Biofuel Production and Water Constraint: An effective utilization of watershed projects in India

Anindya Bhattacharya

Energy Policy Specialist

Institute for Global Environmental Strategies

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Overview of the presentation

- Introduction and Understanding of the basic facts of biofuel production in India
- Behind the screen of bio-ethanol production
- Water requirement for ethanol production
- Existing condition of water supply in sugarcane production
- The model and the objectives this study
- Results and discussion
- Policy Recommendations

Understanding of the basic facts of biofuel production in India

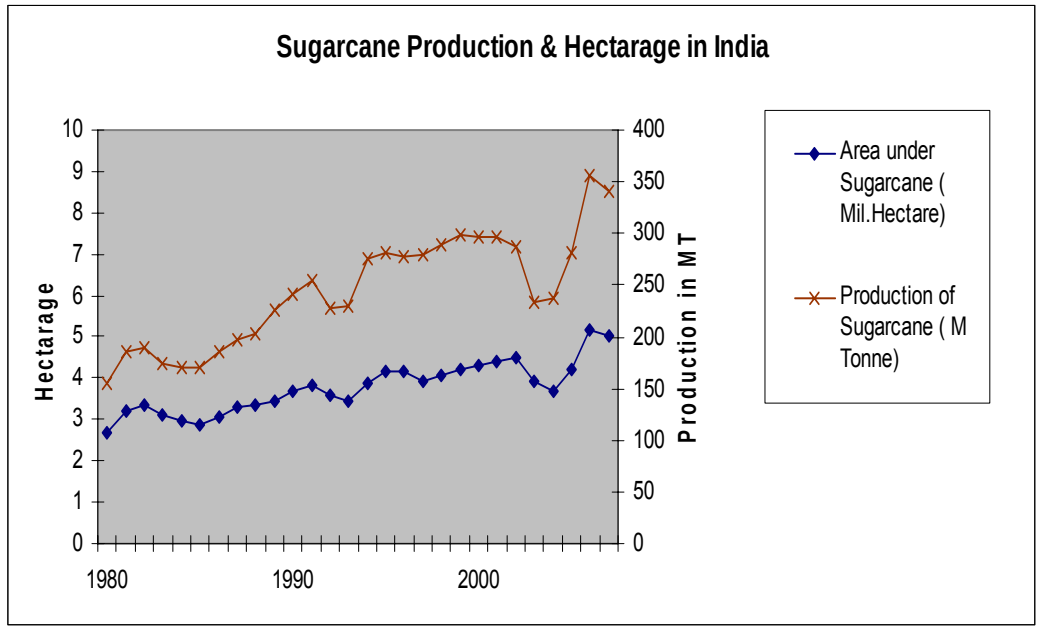
- First generation biofuel feedstock production needs considerable care and attention like other agricultural products and **requires water, nutrients, fertilizer, land, labour and capital** and all other necessary farming knowledge to have an economic level of productivity.
- Water is a major input requirement for biofuel feedstock production especially for sugarcane. **1 liter of ethanol production in India needs 3500 liter of irrigated water** compared to only 90 liters / liter in Brazil (IWMI,06).

Understanding of the basic facts of biofuel production in India

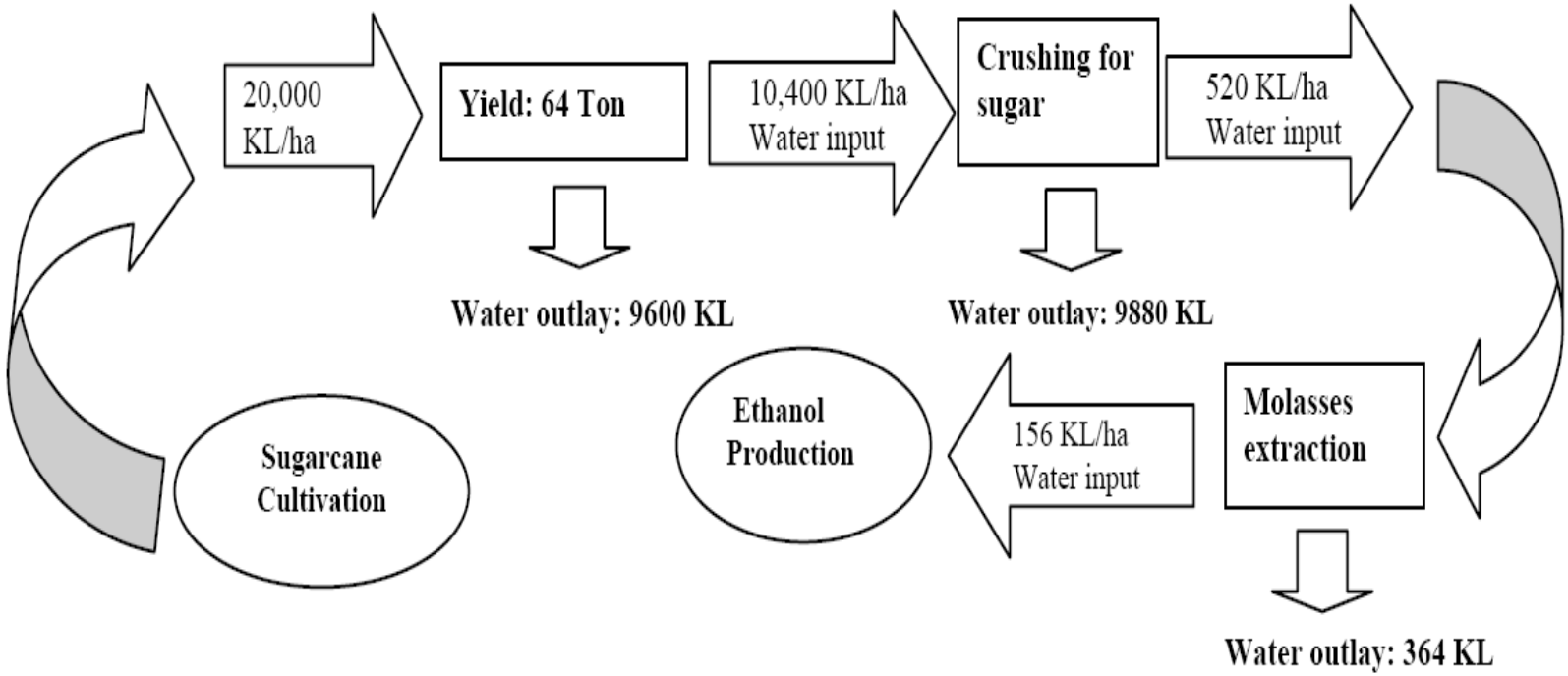
- **Biofuel production depending on irrigation water is 350% more expensive than the rainfed production** (Fratiure et al.08). Unfortunately, most of the sugarcane production is happening with irrigation water due to natural rainfall shortage.
- **Indian biofuel market is mainly ethanol based**. There is hardly any regular supply of biodiesel. Biodiesel production is yet to come up at a commercial scale in India. However, Jatropa based biodiesel production also needs plenty of water.
- **Water availability is an important success factor** for achieving the national biofuel production and utilization target in India.

Behind the screen of bio-ethanol production in India

- Indian sugarcane production needs around 20,000 Kiloliter (20MCM) of water per hectare of cultivation (Jain Inc. 2003).
- Figure indicates lack of efficiency improvement in the sugarcane production in the country.
- 50-60% sugarcane goes for sugar production, 30-40% goes to alternate sweetener production and rest 10-20% goes to seed development.



Water requirement for ethanol production in India



Water requirement for ethanol production in India

- Sugarcane is the main source of bio-ethanol in India. Using around 300,000 ha of land. Out of 5.3 km^3 (5.3 billion meter cube) of water used for evapotranspiration by the total crops in the country, biofuel production through sugarcane used around 0.5% of it (Fratiure et al.08).
- Total amount of irrigation water used for the biofuel production is around 6.5 km^3 (6.5 BCM) which is around 1.2% of the national total of irrigation water (IWMI,06).
- To meet the future biofuel demand as per the given target say of 10% ethanol blending by 2030, India needs the following resources (Schaldach et al.)
  - 30,000 Sq. Km of sugarcane plantation
  - 12 km^3 (12 Billion Meter Cube) of irrigation water
  - With 30-60% efficiency of irrigation, actual irrigation water supply is between 20 to 40 BCM (Schaldach et al.)

Water requirement for biofuel production in India

- Potential of ground water resources available for additional use over the next twenty years is around 245 BCM (CSO, Ministry of Statistics and Program Implementation, GoI).
- **Therefore, only ethanol production itself will take 12% of the future available ground water in the country just to maintain 10% blending target.**

(Unit : BCM per Year)

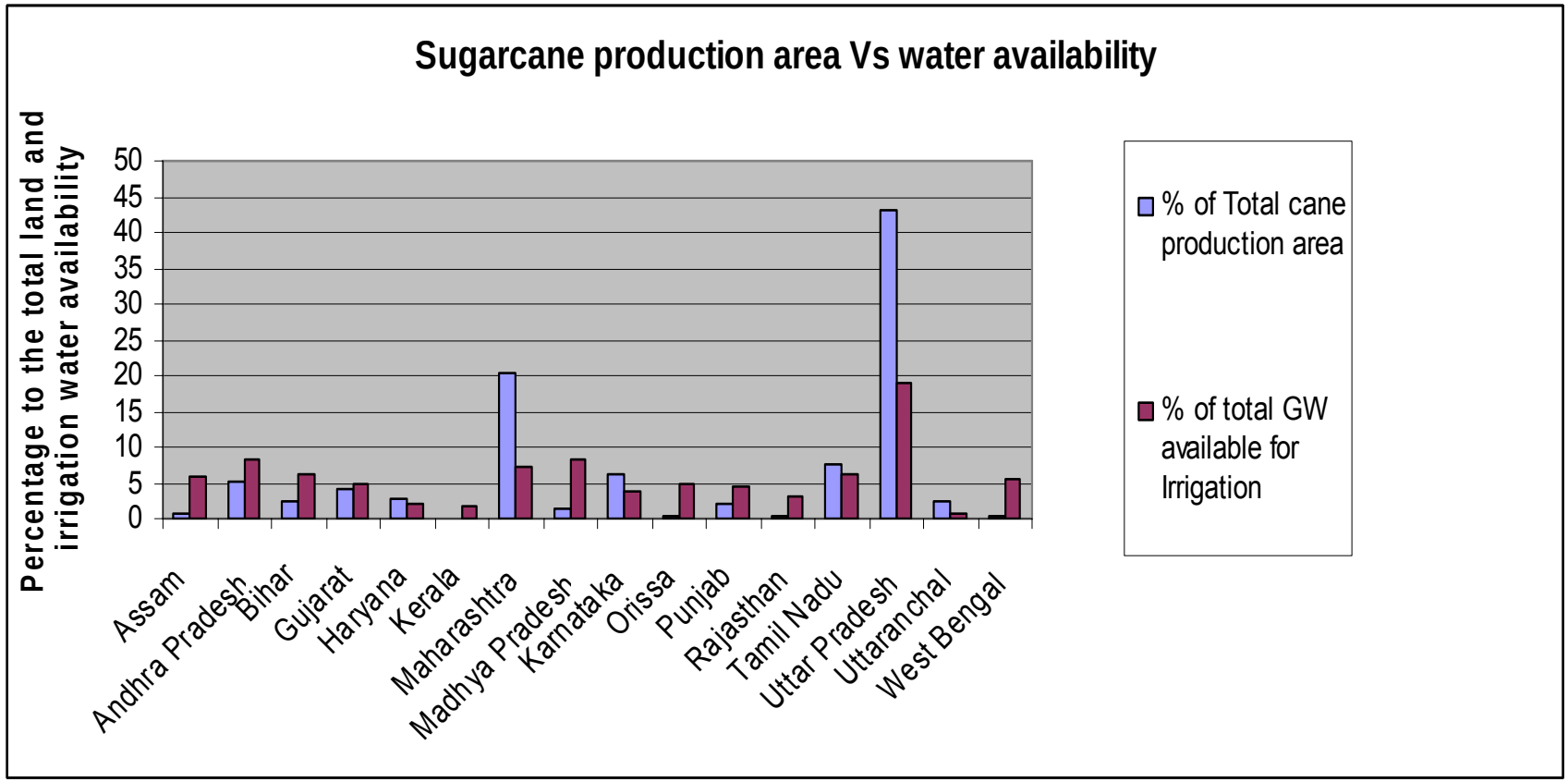
S.No.	Name of the States/UTs.	Total Replenishable Ground Water Resource	Provision For Domestic Industrial and other Uses	Available Ground Water Resources for Irrigation	Net Draft	Balance Ground Water Potential Available for Exploitation	Level of Ground Water Development (%)
1	2	3	4	5	6	7	8
STATES							
1	Andhra Pradesh	35.29	5.29	30.00	8.57	21.43	28.56
2	Arunachal Pradesh	1.44	0.22	1.22	Negl.	1.22	Negl.
3	Assam	24.72	3.71	21.01	1.84	19.17	8.75
4	Bihar	26.99	4.05	22.94	10.63	12.31	46.33
5	Chattisgarh	16.07	2.41	13.66	0.81	12.85	5.93
6	Delhi	0.29	0.18		0.12		
7	Goa	0.22	0.03	0.19	0.02	0.17	8.30
8	Gujarat	20.38	3.06	17.32	9.55	7.77	55.16
9	Haryana	8.53	1.28	7.25	8.13	0.00	112.18
10	Himachal Pradesh	0.37	0.07	0.29	0.03	0.26	10.72
11	Jammu & Kashmir	4.43	0.66	3.76	0.03	3.73	0.81
12	Jharkhand	6.53	0.98	5.55	1.84	3.71	33.13
13	Karnataka	16.19	2.43	13.76	4.76	9.00	34.60
14	Kerala	7.90	1.31	6.59	1.46	5.13	22.17
15	Madhya Pradesh	34.82	5.22	29.60	8.02	21.58	27.09
16	Maharashtra	37.87	12.40	25.47	9.44	16.04	37.04
17	Manipur	3.15	0.47	2.68	Negl.	2.68	Negl.
18	Meghalaya	0.54	0.08	0.46	0.02	0.44	3.97
19	Mizoram	1.40	0.21	1.19	Negl.	1.19	Negl.
20	Nagaland	0.72	0.11	0.62	Negl.	0.62	Negl.
21	Orissa	20.00	3.00	17.00	3.61	13.39	21.23
22	Punjab	18.66	1.87	16.79	16.40	0.00	97.66
23	Rajasthan	12.71	1.99	10.71	9.26	1.45	86.42
24	Sikkim	0.07	0.01	0.06	Negl.	0.06	Negl.
25	Tamil Nadu	26.39	3.96	22.43	14.45	7.98	64.43
26	Tripura	0.66	0.10	0.56	0.19	0.38	33.43
27	Uttar Pradesh	81.12	12.17	68.95	32.33	36.62	46.89
28	Uttaranchal	2.70	0.41	2.29	0.82	1.47	35.78
29	West Bengal	23.09	3.46	19.63	7.50	12.13	38.19
ALL STATES		433.24*	71.14*	361.98*	149.82	212.78*	41.53
		(431.77)	(70.92)	(360.73)		(211.53)	
UNION TERRITORIES							
1	Andaman & Nicobar	0.33	0.01	0.31	Negl.	0.31	Negl.
2	Chandigarh	0.03	-	-	0.03	-	-
3	Dadar & Nagar Haveli	0.04	0.01	0.04	0.00	0.03	12.81
4	Daman & Diu	0.01	0.00	0.01	0.01	0.00	70.00
5	Lakshadweep	0.00	0.00	0.00	0.01	0.00	-
6	Pondicherry	0.03	0.00	0.02	0.12	0.00	-
ALL UTs.		0.442*	0.025*	0.384*	0.16	0.348*	-
		(0.12)	(0.01)	(0.07)		(0.04)	
ALL INDIA		433.88*	71.16*	362.36*	149.97	213.13*	41.57
		(431.89)	(70.93)	(360.80)		(211.56)	

Sources : Ground Water Statistics,2003 (Central Ground Water Board)

Water supply condition for sugarcane production in India

- Sugarcane production is mainly happening in the water stressed areas of the country (north and west and some part of south)
- Starting from the year 1980 till 2006 irrigation coverage increased from 80% to 93% of the total sugarcane cultivated land.
- Sugar producing regions have more than 80% ground water irrigation through deep well pumping.
- In India there is only 162 BCM/year of ground water available for future irrigation out of which only around 40 BCM/year is available in the sugar producing states (CGWB, 2005).

Water supply condition for sugarcane production in India

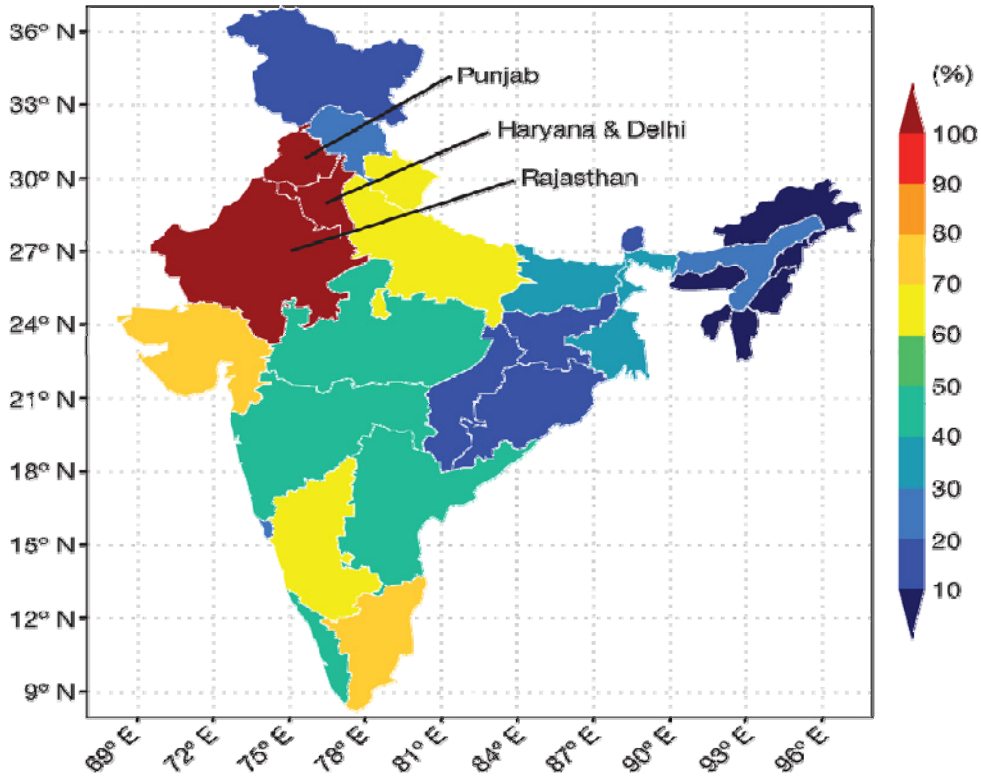


Source: CGWB, 2005

Ground water depletion in India

- NASA's Gravity Recovery and Climate Experiment satellites reveals the faster depletion of the ground water stocks in India especially in the north and north western part of the country (18 BCM /year)
- Around 60% of the country's total sugar cane is produced in these regions with 93% of irrigated sugarcane production system.

Ground water withdrawal as a percentage of recharge



Objective of this study

- The primary objective of this paper is to estimate an optimal production level of sugarcane in India which can produce the required amount of ethanol under the prevailing water resource constraint.

- The secondary objective is to demonstrate that an effective utilization of the available watershed projects to produce sugarcane for bioethanol supply will reduce the impact on future irrigation water availability. This will further help the country to meet the other food crop water supply demand in future.

Model

- A dynamic optimization model of the sugarcane production function with the constraint of water supply at steady state condition.
- We used the Solow type assumption for water supply using the Land-Capital composite factor for biofuel production. We consider a standardized water utilization rate for the whole country . Each unit of water is serving same amount of land area producing sugarcane for bioethanol.

- The production function is; $Y_t = AW_tK_tL_t$
  Again, $K_t/W_t = \alpha$, The proportion of land irrigated by each unit of water for ethanol production and so $W_t = \alpha K_t$
  The production function becomes,
  $Y_t = A\ \alpha\ W_t^2L_t$

- Using the producers' profit as objective function we derived the following optimal control problem

$$\text{Max } \Sigma\ \rho t\ (p\ A\ \alpha\ W_t^2L_t - c_1 W_t - c_2L_t)$$

Where, $\rho = 1/1+\delta$

Subject to $W_{t+1} - W_t = \beta Y_t - \theta W_t$

$$= \beta\ A\ \alpha\ W_t^2L_t - \theta W_t$$

c_1= cost of water supply

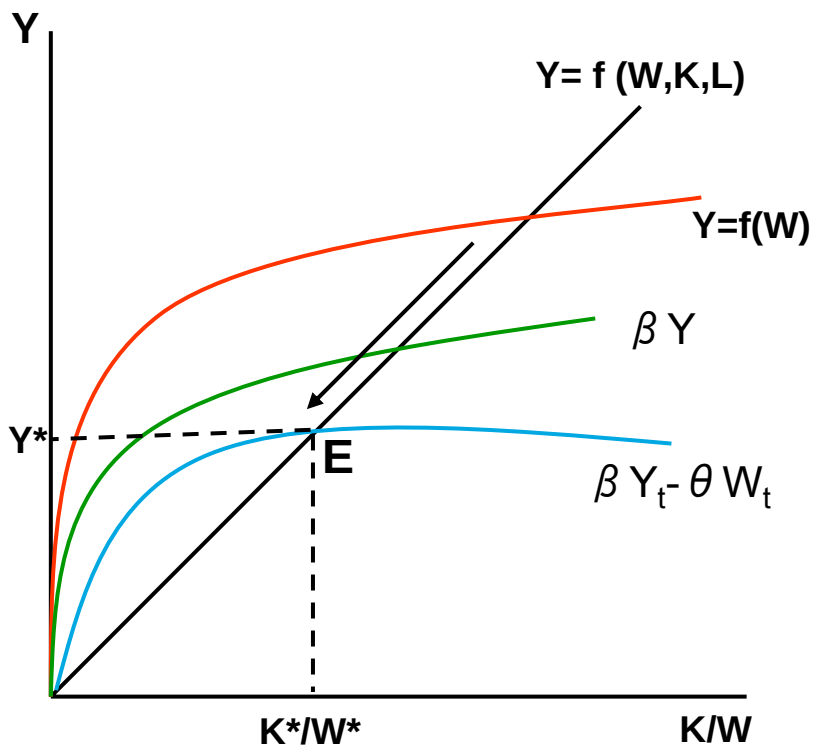
c_2= cost of labour supply

β = rate of savings for future investment

θ = rate of depreciation of water stock

Model description

- The production function assumes diminishing returns to Capital-Land (K) composite factor as denoted by the slope of the production function.
- Water resource available per unit of K is determined by three variables:
  - Investment for water irrigation per unit of K (β)
  - Increasing sugarcane cultivation growth rate (we considered it unity)
  - Depreciation of the water stock for irrigation (θ)



Generic Solution

- Applying the standard dynamic optimization solution technique we obtained the following generic form of the solution which predicts the optimal quantity of the water supply for sugarcane production in India.

$$W^* = \left\{ \frac{c_2(\theta - \delta)}{A\ \alpha (c1\ \beta - p(\delta + \theta))} \right\}^{1/2}$$

Where, $W^* > 0$ iff $\theta > \delta$ and

$$p < \frac{c_1 \beta}{(\delta + \theta)}$$

Using W* we get K* = α W* and finally we get the optimal production of sugarcane as Y*= AW*K*L. Using the exogenously determined ratio of sugarcane used for ethanol we can finally get the optimal level of ethanol production given the dynamic water constraint.

All the parameters have been estimated using the field level data from the two districts of Maharastra State. These districts produce sugarcane as well as other oil seeds like maize, soybeans and ground nuts.

Results and Discussion

Estimated parameter values

Parameters	Values	Description
θ	0.11	Rate of ground water table depletion
δ	0.08	Discount rate of the output values
β	0.10	Indigenous savings rate of the output
A	0.05	Labour augmented productivity
α	0.003	Water utilization factor (water required per unit of output)

Model estimated optimal values

W* (BCM/y)	Y* (M.ton/y)	Ethanol Production (ML/y)
9.7	29.7	300.5

Results and Discussion

- Current level of sugar cane production in India is around 300 MT per annum which is much higher than the estimated optimal production level under the given condition.
- India's average water utilization for the 5.2 million hectare of sugar cane production land is around 144 BCM /year compared to the 10 BCM/ year of the model predicted optimal use.
- Indian sugarcane production is borrowing water resources from the future every year at the range of 130 BCM.
- At the current level of water consumption for sugarcane which is 20,000 KL/ ha, the major sugarcane producing states including Uttarpradesh, Maharastra and Karnataka can keep their production at the current level until 2013 only.
- At the current level of water resource utilization, India can produce more than required amount of ethanol (at 5% mandate by 2017 it requires around 1000 ML) but that cannot continue for long.

Results and Discussion

- Rate of water resource depreciation is a critical factor. If it falls below the standard discounting factor of the sugar companies then future sugarcane production rate will decrease and the ethanol target cannot be reached.

Sensitivity of sugarcane production to GW depletion rate

Ground water depletion rate (θ)	Yield (ton/ha)	Total Sugarcane prod (MT) at current rate	Total Ethanol Production (ML) at current rate	Total water requirement (BCM/y) at current rate	Optimal water requirement (BCM/y)	Optimal sugarcane production (MT)	Optimal ethanol production (ML)
0.088	23	123	1251	38	1.3	4	40.7
0.099	56	292	2976	91	4.9	14.8	150.8
0.11	89	462	4708	144	9.7	29.5	300.5
0.121	121	632	6446	197	15.6	47.1	479.8
0.132	154	804	8191	250	22.3	67.5	687.6

Results and Discussion

- Sensitivity analysis shows that the drop of production may even go up to 75% in the case of 20% water supply reduction. Unfortunately, majority of the water is coming from ground water sources which are depleting very fast. Hence, Indian sugarcane production is in a vulnerable condition due to ground water availability constraint.

Time line of uninterrupted sugarcane production in India

Ground water depletion rate	Year of uninterrupted production
θ>0.088	20 (30)*
θ>0.099	11 (30)
θ>0.11	7 (28)
θ>0.121	3 (17)
θ>0.132	1 (14)

* Within bracket figures indicates the time line with optimal water utilization rate

Implications of watershed projects in sugarcane production

- Watershed projects can help to increase the ground water storage and can significantly reduce the irrigation water requirement for sugarcane production. Watershed projects can provide the following benefits indeed *(Joshi et al. 2005):*
  - *increase in irrigated area by 34% without additional water requirement ,*
  - *Increase in cropping intensity by 64% and*
  - *Reduction of the rate of run-off of the surface water by 13% and*
  - *Reduction in soil erosion by 0.82 ton/ha/year which further decreases the sedimentation rate in the dams*

- Therefore, it is recommend for India especially for sugarcane based ethanol production, to mandate designated sugarcane utilization for bio-ethanol production only and that to using watershed project areas.

Implications of watershed projects in sugarcane production

In India more than 170,000 Ha is under watershed. Out of which 30% is in the northern India and close to sugar production belt.

Sugar producing states have only Net Cropping Area (NCA) under the watershed coverage. Therefore, it needs to be increased drastically and with setting a target.

Status of watershed developments in the states

State	Net Cultivated Area (MHa)	Total planned treated area under IWDP (MHa)	Percentage to the NCA
Maharastra	17.4	0.8	4
Uttar Pradesh	16.8	0.95	5.5
Tamilnadu	4.6	0.65	14

Policy direction

- Promote the use of low water consuming cane species which are now available in the market along with the mandate of using advanced farming techniques which can ensure lower water requirement in the field.
- Increase the watershed coverage in the states like Maharastra and Uttar Pradesh as much as possible to mainly cover the sugarcane producing land areas.
- Use of low cost electricity for sugarcane Irrigation pumping should be abolished by regulation and law to prevent unnecessary use of pumps.
- Water usage auditing for the sugarcane production should be made compulsory to take account of the over and under utilization of the ground water table.

Policy direction

- Based on the annual water audit report, inter and intra regional irrigation water trading among the sugarcane producers' association can be introduced to achieve the market driven efficiency of water use which is otherwise difficult.

- Designate sugarcane plantation area exclusively for bio-ethanol production under the designated watershed projects to avoid use of precious ground water to fill up the gas tanks of the motor vehicles.

- In a long term planning it is prudent to gradually shift the sugar cane production from the water stressed regions to the water sufficient region.

Thank You for your attention !