Climate-smart agriculture: catalyzing behavior change in sugarcane farmers for water-use efficiency

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Abstract  In India, agriculture contributes one-sixth of the country’s gross domestic product (GDP) and provides employment to 56% of the workforce. The growth of commercial crops such as sugarcane has significant potential to promote exports of agricultural commodities and bring about faster development of agro-based industries. India is the second largest producer of sugarcane in the world, after Brazil. In 2013-14, India produced over 340 Gt of sugarcane. Despite the importance of sugarcane in the economy, its cultivation continues to face a number of economic, environmental, and social challenges. A key environmental challenge faced by millions of sugarcane farmers is the declining availability of irrigation water, due to climate change/erratic rainfall and over-exploitation of groundwater. Sugarcane is a water-intensive crop and consumes 500-3000 L of water to produce 1 kg of sugar. Most sugarcane farmers use inefficient water management practices such as flood irrigation, trash burning, etc., leading to over use of water with sub-optimal productivity. With this backdrop, a sustainable sugarcane advisory program focusing on demand-side water management techniques/practices, referred to as the India Sugar Advisory Farmer Support Program, has been implemented in three leading sugar-producing states of Uttar Pradesh, Madhya Pradesh and Maharashtra. From the research findings, water-efficient technologies/practices such as land leveling, addition of organic manure/compost, furrow irrigation, trash mulching were identified, and farmers were trained to adopt these low cost technologies under this programme. A combination of trash mulch and skip-furrow irrigation though micro-irrigation techniques such as drip irrigation and gated pipes was also demonstrated. Due to the program, around 64 GL of water was saved through good water management practices from January 2014 to May 2015 in Uttar Pradesh, Madhya Pradesh and Maharashtra. We conclude that implementable technologies to improve the economics of water use in sugarcane are available with measurable impact.

Key words  Farmer behavior change, demand-side water management

INTRODUCTION

Water is one of the most precious natural resources supporting life on earth. It is an essential part of food production. Around 70% of the fresh water is in the form of glaciers, which limits the amount of fresh water available for sustaining life and all economic activities to less than 1% of the total water available (Anon. 2009). In India, agriculture accounts for over 85% of total water use (Anon. 2008). By the year 2030, water supply in India will meet only 50% of projected water demand, which will lead to severe water stress in most parts of the country (Anon. 2009). However, water-use efficiency in Indian agriculture is currently extremely low. There is a large potential to improve water-use efficiency, thus reducing water use in agriculture while improving (or maintaining) farm productivity.

Sugarcane is a major water-intensive crop in the Indian agricultural landscape, requiring water at farm level of approximately 1500-3000 mm per annum; 60-70% of which is irrigation water (Srivastava and Johari 1979). The India Sugar Advisory Farmer Support Program reaches out to 100,000 sugarcane farmer households across Uttar Pradesh, Madhya Pradesh, and Maharashtra to promote uptake of sustainable sugarcane cultivation practices to improve farm yield and sugar recovery. A key component of the program is its focus on accelerating the uptake of water-use efficiency practices and technologies by small and marginal farmers through demonstration of the business case for farmers adopting such water-efficient practices and technologies. If farmers are convinced about the business case for water-use efficiency (by improved yields and optimal water use and/or reduced irrigation costs, such as diesel for pumps, etc.), they will adopt these practices and reduce overall demand for irrigation water. The strategy is ‘producing more with less’ and improving overall input efficiency in sugarcane farming. This is one of the world’s largest private sector-focused advisory program in water-use efficiency with a focus on behavior change in farmers towards ‘demand-side management’ in sugarcane cultivation (Anon. 2014).
MATERIALS AND METHODS

In this project the International Finance Corporation (IFC) partnered with others to remove barriers to optimal business potential for small land holders. The base line survey of the project revealed that most farmers were using inefficient irrigation practices such as flood irrigation and burning of trash mainly due to a lack of knowledge and finance. Research at various research centres suggested that simple good farm practices such as trash mulching saves 28.7% water (Anon. 2008) and green manure may enhance water use efficiency by 40% (Anon. 2013), skip-furrow irrigation decreases water use by 37%, and furrow irrigation saves 16.7% water as compared to the check-basin method (Prasad et al. 1980). Land leveling helped save water in sugarcane by up to 40% (Jat et al. 2006) and drip irrigation reportedly saved 36% water in sugarcane (Haspe 1991).

After discussions with stakeholders, it was decide to promote cost-effective and locally appropriate water-use efficiency enhancement techniques/practices that could reduce the overall application of irrigation water on sugarcane farms, but not at the expense of farm productivity. The program demonstrates a clear business case for each water-use efficiency practice and technology for farmers, particularly in terms of productivity enhancement and/or reduced cost of irrigation. The program undertook a series of interactive processes with growers, including generating awareness, capacity building/training, community empowerment, access to technology/finance facilitation, demonstrations, knowledge management and communications, and monitoring and evaluation. Due to the agro-climatic and soil conditions of Hardoi and Lakhimpur Khiri districts of Uttar Pradesh, Barwani district of Madhya Pradesh, and Kolhapur district of Maharashtra, six low-cost water-saving techniques are being promoted. These are trash mulching, application of organic manure, furrow irrigation, drip irrigation (particularly in Barwani), land-levelling techniques and demonstration of gated pipes.

Before full engagement by farmers, we undertook a baseline assessment based on information from 1400 program farmers associated with the two participating companies (DSCL Sugars Olam Agro) with respect to irrigation water used to establish a strong case for acceleration of demand-driven measures in water management.

For faster adoption of different programmatic interventions and substantiating water-use efficiencies of different programmatic interventions, demonstration plots were established in the project sites (28 in DSCL and 16 in Olam). These were regularly monitored by the technical teams of the sugar mills and data were recorded by field instruments. Irrigations were applied according to the readings of soil moisture tensiometers and quantity of discharge of water used in each plot was measured using flow meters.

The program to change farmers’ attitudes was based on following 3 ‘S’ principles:

- Suitability: The agronomy and water-management practices were customized to suit local agro-climatic and farmer socio-economic conditions. For instance, as farmers in Uttar Pradesh were not yet ready to adopt drip irrigation systems due to lack of finance, this was not over-emphasized. The program provided a number of other options that were simpler and cheaper to implement and also address farmers’ requirements.

- Sustainability: It was recognized that training and capacity-building should go beyond the life-cycle of the project. The focus of the program was on ‘train-the-trainer’ and, therefore, useful in creating a cadre of project-trained extension workers to lead farmers who will continue to spread knowledge in the community even after the end of the project.

- Scalability: The train-the-trainer approach focused on extension workers and lead farmers to ensure capability. About 2500 lead farmers were identified and trained across the six sugar mills in three states. Together, these lead farmers and the extension support team of these companies, have the capacity to reach out to a further 100,000 sugarcane farmers.

Extensive literature is available on research and development in water-use efficiency practices and technologies in sugarcane cultivation in similar tropical and sub-tropical conditions in India. Literature reviewed for different programmatic interventions included: drip irrigation (Sale et al. 2003), trench/furrow irrigation (Prasad et al. 2000), land levelling (El-Yasal and Wissa 1990), trash mulching (Anon. 2008), irrigation at critical stages (Anon. 2007) and gated pipes (Osman 2000).
RESULTS AND DISCUSSION

Baseline findings on irrigation—DSCL Sugars (4 mills), Uttar Pradesh

- Farmers in both treatment (with training and without training) on average, irrigated at intervals of 19 days, about seven times in a crop cycle.
- The most common method was flood irrigation followed by check-basin irrigation in which the entire field is divided into small beds using embankments. A negligible number of farmers used other methods such as drip or sprinklers.
- In terms of methods available/applied, farmers mentioned check-basin (30%), followed by basic land-leveling (21-28%). Although some farmers reported trash mulching [9% (control) and 13% (treatment)], knowledge of and steps involved in trash mulching were very basic.

Baseline findings on irrigation—Olam Agro India Limited: Barwani, Madhya Pradesh, and Rajgoli, Maharashtra

- Farmers in both treatment and control groups, on average, irrigate at intervals of 15 days, around 10-11 times in a crop cycle at Barwani.
- Almost all farmers used flood irrigation. A negligible number used drip or sprinkler systems.
- In terms of the methods available and applied for improved water-use efficiency, farmers mentioned land leveling, followed by bed preparation.

Experience and lessons from the program

- The rigorous and systematic training and capacity-building efforts have led to a significant increase in the adoption of some good water management practices by the farmers (Table 1). This is a testimony to the fact that farmers are beginning to change their behaviour and practices towards water-use efficiency. This shows that the training and capacity-building are showing positive results and are effective.
- In terms of management practices, the main focus was on organic manure, land levelling, trash mulching, and furrow irrigation. Other practices were also encouraged. The new gated pipe method was introduced as a demonstration in four sugar mills areas.
- There was a significant increase in the adoption of trash mulching by farmers in some districts (Table 1). This has twin benefits of water-use efficiency and soil health improvements. Farmers in central Uttar Pradesh earlier would burn trash on a large scale. These farmers have now taken to trash mulching on their farms as a result of the program’s training and capacity-building efforts. The coverage of area under trash mulching has more than doubled in the last 3 years. Similarly, the practice of composting of press-mud has gained momentum among farmers who have understood the long-term benefits of press-mud compost in soil health improvement, fertilizer application reduction and water-use efficiency. The area under farm yard manure/press-mud compost has increased by more than three times from 2012 to 2105 (Table 1). Earlier, the sugar companies used to sell this by-product elsewhere. If provided to the farmers, they in turn sold this press-mud to brick kiln operators rather than composting it for use in their fields. Now as a result of training they have realised its importance as bio-compost. Similarly the area under furrow irrigation has increased by 2.5 times.
- There was a significant increase in the adoption of good water management practices among farmers working with Olam Agro (Table 2). The area under farmyard manure/press-mud compost increased by 6 times from 2012 to 2015. Similarly, there was a marked increase in the area under trash mulch and furrow irrigation by 10 times and 1.23 times respectively. Furrow irrigation increased, particularly due to the increased adoption of trench planting. There was also an increase in the area under drip irrigation, although overall adoption remained small.
- In relation to the field experiments/demonstrations to confirm impact of good practices under local conditions: Twenty eight demo plots (control and treatment plots) were established under the program (in DSCL), which yielded very positive results where water-use was avoided at the farm level. Measurements in farmers’ fields (demonstration plots) established that application of trash and organic manure (in the form of farmyard manure and press mud) led to some avoidance of water-use at farm level by 24% and 27%, respectively (Table 3).
- Sixteen demonstration plots (control and treatment plots at farmer fields) were established in Olam (Barwani). These showed positive results with respect to ‘water-use avoided’ at the farm level (Table 4).
Table 1. Adoption of recommended good water management practices by farmers: DSCL Sugar.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Ajbapur (ha) 2012</th>
<th>Loni (ha) 2012</th>
<th>Hariawan (ha) 2012</th>
<th>Rupapur (ha) 2012</th>
<th>Group total (ha) 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmyard manure/press mud manure/press-mud compost</td>
<td>875</td>
<td>2808</td>
<td>1056</td>
<td>2971</td>
<td>1560 2800 11631</td>
</tr>
<tr>
<td>Land levelling</td>
<td>100</td>
<td>348</td>
<td>2</td>
<td>91</td>
<td>94 166 902</td>
</tr>
<tr>
<td>Trash mulching</td>
<td>2350</td>
<td>4692</td>
<td>1726</td>
<td>3195</td>
<td>2613 5936 12901</td>
</tr>
<tr>
<td>Furrow irrigation</td>
<td>160</td>
<td>1043</td>
<td>258</td>
<td>266</td>
<td>1560 11631</td>
</tr>
</tbody>
</table>


Table 2. Adoption of recommended good water management practices by farmers: Olam Agro.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Barwani (Madhya Pradesh) (ha) 2012</th>
<th>Rajgoli (Maharashtra) (ha) 2012</th>
<th>Group total (ha) 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmyard Manure/Compost</td>
<td>770</td>
<td>2347</td>
<td>980 6722</td>
</tr>
<tr>
<td>Trash mulching</td>
<td>380</td>
<td>1606</td>
<td>95 2488 475 4094</td>
</tr>
<tr>
<td>Furrow irrigation</td>
<td>5954</td>
<td>7300</td>
<td>5540 6863 11494 14163</td>
</tr>
<tr>
<td>Drip irrigation</td>
<td>396</td>
<td>500</td>
<td>82 101 478 601</td>
</tr>
</tbody>
</table>


Table 3. Results from field measurements of different programmatic interventions in DSCL.

<table>
<thead>
<tr>
<th>Programmatic intervention</th>
<th>Water-use avoided (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furrow over flood</td>
<td>17</td>
</tr>
<tr>
<td>Levelled over non-levelled</td>
<td>20</td>
</tr>
<tr>
<td>Trash over no trash</td>
<td>24</td>
</tr>
<tr>
<td>Organic manure over no organic manure</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 4. Results from field measurements of different programmatic interventions in Olam, Barwani.

<table>
<thead>
<tr>
<th>Programmatic intervention</th>
<th>Water-use avoided (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furrow over flood</td>
<td>13</td>
</tr>
<tr>
<td>Drip over furrow</td>
<td>46</td>
</tr>
<tr>
<td>Trash over no trash</td>
<td>20</td>
</tr>
</tbody>
</table>

The findings of above mentioned experiments/demonstration plots established to validate the quantity of water saved as per requirement of an independent audit confirms similar trends as reported in the literature. As a result of the collective efforts of the program’s partners, including the sugar companies, up until May 2014 over 64 GL of water-use was avoided, of which 27 GL is due to the adoption of the practices mentioned above by farmers (14.7 GL in DSCL Sugar, 8.43 GL in Olam (Barwani) and 3.8 GL in Olam (Rajgoli)). This was validated by Grant Thornton and Ernst and Young, third-party audit firms (from October/November 2013 to May 2014). The methodology looks into the stage-wise water requirement of the sugarcane crop and the irrigation water required (with rainwater also being considered) at a particular project site.

CONCLUSIONS AND FUTURE CONSIDERATIONS

- Based on the practical work carried out under the India Sugar Advisory Farmer Support Program, farmers’ adoption of water efficient practices was accelerated on a large scale. Despite these practices being well-known, local demonstrations were required to allow farmers to verify benefits and risks associated with adoption of good water-management practices. Experimental demonstration plots on program sites enabled farmers to experience the water-saving methodologies. Utilizing these environmentally sustainable and economically viable options offered significant benefits, which if adopted widely, would contribute to sustaining sugarcane productivity and economic use of water under conditions of ever-depleting water resources.
• A long-term policy implication can be seen in the program, which is attempting to build a robust business case for farmers adopting cost-effective water-efficient techniques. The program qualitatively defines benefits and quantitatively defines economic and social benefits. It sets an example in building a sustainable model by ensuring knowledge dissemination through formation of lead communities (farmer clubs), and leveraging company’s (sugar mills) agriculture extension services to farmers in the remotest of areas. With the climate change challenges looming large, programmatic interventions have catalyzed farmers’ behaviour for ‘climate-smart’ approaches to agriculture.

• The value proposition of the program has been its focus on ‘collective action’. This encourages programmatic interventions in water-use efficiency that fundamentally transform the outlook of the sugar companies regarding water as acritical input and risk to their business. The interventions create awareness among local communities, resulting in long-term environmental, social, and economic benefits for all. Water is a key input to sugarcane cultivation and with growing vulnerability to water security in the region, growing business can be a challenge for sugar mills if the threat to water availability and access is not addressed. This project facilitates the private-sector entities—DSCL Sugars and Olam—to understand the ‘water story’ in their catchment areas and plan their short and longer-term growth accordingly.

• The objective of the continuing program is not just ‘More Crop per Drop’ but to manage the ecosystem, community, and business risks emerging from future water challenges in sugarcane cultivation. The program is moving to the next phase of implementation, which will be more inclusive, participatory, and comprehensive in its outreach efforts by the inclusion of women and the community at large. This will make them the drivers to improve the agricultural water landscape story in their respective regions.

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Agriculture adaptée au climat: Un catalyseur pour un changement de comportement vers une efficience accrue de l'utilisation de l'eau chez les producteurs de canne à sucre

Résumé. En Inde, l'agriculture contribue à un sixième du produit intérieur brut (PIB) et emploie 56% de la population active. L'intensification des cultures commerciales telles que la canne à sucre a un fort potentiel pour promouvoir l'exportation des produits agricoles et pour accélérer le développement de l'agro-industrie. L'Inde est le deuxième producteur de canne à sucre dans le monde après le Brésil, avec une production de plus 340 Gt de canne en 2013-14. Malgré son importance, la culture de la canne à sucre continue à faire face à un grand nombre de défis économiques, environnementaux et sociaux. Un défi environnemental crucial auquel sont confrontés des millions d'agriculteurs, est la baisse de la disponibilité de l'eau d'irrigation, en raison de précipitations erratiques/changement climatique et de la surexploitation des eaux souterraines. La canne, étant une culture axée sur l'eau, consomme
500 à 3000 L d'eau pour produire 1 kg de sucre. La plupart des agriculteurs utilise des pratiques inefficaces de gestion de l'eau telles que l'irrigation par épandage, le brûlis, etc., menant à une utilisation accrue de l'eau et une productivité sous-optimale. Avec ce constat en toile de fond, un programme consultatif et durable qui met l'accent sur les techniques et pratiques de gestion de la demande en eau, a été mis en œuvre. Ce programme, appelé «India Sugar Advisory Farmer Support Program», a été introduit dans trois principaux états producteurs de sucre, à savoir l'Uttar Pradesh, le Madhya Pradesh et le Maharashtra. Les résultats indiquent que des techniques économiques en eau, telles que le nivellement des terres, l'ajout de fumier organique/compost, l'irrigation à la raie et le paillis, ont été identifiées et les fermiers ont été formés pour adopter ces technologies à faible coût sous ce programme. Une combinaison de paillis et de l'irrigation sur une entreligne sur deux, par des techniques de micro-irrigation telles le goutte à goutte et le tuyau à vannette, a aussi été démontrée. Grâce à ce programme, de janvier 2014 à mai 2015, environ 64 GL d'eau ont été économisés par le biais des bonnes pratiques de gestion de l'eau dans les trois états en question. Nous en concluons que des technologies sont disponibles pour améliorer la gestion de l'utilisation de l'eau dans le canne à sucre, avec un impact mesurable.

Mots-clés: Changement de comportement des agriculteurs, gestion de la demande de l'eau d'irrigation

Agricultura climáticamente inteligente: catalizando el cambio de comportamiento de los productores de caña de azúcar para el uso eficiente del agua

Resumen. En la India, la agricultura contribuye en una sexta parte del producto interno bruto del país (PIB) y proporciona empleo al 56% de la fuerza laboral. El crecimiento de los cultivos comerciales como la caña de azúcar tiene un potencial significativo para promover la exportación de productos agrícolas y lograr un desarrollo más rápido de las industrias basadas en la agricultura. India es el segundo mayor productor de caña de azúcar en el mundo, después de Brasil. En 2013-14, la India produjo más de 340 Gt de caña de azúcar. A pesar de la importancia de la caña de azúcar en la economía, su cultivo continúa haciendo frente a una serie de retos económicos, ambientales y sociales. Un desafío ambiental clave que enfrentan los millones de agricultores de caña de azúcar es la menor disponibilidad de agua de riego, debido al cambio climático/irregularidad de las precipitaciones y por la sobreexplotación de las aguas subterráneas. La caña de azúcar es un cultivo que requiere mucha agua y consume 500-3000 litros de agua para producir 1 kg de azúcar. La mayoría de los productores de caña de azúcar hacen un uso inadecuado del agua con prácticas ineficientes como el uso de riego por inundación, la quema de los residuos, etc., lo que conlleva a un uso excesivo del agua con baja productividad. En este contexto, un programa de asesoramiento de caña de azúcar sostenible, centrado en la gestión del manejo de técnicas y prácticas de la demanda del agua, conocido como “India Sugar Advisory Farmer Support Program” fue implementado en tres principales estados productores de azúcar de Uttar Pradesh, Madhya Pradesh y Maharashtra. A partir de los resultados de la investigación se identificaron, tecnologías de uso eficiente del agua, prácticas tales como nivelación de tierras, la adición de abono orgánico/compost, riego por surcos, residuos de cobertura y los productores fueron capacitados para adoptar estas tecnologías de bajo costo bajo este programa. Una combinación de la práctica de retención de residuos como cobertura, riego por surco alternativo aunque las técnicas de micro-riego, como el riego por goteo y tubos cerrados también fueron demostrados. Alrededor de 64 GL de agua fue ahorrado por el Programa por medio de buenas prácticas de manejo del agua desde enero 2014 hasta mayo 2015 en Uttar Pradesh, Madhya Pradesh y Maharashtra. Se llegó a la conclusión de que las tecnologías implementadas para mejorar la economía del uso del agua en la caña de azúcar están disponibles con un impacto medible.

Palabras clave: Cambio de comportamiento de los productores, manejo de la demanda del agua demanda