer | -328.47 | -201.89 | -1592.24 | -1794.13 | 1465.66 |

**Table 8. Result of environmental PAM on SSI method of sugarcane production**

($ per hectare)

| | Value of output | Value of input | | Total cost | Profit |
|---|---|---|---|---|---|
| | | Tradable | Domestic factor | | |
| Private prices | 5450.16 | 277.94 | 3265.47 | 3543.41 | 1906.75 |
| Social prices | 5580.26 | 482.59 | 4621.25 | 5103.84 | 476.42 |
| Policy transfer | -130.11 | -204.65 | -1355.79 | -1560.43 | 1430.33 |

**Table 9. Trade Indicators for environmental PAM**

| Trade indicators | Conventional production | Conventional production with drip system | SSI method of production |
|---|---|---|---|
| DRC | 1.247 | 0.991 | 0.907 |
| EPC | 0.981 | 0.974 | 1.015 |
| SBC | 0.818 | 1.009 | 1.093 |
| PSE | 0.421 | 0.288 | 0.262 |
| SRP | 0.395 | 0.270 | 0.256 |

The trade indicators derived from unsustainable PAM is presented in Table 5. The DRC value was well below zero for all the production systems indicating the domestic production of sugarcane to serve as an import substitution commodity. Through DRC ratio the efficiency of resource use can also be derived; lower the value higher the efficiency. The SBC ratios of 1.892, 2.026 and 2.024, further strengthens the result of DRC ratios that drip system and SSI method are efficient method of sugarcane production. The EPC ratio of SSI method alone was little more than one indicating that when SSI is adopted producer could be profitable.

## 3.2 Environmental PAM

The environmental impacts of sugarcane production included in environmental PAM were cost of irrigation water and cost of emission due to post harvest burning. The cost of irrigation water per hectare in conventional production, conventional production with drip system and SSI method of production were $3289.80, $2630.28 and $2272.04, respectively. The cost of $CO_2$ emission due to post harvest burning were $62.18, $69.73 and $74.60, respectively. As seen the impact of post harvest trash burning was very meagre compared to that of cost of irrigation water on PAM. The environmental PAM with private and social costs and profits were calculated for all the three production systems and presented in Tables 6-8. The profits remain the same in private prices but the profits in social prices vary because of inclusion of environmental costs-benefits. The profit per hectare in social prices in conventional production, conventional production with drip system and SSI method of production were $-1072.36, $ 46.60 and $476.42, respectively. The profit per hectare in social prices for all the three production systems fell after inclusion of environmental costs-benefits while the profit turned as loss in case of conventional production.

The trade indicators derived from environmental PAM was presented in Table 9. The DRC ratio based on environmental PAMs was 1.247, 0.991 and 0.907 respectively for conventional production, convention production with drip system and SSI method of production inferring the advantage in cane production by SSI method and conventional production with drip system when compared to conventional production. It also has to be recorded that irrigation water being an undervalued input in the country, when priced would impact even to reduce the comparative advantage of the country in cane production. Similarly, the SBC ratios for SSI method of production and conventional production with drip system were at 1.093 and 1.009, indicating the relative superiority of drip system and SSI method in production of cane whereas for conventional method the SBC ratio stood at 0.818.

## 4. CONCLUSION

The indicators from PAM have shown that the second largest sugar producer in the world could be in a disadvantageous position when cost of irrigation water is accounted into cost of production of sugarcane. Overall, the trade indicators derived from environmental PAMs has shown import substitution ability of sugarcane and better water resource efficiency in case of conventional production with drip system and SSI method of production. Hence, such improved technologies in sugarcane production must be disseminated extensively for better economic and environmental efficiency.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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