Towards a sustainable sugarcane industry in India

Improving livelihoods and increasing water use efficiency in sugarcane growing in India through adoption of improved practices and technologies

Evaluating progress between 2016 and 2021

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This report presents the findings of the evaluation of the Sustainable Water Fund project by Solidaridad and its partners, which aimed to improve irrigation techniques and farming practices in the Sugarcane sector in two states in Southern India. Farmer data was collected and analyzed in three years: 2016 (baseline), 2018 (midline) and 2021 (endline). A project document review and project staff interviews were used to explain and validate results. These results show initial improvements in the adoption of good agricultural practices, including the use of improved irrigation practices, as well as improvements in productivity, followed by deteriorations in more recent years as a result of various challenges affecting the sugarcane sector. For future projects we recommend, among others, to consider shocks and improve farmer resilience, to apply different interventions for different types of farmers (including non-commodity focus interventions) and to engage farmers more strongly in the design of interventions.

Key words: Impact evaluation, Sugarcane, India, Water use efficiency, Irrigation, Farmer livelihoods

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Summary

The sugar sector plays a crucial role for India's economy, but faces challenges in terms of stagnating production, price regulations, unstable sugarcane market and water scarcity.

The sugarcane industry is India's second largest agro-based industry and about 6 million farmers and a large number of agricultural labourers are involved in its cultivation. More than half a million workers, mostly from rural areas, are engaged in the sugar industry. The demand for sugarcane is increasing, while productivity has been stagnant for the last 20 years. The recovery rates (% of sugar gained from sugarcane) are among the lowest in the world. This influences profitability for farmers as well as the mills. While the sugarcane market in India is highly regulated, prices are not entirely stable. The sugar price for consumers is not regulated; the result is a three to five-year production cycle which makes sugar manufacturers vulnerable to industry oscillations, which also showed throughout the course of the project. In addition to stagnating production, price regulations and the unstable sugarcane market, water scarcity is fluctuating and increasing on the long run, affecting sugarcane farming areas as sugarcane is high in irrigated water use. With support from the Sustainable Water Fund (FDW), the 'Increasing water use efficiency in sugarcane growing in India' project, of Solidaridad and its partners, intends to enhance both sustainability of sugarcane growing and to raise smallholder incomes. FDW is a fund provided by the Dutch Ministry of Foreign Affairs and managed by the Netherlands Enterprise Agency.

To address challenges a public-private partnership was established and a large-scale roll-out of irrigation techniques and farming practices took place.

These challenges at farmer, mill and public-good level ask for an approach where forces are joined including private sector (e.g., sugarcane mills), knowledge VSI and Osmania University and Solidaridad. The cooperation of these players was organised through a public-private partnership (PPP) with the objective to support, expand and sustain the intervention, long after the FDW project has ended. The aim of the partnership – funded through the FDW - is to enhance the social, economic and environmental sustainability of sugarcane production. The key intervention was a large-scale roll-out of irrigation techniques and farming practices that have proven to raise water productivity and farm income of sugarcane farming in smallholder settings in India. Capacity building was assumed to result in increased productivity and higher water use efficiency. Activities included training of trainers, cultivation of demonstration plots, capacity building in financial literacy and service delivery. A total of 35,000 farmers have been reached with several activities. Mechanisation and equipment components were new elements of the activity plan added after the project started.

Challenges in the sugarcane sector affected implementation of activities for the three mills selected as project partner.

The FDW project was established with three mills from two leading companies in India. Both companies have several mills in operation in various states of Southern India, and as such vary in environment, climate, soil condition and water availability, farmer profiles and mill management. The selected mills are located in Karnataka and Telangana state. Selection of mills was based on production levels, water scarcity and sound monitoring. The mills differ in terms of size, capacity, production but also soft parameters. Changing ownership at mill level, fluctuating rainfall and shortages of labour had strong influences on the possibility to implement activities as planned. The project was extended for two years from 2018 to 2020. However, in 2020 another major challenge was faced with the outbreak of the COVID-19 pandemic. As a result of COVID-19 restrictions various activities such as training activities and the procurement of hardware faced significant delays.

Ability to contribute changes to the programme is very limited because of delay in implementation and shifting away to other crops.

To capture impact at the different levels and objectives and to interpret and validate pathways, monitoring and evaluation (M&E) activities were conducted with several parties all with their specialism and expertise focusing on a specific target. The aim of this research project was to show the projects'

impact on behavioural changes aimed at improving sustainability in sugarcane farming and at improving the socio-economic conditions of the supported farmers. This requires a counterfactual: we need to identify what would have happened had the project not (or otherwise) been implemented. For the purpose of impact evaluation we therefore decided in 2016 to exploit the fact that the project is implemented gradually over the years - the so-called 'quasi-experimental pipeline design'. This means we would compare farmers based on their different stages in the project support. To gain insight into short and long-term effects data was collected on a yearly basis. However, the key condition to proceed with the pipeline approach - gradual implementation over time – did not happen as planned as a result of delays in implementation. Therefore, the ability to contribute changes to the programme is very be limited.

Random selection of 1,018 sugarcane farmers in 2016; high attrition resulting in a sample of 385 farmers for the endline evaluation.

We used power calculations to determine the appropriate sample size. The sample size was defined by a random selection of farmers from the mills' management information system whereby all farmers were divided into three groups based on the year they were expected to start receiving training and other project interventions. The baseline survey was conducted among 1,018 farmers (3% of the total sugarcane population in the area). However, there was high attrition at midline and endline. Between baseline and midline this was because famers who were no longer producing sugarcane were excluded from the survey. Between midline and endline attrition was high because farmers could not be reached. To maximise the use of data for the purpose of evaluation we matched mill 1 farmers from the endline sample to the midline sample.

Household survey to collect data several indicators and project document review to understand and better explain observed changes.

The evaluation of Wageningen Economic Research focuses on the producer level and evaluates the changes and effects at outcome and impact level. Data was collected on a wide range of personal, household and farm characteristics. Other sections include questions that give insight into the challenges sugarcane farmers face and their personal opinion to training needs to test the relevance of the programme from the farmers' perspective. Also various potential drivers (e.g. shortage of water) and barriers (e.g. no financial resources) for adoption are covered to be able to clarify and interpret (differences) in impact. The surveys were translated into the two local languages (Telugu and Kannada) and conducted by the local research partner Q&Q Research Insights Pvt Ltd in the period June to August 2016, September to December 2018 and November 2021 to January 2022. In addition to survey data we analysed project documents and conducted stakeholder interviews in 2018.

Data analysis in four steps to gain insight into changes over time and relation to project activities.

Data analysis was conducted in four steps. First, we look at descriptive data to give insight into situation of targeted sugarcane farmers. Second, we show changes over time and its relation to the overall project. Third, we do statistical analysis to give insights into the determinants of envisioned project outcomes and impact. Finally, we will validate and correct interpretation of results by sharing and discussing results with different stakeholders.

The importance of sugarcane decreased but still represents 56% of income.

Farmers are predominantly male (90%) and head of the household (88%); households consist of 5.7 persons on average. Some farmers (temporarily) stopped growing sugarcane; mostly shifting to paddy. The share of income generated from sugarcane decreased since 2016, representing 56% of the households' total income at the time of the endline. Farmers producing sugarcane on average own 3.9 acres of sugarcane area: 3.7 acres owned, and 0.2 acres leased. Almost all famers who currently produce sugarcane plan on continuing to do so in the future. Sugarcane farming is not always done by choice (44%) and 48% of farmer prefer if their children do not end up working as farmers, yet most farmers indicate they are proud to be a farmer (81%).

Over time farmers received fewer subsidies, have less access to loans or savings and have become more risk averse.

The Indian government had been providing subsidies to farmers in various agricultural and development programmes. However, since the midline almost no farmers have received a subsidy. In terms of other financial activities, farmers also seem less able to invest despite the fact that 28% of the farmers indicated to have followed a training on financial literacy in the past 2-3 years at midline. At endline this was only 3%. Farmers less often take out loans or save money. Adoption of new or improved agricultural practices is also influenced by farmer attitudes towards investment and risk. Farmers have

become more risk averse in recent years. In line with this we see they are increasingly sceptical towards investing in agriculture. On the positive side we see that farmers became slightly more trusting in the advice of the mill since 2016.

Challenges faced by farmers change over time without clear relation to project activities.

Unavailability of labour remains the main challenge according to farmers (97%). The bulk of rural poor are migrating to urban areas. The face of agriculture is changing and to address this there is a need to provide emphasis on mechanisation and agri-entrepreneur services. Delays in getting payments from the mill and transportation issues for the produce to the mills are other major issues. The unavailability of water was another major issue previously but is not perceived as such anymore. Based on interviews with project staff and project documents it became clear this is strongly related to the fact that rainfall was higher between midline and endline.

All farmers in our sample have been engaged in the programme and indicate to have more need for training than in 2016.

At endline all farmers in our panel data set (385 farmers) indicate to have been engaged with the programme in some way; mostly though demo plots or lead farmers. Drip irrigation and mechanisation are the most common topics that farmers remember from training. This aligns with the key focus areas of the FDW project. Training needs are more satisfied at endline than at midline, especially for mechanisation, irrigation practices and GAP. However, many farmers still indicate a need for training in the future – for example in terms of good agricultural practices (40%) or financial management (35%).

Improved agricultural practices are key to FDW's theory of change.

It is assumed that good agricultural practices lead to higher production levels, higher productivity, higher farm incomes from sugarcane and increase water efficiency. We therefore analysed changes over time in terms of input use, several good agricultural practices, irrigation system used and level of mechanisation.

We see a strong increase in the number of farmers using more efficient and effective seed nurseries while the increase in use of organic fertilisers lagged behind.

A key element of the programme was the development of shade houses by Solidaridad and sugar mills in the villages. Seedlings from seed nurseries were hardly used at the time of the baseline. In the course of the project more farmers started using seed nurseries (33%). Moreover, the use of shade houses did not result in an overall increase in use of other variety in planting material. Another key element of the programme relates to promotion of organic fertilisers rather than chemical fertilisers. After an initial increase in organic fertilisers (almost all manure), farmers started using fewer organic fertilisers after 2018. Having no access (55%) and no resources (28%) are two common reasons for not using it. The percentage of farmers using chemical fertilisers remained high and increased for pesticide use.

Initial adoption of several good agricultural practices, but a strong decline at endline; mostly related to lack of labour and other resources.

Application of correct row-to-row spacing and trash mulching – two good agricultural practices promoted as part of the project - decreased since the midline. The practice of trash mulching – rather than thrash burning - declined. Lack of trash shredders (42%) and knowledge (36%) are key reasons mentioned at endline. Farmers that are more likely to invest less often burn trash. This make senses as costs are involved in shredding trash instead of burning, so an investment should be made. At the same time, we see a steep increase in application of another good agricultural practice: the share of farmers applying intercropping increased from almost 0 to 14%.

After an initial surge in adoption of improved irrigation practices, a decline is observed at endline strongly related to increased rainfall, shortage of labour in COVID-19 times of COVID-19 and overall lack of resources.

After an initial strong increase in drip irrigation between 2016 (45%) and 2018 (76%), a decrease in observed in 2021 (57%). The decrease in use of drip irrigation between midline and endline is partially explained by increased rainfall (less perceived need), shortage of labour in COVID-19 times of COVID-19 and overall lack of resources. The main source of finance – governance subsidy – is insufficient to overcome lack of resources in increasing or even

maintaining level of drip irrigation. Despite increasing awareness on the need for maintenance, the vast majority of farmers indicate that the drip jams frequently and that the wires break easily. Education, sugarcane dependency, sugarcane area and membership of a farmer group are positively related to adoption of drip irrigation.

Farmers mechanised fewer activities compared to the midline because it is too expensive.

A component of the FDW programme that was added after the start of the programme is entrepreneurship training on mechanisation and the provision of equipment. This was a response to the fact that labour shortage remained the key challenge, and still is. However, at endline less farmers mechanised one or several activities (65% versus 96% at midline). The most important reason mentioned by farmers for not mechanising any of their activities is that it is too expensive (95%). Land preparation and plant protection are most often mechanised.

Improved agricultural practices were supposed to reduce costs and water use, and increase quality, productivity and profitability.

Following the intervention logic, improved agricultural practices, input use and irrigation systems are the immediate outcomes of the intervention which would lead to higher crop productivity, lower production cost, lower water use and higher quality and price for the crops. Eventually this should translate to increased farm incomes and water efficiency of the farmers.

Productivity increased initially but decreased again between the midline and the endline with no strong statistical relation to differences in agricultural practices.

In 2016 productivity was 36.6 tonnes per acre, it increased to 37.9 tonnes in 2018 but decreased again to 33.8 tonnes per acre in 2021. There is no relation between productivity and several agricultural practices except for trash burning (for who it is lower) and farmers with higher production costs per tonne of sugarcane have lower productivity. Productivity is positively related to a higher dependency on sugarcane but lower for larger sugarcane area and higher levels of education. Main reasons mentioned by farmers for decrease in productivity are the unavailability of labour and (partially related) late cutting orders which is regulated through the mills.

Total production cost and sugarcane prices decreased over time.

Input costs per tonne increased reflecting the higher input prices mentioned already as a key barrier to improved practices. However, total production costs per tonne decreased over time as a result of labour shortages rather a than a good agricultural practices (GAP)- based decision. Total production costs per tonne is lower for farmers with more sugarcane area, for farmers with high sugarcane dependency, and for larger households. There is a significant positive relation between applying drip irrigation and production cost in our sample. This is contrary to expectations in the FDW partnership as the assumption is that applying drip irrigation should save resources. The total production costs per acre remained stable between midline and endline. The sugarcane prices decreased since 2018. The low prices in 2019-2020 season are related to the overall challenges in the sugarcane sector around that time. In addition to the price decrease, farmers also were also paid late which influences investments in subsequent years.

Reliance on sugarcane income has strongly declined over time.

The average farm income from owned and leased sugarcane land of the farmers at the baseline was INR 156,537, and it rose significantly to INR 380,203 at the midline but decreased again to INR 249,123 at the endline. Surprisingly, 60% of the farmers indicate not having experienced any changes in farm incomes in the last 3 years. Aside from the expected relation between profitability and productivity, production cost and price, we also see that demographics and which mill farmers belong to influence profitability. Overall, we see farmers are becoming rapidly less reliant on sugarcane: at baseline 97% of farmers was dependent on sugarcane income for more than 75%, at endline this reduced to 46%. Sugarcane farmers most often receive additional farm income from soybean, cotton and ginger. We estimate that, taking all sources of income into account, 85% of the sugarcane farmers in our sample achieve an income that allows their households to afford a decent standard of living.

Based upon the findings in this study, we have six key recommendations:

1. **Conduct a food system analysis.** This report shows how farm system outcomes of sugarcane farmers and related project goals were strongly influenced by socio-economic and environmental drivers. A food system analysis can help to identify and mitigate these Usually a food systems includes: 1) identifying drivers of food system activities and root causes of problematic system behavior, 2) mapping the diverse spectrum of economic, social and environmental food system outcomes, 3) analyzing the trade-offs and possible synergies between different food system outcomes, 4) pointing to feedback loops and tipping points in the relation of the food system with other systems.
2. **Apply targeted interventions for different types of farmers**. The analysis shows some farmers are able to maintain profitable sugarcane businesses despite challenges faced, and some are not. At the same tie we see that project activities impact different farmers differently. In particular, some farmers are better able or willing to invest. Therefore, we recommend future interventions to be adjusted to the realities of different kinds of farmers.
3. **Resource poor farmers may require non-commodity focus interventions.** Results show that some interventions are not accessible for resource poor farmers, or not sustainable on the long run. We also saw many farmers shifting away from sugarcane. For farmers without possibilities to invest in better agricultural practices that cost additional money, or that are not able to achieve a living income from sugarcane production, other focuses for interventions must be prioritised.
4. **Engage farmers in design of interventions more strongly.** In our report we show that a number of practices promoted by the programme have declined in uptake in recent years as a result of shortages of labour and resources. This was also related to increased rainfall, shortage of labour in times of COVID-19 and overall lack of resources. Our analysis also does not show a strong link between agricultural practices and productivity, costs or profitability. To better meet farmers' needs and possibilities in terms of resources we recommend stronger engagement with the farmers. This should include efforts to build effective partnerships and carefully manage farmer expectations on the short and long term.
5. **Consider shocks and farmer resilience.** The report shows that decreasing price, sector unrest and shortage of labour led to a shift to other means of income. This can be considered beneficial to the resilience of farmers to shocks and should not be discouraged. We also recommend to better understand the value chain so that the effects of shocks on farmers can be minimised in the future.
6. **Extract value from this evaluation by using data and sharing findings.** We believe this report provides evidence that can help to further improve programs that contribute to improved livelihoods of sugarcane farmers in India, but also smallholders elsewhere. We therefore recommend to share the findings, which may also inspire longer term partnerships and future collaborations in research and design of future interventions.

1

Introduction

1 Introduction

Project aims to enhance sustainability of sugarcane growing and to raise smallholder incomes.

The sugarcane industry is India's second largest agro-based industry and about 6 million farmers and a large number of agricultural labourers are involved in its cultivation. Sugarcane is a major consumer of water and the decreasing level of the natural groundwater resource threatens food security, economic growth and livelihoods. With support from the Sustainable Water Fund (FDW), the 'Increasing water use efficiency in sugarcane growing in India' project, of Solidaridad and its partners, intends to enhance both sustainability of sugarcane growing and to raise smallholder incomes.

A large-scale roll-out of irrigation techniques and farming practices to improve water productivity.

The overall objective of the FDW project was:

> 'To stop and reverse the depletion of the critical groundwater resource, thereby sustaining and improving the livelihoods of smallholder sugarcane growers and securing employment at sugar mills and downstream agro-industry in India' (FDW Project Plan Solidaridad 2014).

Achieving this objective requires that less water is extracted in cultivating sugarcane. Therefore, FDW proposed a large-scale roll-out of irrigation techniques and farming practices that have proven to raise water productivity and farm income of sugarcane farming in smallholder settings in India. Major activities of the project included training on good agricultural practices (e.g. water conserving practices), introduction to improved irrigation systems (e.g. training on drip irrigation and distribution of crop calendars and drip manuals), and farmer trainings on entrepreneurship, mechanisation and financial literacy. Training was provided to all interested farmers in the command areas of three sugar mills in the southern states of Karnataka and Telangana.

Providing insights into the changes over time of the project despite limitation in data and delay in project activities.

Following a baseline study in 2016 and a midline study in 2018, this endline report provides insights into the situation at project closure in 2021. The extent to which we can relate these changes to project impact is limited for several reasons. First, the final report is based on data from 385 farmers. This is much lower than the 1,018 farmers covered in the baseline report because farmers could not be reached, switched to other crops or were unwilling to participate. Second, trainings started much later than foreseen. In 2018 less than 10% of the farmers in our sample had received some form of training. In addition COVID-19 set in which affected the programme in three ways: delayed agricultural operations, no availability of farmers input and market and price disturbance (Solidaridad, 2020). Despite these limitations we can provide accurate and valuable insights into the changes over time of these 385 farmers and the challenges still ahead. Moreover, our analysis shows these 385 farmers are largely representative of the 1,018 we started with in 2016.

The findings from our research should be interpreted within the larger food systems.

Since the start of this research – in 2015 – the science and practice to contribute to sustainable change has changed considerably. Increasingly, we take a food systems approach to investigate why current systems are not working properly or to demonstrate the contribution of interventions to make systems more sustainable. A food systems approach is a useful interdisciplinary conceptual framework for research and policy aimed at sustainable solutions for the sufficient supply of healthy food. All over the globe and through the history of mankind, food systems have been in transition, changing their configurations and results. Yet, under pressure by climate change, new geopolitics, digitalisation and other drivers food systems are being increasingly scrutinised as to their internal functioning and external outcomes. Increasingly, food systems have to respond to changing demands, raising questions how to guide processes of transformation towards desired outcomes. This also became evident in the course of this research project. While this is not addressed explicitly in the results, it is

important to interpret the findings and conclusions within the broader food system when informing future programmes in the sugarcane sector.

Structure of the report.

The report provides a detailed insight into the socio-economic conditions of sugarcane producers and changes in their practices over time. We start with brief description of the sugarcane sector and FDW project in Chapter 2 and the methodology in Chapter 3. In Chapter 4 we describe the farmers in our sample in more detail in terms of socio-demographics but also challenges and future perspectives. This chapter also include an overview of programme engagement. Chapters 5-7 show changes in the domains of agricultural practices including irrigation systems used (5), productivity (6) and cost and revenues (7). For a detailed description of the context, the theory of change, and the methodology we refer to the baseline report and midline report which can be accessed online. All the output tables are presented in the appendix.

2

Context

2 Sugarcane and the FDW project

2.1 Sugarcane sector

India is one of the largest producers and consumer of sugarcane.
Eighty per cent of sugar produced worldwide comes from sugarcane, the remaining 20% comes from sugar beets. Brazil, India and China are the top three producers of sugarcane globally. India alone contributes 17% of total production (Harender et al., 2021). As for consumption rates, India and China use about as much as they produce (Fairtrade and Sugar, 2013). The sugar industry is India's second largest agro-based industry, after cotton & textile (Solomon 2011; Harender et al., 2021). At the start of the project about 6 million farmers and a large number of agricultural labourers are involved in sugarcane cultivation. More than half a million workers, mostly from rural areas, are engaged in the sugar industry. A total of 642 sugar mills in ten states in Southern and Northern India process sugarcane into around 25 million tonnes of sugar per year (Indian Sugar Mill Association 2016). Other than sugar, products derived from sugarcane include molasses (used for production of alcohol or ethanol), bagasse (used for biofuels and binding material), or press mud (organic manure or plant nutrient).

Sugarcane demand increases while productivity is stagnating.
It is estimated that by 2030, India will require about 520 million tonnes of sugarcane to keep up domestic consumption of sugar and ethanol. Considering that there is little scope for area expansion, this will entail a productivity requirement of around 100-110 tonnes per hectare compared to the actual 70 tonnes per hectare (Duttamajumder et al., 2011). After decades of increasing sugarcane yields, however, productivity has stagnated in the last 20 years. And sugar recovery (9%-10%) is one of the lowest in the world. Recovery is the amount of sugar produced out of sugarcane, so 10% recovery means: 10 kg of sugar out of 1,000 kg of sugarcane. From the sugar mill perspective it is crucial to ensure a guaranteed supply of sugarcane but also to increase recovery in order to be profitable, as the minimum price which has to be paid to farmers is set. The recovery percentage is influenced by several factors: a) altitude (the higher the altitude, the lower the quality/moisture content), b) variety used, c) efficiency of production process and d) cultivation process. The latter three can be influenced by the mill and the farmers themselves. The sugar mill has immediate benefit from economies of scale if the producer uses the right variety and good agricultural practices to improve quantity, quality and as such recovery percentage.

The sugar sector in India is highly regulated but not entirely stable.
Sugar, being an essential commodity, is controlled through various regulatory mechanisms in India. The sugar mills procure sugarcane from the farmers in their government-mandated 'command areas'. Mills have to buy the crop from the farmers at or above the Fair and Remunerative Price (FRP) set by the Union Government or the (higher) State Advised Price (SAP) fixed by the State Government. This pricing mechanism helps sugarcane farmers in getting an assured and generally higher income. The sugar price for consumers, however, is not regulated; the result is a three to five-year production cycle which makes sugar manufacturers vulnerable to industry oscillations. This vulnerability also showed throughout the course of the project; for example in 2017 when a government installed cap on quantity of sugarcane resulted in financial problems at mill level and delayed payment to farmers. Sugar by-products partly aid the sugar mills in diversifying risks and lending stability to their revenues (Solomon 2011).

The tragedy of groundwater depletion.
In addition to stagnating production, price regulations and the unstable sugarcane market, water scarcity is fluctuating and increasing on the long run, affecting sugarcane farming areas as sugarcane is high in irrigated water use. The situation is exacerbated by increased rainfall variability due to climate change which may reduce sugarcane yields (WorldBank 2008). The common method of water delivery in growing sugarcane in southern India is either by flood or furrow irrigation. However, the irrigation efficiency of these

(traditional) methods is only 30-50% so there is considerable wastage of water. In addition, these practices harm soil fertility by leaching soil nutrients. To compensate for the loss of soil nutrients, high levels of unbalanced fertilisers are applied contributing to groundwater pollution (Solidaridad 2014).

2.2 The FDW project

Joining forces to combat production and water shortages.

These challenges at farmer, mill and public-good level ask for an approach where forces are joined and are mutually beneficial to all participating actors. The intervention is sustainable if it strengthens the sugarcane farming business case – at producer and mill level - while at the same time effectively addressing the over-extraction of groundwater. As the mills and extension staff have frequent contact with their farmers, they can play a crucial role in training and convincing farmers to adopt best practices. Given the political difficulties associated with bringing about effective policy reforms to achieve the objective of water conservation, the Government of India's response to the emerging water crisis is focused on technological solutions backed by subsidies to aid and facilitate adoption of water efficient technological solutions by farmers. Local governments can play an important role in transitioning from exploitation to management of the critical groundwater resource. The knowledge institutes VSI and Osmania University are crucial actors in generation and dissemination of knowledge and in influencing political decision-makers. Solidaridad as an NGO can play an important role as multi-stakeholder and independent convenor. The cooperation of these players is organised through a public-private partnership (PPP) with the objective to support, expand and sustain the intervention, long after the FDW project has ended.[1]

Enhance the social, economic and environmental sustainability of sugarcane production.

Achieving the FDW objective requires that less water is extracted in cultivating sugarcane. Therefore, it proposed a large-scale roll-out of irrigation techniques and farming practices that have proven to raise water productivity and farm income of sugarcane farming in smallholder settings in India. See Appendix 10.1 for the visualisation of the intervention logic of the FDW project at baseline.

Capacity building is assumed to result in increased productivity and higher water use efficiency.

The aim of the FDW projects was to train 35,000 smallholder sugarcane farmers in best farming practices by extension workers of three selected mills and selected lead farmers. Improved practices result in increased production and productivity and in higher water use efficiency. Increased income and water use efficiency result in better livelihoods.

Activities included training of trainers, cultivation of demonstration plots, capacity building financial literacy and service delivery.

Several activities were foreseen and implemented over the course of the programme between 2016 and 2021 (FDW progress report 2020, Water use report 2022). A key component was reaching out to farmers. This included the making of a farmers' film, financial literacy training sessions to farmers, a ground water study by Osmania University, the installation of water meters and distribution of Soil Moisture Indicators (SMIs) and outreach to farmers through various village meetings including initiation of water clubs. The crop calendars, drip diaries and diaries for demonstration plots have been printed in local languages and were distributed to the farmers. Another key element of the FDW partnership included support in monitoring water use efficiency. This component was developed and implemented together with E-Leaf. Results are reported in a separate report and not included in the scope of this evaluation. Finally, Solidaridad also invested in the construction of percolation tanks, sunken pits and desilting dams. The structures were commissioned in 2020.

A total of 35,000 farmers have been reached with several activities.

The total number of farmers trained according to project documents are:

- Training of trainers: The project aimed to reach out via the so-called training of trainers (ToT) and training of farmers (ToF) model, lead farmers are defined and trained (ToT) who are responsible for training and coaching of

[1] Bonsucro certification was initially also engaged in the partnership. Bonsucro certification however never materialized given the limited demand for certified sugarcane, the high internal demand for sugarcane en the lack of incentives as perceived at Mill level.

the farmers (ToF) which are organised in groups. Throughout the course of the project 1,300 trainers were trained.
- Demonstration plots: Theory and practice were both foreseen as components of the training (see Table 2.1 for an overview of topics) and 40 on-farm best-practice demonstration/control fields were set up.
- Training through extension services, demonstration plots or farmer field schools. An estimated 35,000 sugarcane farmers were trained through farmer field schools.
- Financial literacy: in addition to GAP training, many farmers were also trained financial literacy with the aim to be able to finance investment in irrigation systems. In total 4,350 farmers were trained in 109 trainings.
- Shade house development. Ten shade houses for seedling production were developed together with the mills in the villages. The seedlings developed at the shade houses were distributed to the farmers.
- Service delivery: An additional number of farmers are trained and equipped to provide trash shredding services, produce and supply sugarcane seedlings, and provide drip irrigation maintenance services. This included entrepreneurial training of 90 farmers on mechanisation.

Table 2.1 Priority areas sugarcane producer trainings on irrigation and water conserving practices

Irrigation systems	Water conserving practices
Surface drip irrigation	Improved fertigation
Sub-surface drip irrigation	Trash mulching and shredding
Drip irrigation with fertigation	Composting and bio-fertiliser
	Intercropping and wide-spacing
	Seedlings and gap filling

Mechanisation and equipment components new elements of the activity plan.

The baseline study done by Wageningen Economic Research pointed out that the shortage of labour was the most pressing issue in all three command areas (and in the entire sugarcane sector in India). These observations led to a revision of the originally planned list of hardware and to a request for changes focusing more on mechanisation. Mechanisation will help in increasing the productivity, while reducing the cost of cultivation. It will also enable the farmer to complete farming operations in time. Depending upon the types of crops grown, soil conditions, local situations and requirements in the location, the project team would encourage farmers to use various farm machinery and implement it on an available government subsidy basis. The government subsidy is available up to 50%.

2.3 Scope of the FDW partnership

The FDW projects is established with 3 mills from 2 leading companies.

The partnership is established with 3 mills from 2 leading companies in India, here referred to as company A and company B. All companies have several mills in operational in various states of Southern India. When the FDW project started in 2016, company A had 5 integrated sugar factories with a crushing capacity of 27,000 tonnes of sugarcane per day (TCD) located in 3 states in southern/western India with a total command area of 2,300 villages with 57,000 sugarcane growers. They selected two mills out of the five to participate in the project: one is located in Karnataka state and the other in Telangana. Company B had four sugar mills in Tamil Nadu and Telangana with a total crushing capacity of 13,500 TCD.

Selection of mills based on production levels, water scarcity and sound monitoring.

The mills differ in production capacity and are located in different states and as such vary in environment, climate, soil condition and water availability, farmer profiles and mill management. The companies based their selection of the participating mills on the following criteria.

1. Farmers in the command area are consistent and loyal in sugarcane production, as such guaranteeing a certain volume of sugarcane to be supplied and showing the relevance of sugarcane as an income source.
2. A command area marked by water scarcity and soil conditions which can be improved by certain good agricultural practices.
3. The mills have an up-to-date management information system in place with registration of all sugarcane farmers in their command area including their basic characteristics; as such they are able to realistic targets, approach and monitor the farmers and providing the methodological basis for a representative sampling.

Mills differ in terms of size, capacity, production but also *soft* parameters.

Table 2.2 below shows the main characteristics of each mill. Mill 1 and 2 are of the same company and Mill 2 and 3 are located in the same state. It is important to consider these differences when interpreting the results (e.g. high differences in temperature of rainfall influences levels of sugarcane production and productivity). In the last 5 years, the amount of annual rainfall in the two states varied (Water use report 2022). In Karnataka, the annual rainfall increased by 20 to 35% every year compared to the previous year between 2016 and 2019 but reduced again to levels comparable to 2018 in 2020. In Telangana, 2017-2018 was the year with the lowest annual rainfall and rainfall strongly increased ever since, with 2020 having close to double the amount of rain compared to 2018. The policy or reputation of a specific mill could also explain differences observed. These 'softer' parameters cannot be captured objectively in figures. However, these issues are topics of discussion with the implementing parties.

Table 2.2 Characteristics of mills at baseline

Parameter	Mill 1	Mill 2	Mill 3
Company	--	--	--
State	South Karnataka	Telangana	Telangana
Command area sugarcane (acres)	24,000	11,500	21,000
Irrigated area all crops (acres)	75,000	250,000	29,966
Number of farmers registered	12,200	3,200	11,130
Capacity (tonnes of sugarcane per day)	6,000	3,500	3,500
Average yield (metric tonnes/acre)	30	28	29
Average annual rainfall (mm)	650-700	600	837
Revenue/acre (INR) plant/ratoon	84,000/72,000	75,000/62,500	Unknown
Costs/acre (INR) plant/ratoon	49,500/33,200	42,360/27,200	Unknown
Gross income/acre (INR) plant & ratoon	36,650	33,970	Unknown

Farming areas differs in terms of soil quality and condition.

There are several contextual and climatological differences between the two states explaining some of the differences noticed between farmers in these states. For example in terms of temperature. The temperature influences the growth of sugarcane: very high temperatures reduce moisture content and thus increase the need for water. Another important difference concerns soil quality and condition. In general soil of Karnataka has a better quality compared to Telangana as it is river basin soil with higher soil nutrients. Appendix 10.2 gives a short narrative of the main mills characteristics relevant to this project.

Challenges in the sugarcane sector affected income of farmers and implementation of activities.

The FWD project faced several challenges throughout the course of the project. First, there was a change in ownership of one of the mills a few years after the start of the project. Second, the sugarcane sector changed over time. For example, in 2017 good rainfall led to an increase in sugarcane cultivation. Because of non-availability of labour gangs to harvest the sugarcane, the crushing period had to be extended. In addition, the central government installed a cap on quantity of sugarcane that could be sold by a sugar company greatly influencing adversely the profitability at mill level. As a consequence, payment to farmers was delayed and all development activities on the ground were deferred. A third challenge related to the purchase of hardware. Because of these challenges the FDW project got extended by two years from 2018 until 2020. However, in 2020 another major challenge was faced with the outbreak of the COVID-19 pandemic. As a result of COVID-19 restrictions various activities such as training activities and the procurement of hardware faced significant delays.

3

Methodology

3 Methodology

3.1 Overall research approach

Data for M&E are collected by several parties.
Monitoring and Evaluation (M&E) is crucial to demonstrate the level of success of the project, i.e. the effectivity of the intervention to bring about large-scale adoption of improved techniques and best practices, and to translate learnings in a road map for sugarcane sustainability. To capture impact at the different levels and objectives and to interpret and validate pathways, M&E was conducted with several parties all with their specialism and expertise focusing on a specific target. Increased margins at mill level, Bonsucro certification[1] and sustainable water use (i.e. lower water foot prints) are not incorporated in this study. These indicators are monitored and evaluated by the other parties involved (i.e. eLEAF, Vasantdada Sugar Institute and Osmania University).

Impact evaluation requires a strong counterfactual design.
The aim of this research project was to show the projects' impact on behavioural changes and the socio-economic development of the supported farmers. This requires a counterfactual: we need to identify what would have happened had the project not (or otherwise) been implemented. A simple comparison between baseline and endline indicators is not enough, because changes might have resulted from other issue than the project (e.g. rainfall, economic development, policy changes etc.).

A quasi-experimental pipeline approach was selected as the key method for evaluating impact.
A strong counterfactual is built on an adequate research design, including issues such as an appropriate sample size (large number of farmers), sampling strategy and data analysis. It is based on an appropriate identification strategy; this means we can only identify impacts (and attribute these to the projects efforts) making correct assumptions on 'what would have happened to the farmers if they would not have participated in the projects'. In the FDW project this is a challenge because they aim is to cover all sugarcane farmers in the command area. For the purpose of impact evaluation we therefore decided in 2016 to exploit the fact that the project is implemented gradually over the years - the so-called 'quasi-experimental pipeline design'. This means we would compare farmers based on their different stages in the project support. This so-called pipeline design can be used to (better) control for unobserved differences, in absence of experimental designs and a control group (Khandker 2010, Stern 2012, DCED 2013)

To gain insight into short and long-term effects data was collected on a yearly basis.
The pipeline method constructs a comparison group from subjects who are eligible for the programme but have not yet received it. Before project implementation Solidaridad and Wageningen Economic Research agreed project implication will be phased in by Taluka (sub-district) spread across different mills. Mills indicated they would implement training and support gradually among the 35,000 targeted beneficiaries (see Section 2.3): one-third in 2016, one-third in 2017 and one-third in 2018. We would than compare the average status of farmers that have already received support with the baseline status of the farmers that have not received it yet. As such, we could compare farmers in different stages in the project intervention. For example, on the assumption that farmers trained will apply the lessons learnt and new methodologies within one year (i.e. at the next planting round) the pipeline approach is suitable for estimating one-year effects.

The key condition to proceed with the pipeline approach - gradual implementation overtime – did not happen.
In practice, project implementation was delayed for several reasons (see Section 2.2). Even though we collected midline data at a later stage (2018 rather than 2017), for two out of three mills less than 10% of farmers indicated to have received some sort of support by 2018 (Plaisier et al., 2019). In addition, many farmers shifted to other crops (mostly paddy) and were not

interviewed at midline (see Section 3.2). At endline everybody indicated to have received some sort of support (see Section 4.4 for more details). This means there is almost no support for the foreseen pipeline approach.

Ability to contribute changes to the programme is very be limited as a result of delay in implementation and shifting away to other crops.
The delay in implementation and shift to other crops has three major implications in terms of impact evaluation. First, while we can still report on changes for the farmers in our sample, we can no longer attribute these changes (robustly) to the programme as we do not possess the right data to do so. Second, we cannot detect any changes for farmers that shifted away from sugarcane production. Third, due to delayed implementation we may not capture changes in productivity as foreseen in the intervention logic.

3.2 Sampling approach

2016 sample size was calculated at 1,018 sugarcane farmers.
We used power calculations to determine the appropriate sample size. The sample size was defined by a random selection of farmers from the mills' management information system whereby all farmers were divided into three groups based on the year they are expected to receive the training. The baseline survey was conducted among 1,018 farmers (3% of the total sugarcane population in the area). The sample size by mill and cohort year is in line with shares in total target group as defined in 2016.

High attrition rates between baseline and midline because famers no longer producing sugarcane were excluded.
In line with the pipeline approach, the aim was to interview the same 1,018 farmers at midline and endline. Attrition in both years however was really high (see Table 3.1). Between baseline and midline the attrition rate was 22% (798 out of 1,018). The main reasons for attrition were the shift to other crops (see midline report for more details). At the endline we decided to keep farmers that shifted away from sugarcane in our sample as the foreseen impact pathways are also relevant for other crops. These farmers are included in the analysis for most indicators related to practices and non-sugarcane income as impact is assumed to materialise despite the crop choice.

High attrition rates at midline and endline because farmers could not be reached.
Another source of attrition became apparent between midline and endline. At endline it was really difficult to identify the farmers from the midline. For mill 1 even impossible given the change in management of that particular mill. Moreover, farmers were unwilling to collaborate because of delay in payments (see Section 2.1). Out of the 568 farmers that were interviewed we could only match 289 farmers (214 for mill 1 and 84 for mill 2).

To maximise the use of data for the purpose of evaluation we matched mill 1 farmers from the endline sample to the midline sample.
For mill 1 data was collected from totally different farmers in 2022. Upon analysing the data many farmers appeared to be different in terms of various socio-demographic and farm characteristics. We used propensity score matching to select the farmers who are most comparable to farmers in the initial sample. This resulted in a well-balanced though strongly reduced the sample (see Appendix 10.4). We also looked into attrition rates of the final sample for mill 2 and mill 3 compared to the baseline and conclude attrition rates are random: composition of the farmers in terms of key household and farm characteristic are similar between baseline and endline (see Appendix 10.3).

Table 3.1 Final sample and attrition rates

Sample sizes per year and mill	2016	2018	2022			Total attrition
	all	all	all	total matched	sugarcane only	
Mill 1*	547	381	251	87	87	84%
Mill 2	142	113	103	84	24	41%
Mill 3	329	304	214	214	197	35%
Total	1018	798	568	385	308	62%

* for mill 1 these are not the same farmers in 2021, but matched using nearest neighbour propensity score matching.

3.3 Household survey

Scope of this study is limited to the producer level.

The evaluation by Wageningen Economic Research focuses on producer level and evaluates the changes and effects at outcome and impact level. The project indicators at producer level are the point of departure in choosing the household survey as the tool for measuring impact. The intervention logic assumes that a certain change at producer, household level, leads to the desired outcomes and impact. A household survey gives the possibility to follow this logic. The intermediate steps are covered by measuring behavioural changes and quantitative data are collected on outcome areas concerning productivity and margins. Although the intervention is based on a clear business case (Catalyst, Business Case 2014) there are various assumptions underneath its logic. Table 3.2 below represents these assumptions per outcome level. The survey and statistical analysis make it possible to test the underlying assumptions and as such the logic itself. Besides, information can be gathered about drivers and possible barriers for (no) adoption.

Table 3.2 Assumptions per result area

Influence	Level	Result	Assumptions
High	Outputs	Training interventions such as information, goods and services delivered to farmers. Lead farmers are defined and trained, farmers are organised in water clubs, demonstration plots are established.	The right message. Project is relevant and people need the intervention, project is the right solution for the defined problems, enough resources are available, legal grounds for operation.
Medium	Immediate outcome	Enhanced knowledge on cultivation practices and irrigation systems due to the training received	Message is accepted. People, staff, timing, message is understandable, message is applicable, people want to be trained and willing to learn. No unforeseen events during intervention.
Low	Intermediate outcome	Changes in agricultural practices, including adoption of mechanisation and irrigation techniques thanks to increased knowledge, awareness and access to finance	Willingness to change, people are willing to take a risk, people are willing to trust the new insights and trainers/mill extension staff and lead farmers Enabling environment allows change.
Lower	Ultimate outcomes	Increased productivity, reduced cost price, increased gross margin, decreased chemical use, increased water efficiency, thanks to adapted agricultural practices.	Proven correct technology, implementation, risks are controlled for, access to finance (loans, subsidy) no constraining unintended outcomes.
Lowest	Impact	Improved livelihoods and food security, sustainable water use, Bonsucro eligible sugarcane	Increased gross income is spent on healthy and nutritious food, water savings in sugarcane production are re-used for vegetable crop production; vegetable and fruit crops are used for intercropping.

Data collection on a wide range of personal, household and farm characteristics.

Data was collected on nine topics (see Table 3.3). The sections gather data on personal and farm characteristics. Other sections include questions that give insight into the challenges sugarcane farmers face and their personal opinion to training needs to test the relevance of the programme from the farmers' perspective. Also various potential drivers (e.g. shortage of water) and barriers (e.g. no financial resources) for adoption are covered to be able to clarify and interpret (differences) in impact. Incentives for farmers to adopt GAPs differ depending on the focus of the GAP programme and the market failure it addresses. But broadly speaking, these incentives can be divided into economic incentives, regulatory/legal incentives and human-capital incentives. The disincentives for farmers to adopt GAPs include economic disincentives, institutional infrastructure constraints and human capital constraints (FAO 2003). The survey collected data on the main known incentives and disincentives to get insights into decision making and the rationale of the sugarcane farmers. Besides, based on literature (FAO 2012, Laeequddin et al., 2012; Kwon & Suh, 2005; Barham et al., 2014; Feder et al., 1985; Borgen, 2004; Murphree, 1993) aspects of trust, willingness to invest and risk perception are taken into account. Previous studies have shown that these behavioural aspects are influencing decision making of an individual farmer in whether to adopt certain practices or not. The intervention logic, the project plan, literature and information gathered during the field visit before the baseline are the basis of the survey and the topics covered. In the midline and end evaluation, additional data was collected about the trainings received, attendance, satisfaction and relevance according to the target group.

Table 3.3 Sections and topics household survey

Section	Details/Main indicators
General characteristics	Gender, age, household size, education
Farm characteristics	Acreage, crop cultivation, plant/ratoon, own/leased land
Sugarcane production characteristics	Production, labour, price received Challenges, farmers organisation
Agricultural practices sugarcane	Seed and seedlings, chemical/biological inputs, trash shredding/burning, row space, intercropping, pest & disease
Irrigation practices	Irrigation systems applied/preferred, source of water, challenges
Inputs for sugarcane production	Types, volumes and costs of inputs used, share of chemical-biological fertiliser
Household income and diversification	Income composition, dependence on sugar, access to capital, subsidy (for irrigation/production)
Livelihoods	Includes progress out of poverty index
Risk, willingness to investment and time horizon	(un)Willingness to invest (in agriculture), risk attitude (aversion/taking), time horizon (short/long term)

The household survey is customised to local context and pilot tested.

A draft survey was developed based on FDWs intervention logic, the local context, and the available literature on impact of comparable interventions. This survey was discussed, refined and customised during a stakeholder meeting in April 2016. Stakeholder present were the partnering mills, the local research partner and visiting sugarcane farmers and the survey was pre-tested in the field. The surveys are translated into the two local languages (Telugu and Kannada) and conducted by the local research partner Q&Q Research Insights Pvt Ltd in the period June till August 2016, September till December 2018 and November 2021 till January 2022.

3.4 Advanced data analysis in four steps

Step 1: Descriptive data to give insight into situation of targeted sugarcane farmers.

A first step in the analysis is to show the current situation of targeted sugarcane farmers as defined by the indicators discussed in the previous section.

Step 2: Showing changes over time and its relation to the overall project.

The second step is to show changes over time for the final sample of farmers, which are either exactly the same farmers among all three rounds of the survey, or farmers with similar characteristics compared to earlier rounds of the survey using propensity score matching. In order to show the relation to the project we use the variable of programme engagement, which includes access to demonstration plots, training and extension services.

Step 3: Statistical analysis to give insight into the determinants of envisioned project outcomes.

In this report we validate whether the envisioned impact pathways are evident. We use regression analyses to link the different stages of the intervention logic: e.g. in estimating the determinants of productivity we include indicators of adoption. We used a standard linear regression model including an interaction term between survey round and programme engagement to show whether early engagement with the project (with early we refer to engagement before the midline analysis) had an effect on different outcomes, by comparing the changes over time between these farmers and the farmers who did not have early engagement. This model controls for key farm(er) characteristics[2], as well as time and mill effects. In case of variables that were only added in later rounds of the survey we use a standard linear regression with survey rounds (as well as farm(er) characteristics mill dummies) to show whether the changes over time were significant after correcting for the beforementioned characteristics. In this case it is not possible to conclude on the effect of the program, as we have no counterfactual.

Step 4: Validation and correct interpretation of results.

Results of the endline will be shared and validated with the project staff, research partner Q&Q, as well as the participating mills. Their reflections, as well as results from the project staff's field visits and other project documentation will be used to finalise the report.

[2] The characteristics we correct for are: which mill a farmer belongs to, whether they produced sugarcane or not (endline only), gender of the respondent, whether the respondent is the household head or not, household size, owned sugarcane area, leased sugarcane area, years of experience in sugarcane, whether the farmer is a member of a farmer group or not as well as the farmers' willingness to invest and risk attitude.

4

Profiles of sugarcane farmers & programme engagement

4 Farmer profiles & programme engagement

This chapter presents the general socio-demographic characteristics of the targeted sugarcane farmers, their views on investment, the farm and production characteristics of their sugarcane cultivation, and the perceived challenges and training needs. It also gives an overview of some key changes over time.

4.1 Socio-demographic characteristics

Sugarcane farmers are predominantly male, received education and have 6 people in their households.

Farmers are predominantly male (90%) and head of the household (88%), households consist of 5.7 persons on average. Eighty-four per cent have received some kind of education. The farmers are on average quite experienced with 14 years of sugarcane cultivation. In terms of motivation, 57% of the farmers producing sugarcane, indicate being sugarcane farmers because their parents were.

Some farmers (temporarily) stopped growing sugarcane; mostly shifting to paddy.

Many farmers shifted away from sugarcane in the course of the programme (also see Section 3.2). Almost 19% of farmers in our final sample did not produce sugarcane in 2020/2021 (out of which the majority belong to mill 2). The key reasons for no longer producing sugarcane are: no availability of labour (mentioned by 86%) and payment delays or inability to sell all sugarcane to the mill (75%). Some farmers also mentioned that sugarcane is no longer profitable (32%) or that the costs of cultivation increased (24%). The majority of these farmers (66%) switched to rice/paddy. Forty-two per cent of these farmers indicated that they surely intend to grow sugarcane again in the next season.

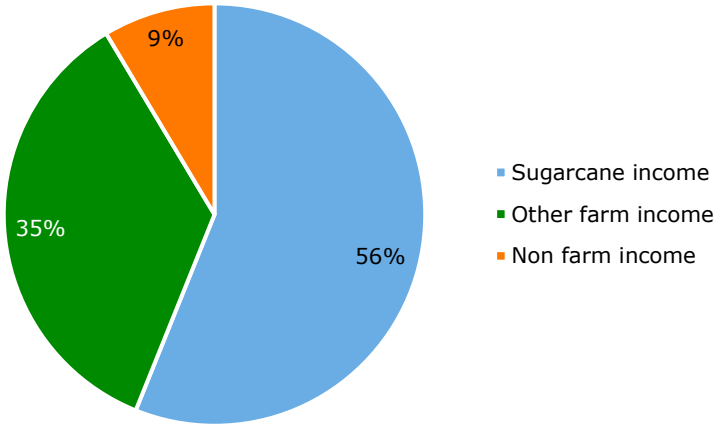

Figure 4.1 Share of income from different sources at endline (n=385)

Share of income generated from sugarcane decreased since 2016.

The economic relevance of sugarcane for the farmers has decreased since 2016. In 2016, we found that for almost all farmers (97%), sugarcane accounted for 75% or more of their income. Two years later, this percentage dropped to 77%, and another 3 years later it had dropped to 46%. At the endline sugarcane contributed to 56% of the households' total income. See Figure 4.1 for an overview of the different sources of income of farmers at the time of the endline. For more information on changes in incomes see Chapter 7. From the farmer perspective it can be a positive trend if they are able to diversify their income sources and spread their risk. Solidaridad confirmed an overall trend in the areas of operation where farmers aim to have various income sources.

4.2 Willingness to invest and risk attitude

Adoption of new or improved agricultural practices is influenced by farmer attitudes towards investment and risk.

Sugarcane farmers' view in terms of investment, risk, time horizon (short or long) and trust can influence adoption of certain agricultural practices and techniques (Barham et al., 2014; Laeequddin et al., 2012; Kwon & Suh, 2005; Juma, C. 2012; Nato et al., 2016). Willingness to invest is important in deciding whether to adopt a certain practice where investment is needed, i.e. it can be a driver for (willingness) but also a constraint to (unwillingness) changing behaviour and investing in new agricultural techniques.

Farmers have become more risk averse in recent years.

The statement *'I will not make any investment because you never know what will happen'* is a means of illustrating the attitude of farmers towards investment. In 2016, 69% of the farmers (strongly) agreed to this statement. indicating that the majority of farmers was not very eager to make an investment. This increased to 75% at the time of the midline and to 88% at the endline. In the last 3 years, we especially see a sharp increase in farmers strongly agreeing to the statement. This could indicate that farmers have become even more hesitant to invest which can negatively influence uptake and investments in irrigation. The uncertainties farmers have faced as a result of COVID-19 might be an explanatory factor for this development.

Farmers became more sceptical towards investing in agriculture.

The statement *'Investing in agriculture or new agricultural practices is very risky; I rather do not do it'* is an indicator to measure risk attitude and perception. The farmers that (strongly) agree increased from 48% at baseline to 74% at the midline and 87% at the endline. Farmers thus seem increasingly less likely to take a risk when investing in agriculture. This outcome could negatively influence uptake as well.

Farmers generally trust in the advice of the mill since 2016.

The mills are key partners in the FDW project: they provided training on preferred practices and (irrigation) techniques and coach in cultivation. Therefore, trust in the mills was an important enabling (or constraining) condition for uptake. To measure trust with regards to the mills, we use the statement *'I am only willing to invest in new agricultural practices after I find the mill technology reliable'*. At the baseline, 72% of farmers (strongly) agreed with this statement, and during the midline this had increased to 90%, and then stayed relatively stable at 88% at the endline. Especially farmers at mill 2 show an increase in trust. The change between baseline and midline was a positive change as farmers seem to have more trust in the mill which could positively influence uptake and behavioural change.

4.3 Farm and production characteristics

Farmers producing sugarcane on average cultivate 3.9 acres of sugarcane area: 3.7 acres owned and 0.2 acres leased.

Almost all farmers own land with an average of 6.4 acres but with large differences between small and big land owners. Out of this 6.4 acres, 3.7 is dedicated to the production of sugarcane and 2.7 acres to other crops. In terms of leased land farmers own 0.2 acres for sugarcane production and 0.3 acres for the production of other crops. The leased land for sugarcane is a significant decrease compared to the midline, when farmers had 0.6 acres of leased land for sugarcane. The decrease in rented land might have positive effects on investments in irrigation techniques and systems, as many studies indicate that adoption of good agricultural practices and changing farming behaviour can be a constraint when it concerns leased/rented land.

The use of ratoon crops increased mainly between 2016 and 2018.

Cultivating sugarcane by ratoon crops can increase up to 4 or 5 harvests but good quality seeds and agricultural practices are required. Ratoon crops are more cost-efficient but there is a trade-off at a certain time when production decreases and plants might become less resistant to pest and diseases or drought. The majority of farmers cultivate only ratoon crops (89%) at the endline. At the midline this was 86%, which was a significant increase compared to the baseline when it was 76%.

Farmers have become more engaged in farmer groups since the midline.

It is uncommon in all command areas for sugarcane farmers to be organised in a farmer group, although this did significantly increase over time. On average 25% of the farmers is member of a farmer group, compared to 14% at the

midline and 16% at the baseline (see Figure 4.2). Working via farmer groups can be very effective and efficient in reaching out to thousands of farmers. From the farmer perspective, being a member of a well-functioning and organised farmer group could also stimulate adoption of practices as there is a platform of mutual learning and sharing.

Farmers less often take out loans or save money.
In terms of other financial activities, farmers also seem less able to invest. The share of farmers who took out a loan in the last year or who are able to maintain savings both significantly decreased since the midline evaluation in 2016 (see Figure 4.2). The majority of the farmers who did take out loans between 2016 and 2021 took loans provided by the bank. Twenty-eight per cent of the farmers indicated to have followed a training on financial literacy over the past 2-3 years at the time of the midline, and 3% indicated the same thing at the time of the endline. Of the farmers who took a loan/credit in the past year and who had training on financial literacy over the past 2-3 years (n=99 for midline, n=6 for endline): 61% was able to access the loan/credit because of the training at the midline, and 67% at the endline.

Barely any farmers have received a subsidy since the midline.
The Indian government had been providing subsidies to farmers in various agricultural and development programmes.[3] During the midline evaluation we found that subsidies were strong drivers for farmers to invest in drip irrigation. At the time of the endline only 2% of the farmers indicated having received a subsidy (see Figure 4.2). Yet, almost all farmers have received a government subsidy at some point during the program, out of which the focus was on fertiliser and electricity in earlier years (around the baseline) and on surface drip irrigation and electricity in later years (around the midline).

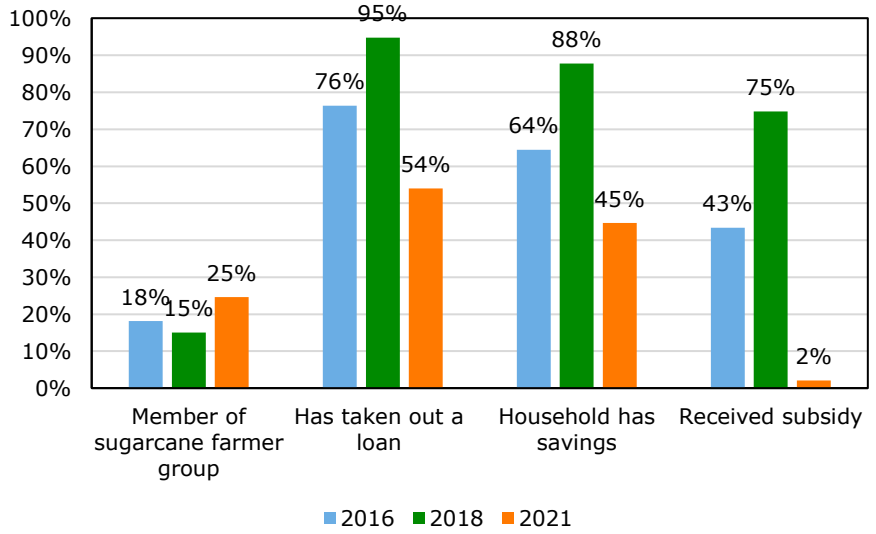

Figure 4.2 Share farmers being members of sugarcane groups, who took out loans, have savings or received subsidies (n=385)

4.4 Programme engagement

At endline all farmers indicate to have been engaged with the programme in some way; mostly though demo plots or lead farmers.
Overall, all farmers indicate they received some kind of support[4] from organisations or interventions similar to Solidaridad and the FDW programme in sugarcane cultivation. According to the survey, demonstration plots are most common. We asked farmers whether they had received any training, and if so, what type, when and from what source (see Figure 4.3). The majority of trainings have been given by either the extension worker of the mill or the lead farmer. Three out of five farmers indicate to have had access to a demonstration plot. Forty per cent have received assistance from a lead farmer; this is lower than at midline, which may indicate that farmers may

[3] For example the government launched in 2005-06 and subsequently upscaled during the Eleventh Five Year Plan (2007-12) the 'National Mission on Micro Irrigation (NMMI)' as a Centrally Sponsored Scheme (CSS).

[4] This does not include governmental subsidies.

have forgotten about the assistance. Only a small groups of farmers indicates to have received support from extension or training on GAP. We cross check these data with data provided by the mills. During the midline 14% of farmers indicated to also receive other support; at endline this reduced to 3%. In terms of GAP training, the mills indicate much higher portion of farmers should have received 'training' (between 28% and 72%) indicate higher numbers (source: monitoring data Solidaridad). Given the different – but comparable - approaches to training it may be challenging to distinguish different types of support.

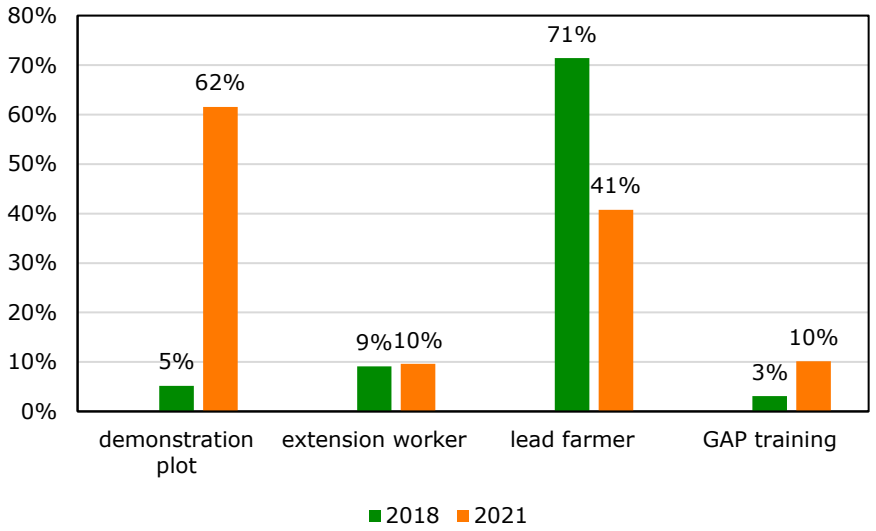

Figure 4.3 Self-reported engagement with the programme (n=385)

Drip irrigation and mechanisation are the most common topics that farmers remember from training.

To gain more insight in the reach and potential impact of the programme we asked farmers to list the topics they have received programme intervention on in the past year (see Figure 4.4). We also asked them whether they applied the obtained knowledge on their field. About 53% of farmers remember being informed about drip irrigation, and 49% applies it. Another 44% of farmers remember being informed about financial management, and 42% applies it on their own field. Another 30% of farmers remember being informed on mechanisation, 18% uses this. This aligns with the key focus areas of the FDW project (see Section 2.2).

Use of wider row spacing is also common despite the fact that only 17% received training.

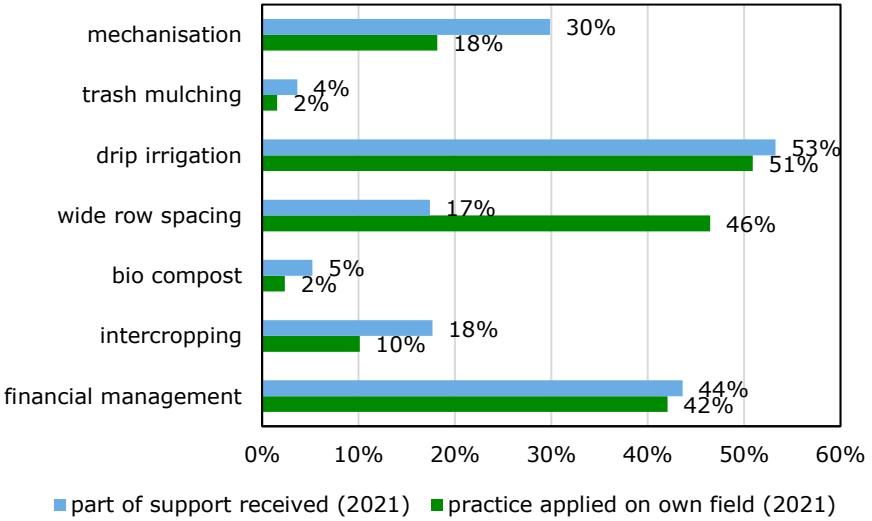

Figure 4.4 Training topics farmers can recall in 2021

Fewer farmers interested in receiving training on sugarcane cultivation, but remains high at endline.

Training needs are more satisfied at endline than at midline, especially for mechanisation, irrigation practices and GAP. (see Figure 4.5). Of all farmers in our sample 27% of the farmers indicate not being interested in additional training, which was 13% at the time of the midline. Reasons for not wanting any more training are: 62% does not have time, 19% already received enough training, 14% does not have the resources to implement the practices and 5% is not satisfied with the quality of the training. In terms of future training,

training on good agricultural practices remains the topic farmers are most interested in.

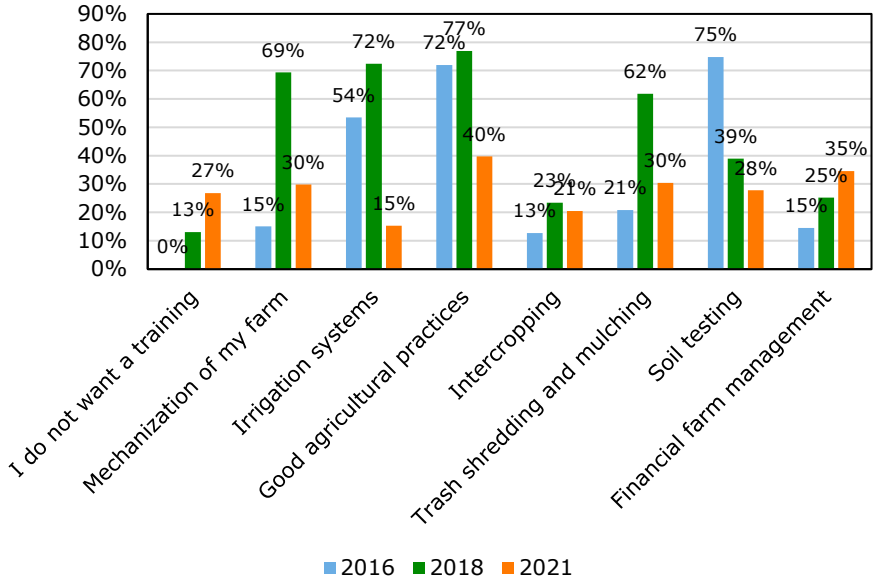

Figure 4.5 Training interests of farmers (n=385)

4.5 Challenges in sugarcane farming

Unavailability of labour is the main challenge according to farmers.

Almost all farmers (97%) agree that unavailability of labour is a serious challenge, which was already the case in earlier rounds of the study as well (see Figure 4.6). The government has been promoting self-employment and rural employment and the internal migration has slowed down, especially rural to urban migration. The bulk of rural poor are migrating to urban areas. The face of agriculture is changing and to address the same there is a need to provide emphasis on mechanisation and agri-entrepreneur services. The project's components on mechanisation and entrepreneurship addresses this to further enhance the provision and availability of mechanised farming to the farmers.

Delays in getting payments from the mill and transportation issues for the produce to the mills are other major issues.

Answer options which were not included in the previous rounds of the survey, but which have become major new issues are delays in getting payment from the mill (reported as a major issue by 92% of the farmers at the endline) and transportation issues to the mill (84%). We further explain and contextualise these challenges in Chapter 5.

The unavailability of water was another major issue previously, but is not perceived as such anymore.

The second biggest challenge faced by farmers at the time of the baseline and midline was the unavailability of water for irrigation, which is also the main focus point of the programme. At the time of the endline however, only 7% of the farmers still reported it as such. Based on interviews with project staff and project document it became clear this is strongly related to the fact that rainfall was higher between midline and endline. We further explain and contextualise these challenges in Chapter 5. Also the lack of facilities for soil testing is reported as a major issue much less frequently compared to earlier rounds of the survey.

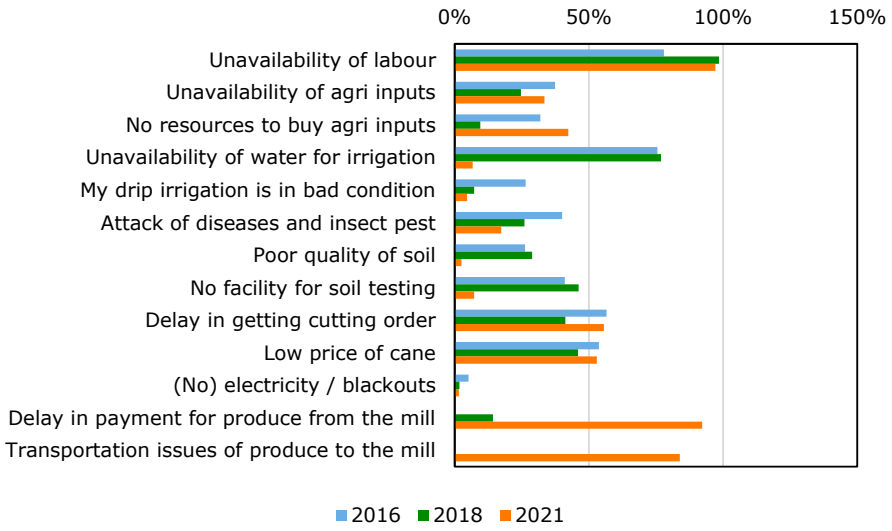

Figure 4.6 Challenges

4.6 Future perspectives of farmers

Almost all famers who currently produce sugarcane plan on continuing to do so in the future.

During the endline evaluation we also asked farmers what their perspectives are on what they will be doing in the future. When asked specifically about their plans regarding sugarcane production almost all farmers that produced sugarcane at the time of the endline (99%) indicated that they plan to continue with sugarcane farming (see Figure 4.7).

Sugarcane farming is not always done by choice, yet farmers are proud to be a farmer.

We also proposed a couple of statements to farmers to see how they feel about the future of farming. These statements show that the decision to remain in farming is not always by 'choice': 44% agrees with the statement 'there is no hope for poor farmers like us to improve' and 48% of farmer prefers if their children do not end up working as farmers. At the same time, many farmers are also positive and see farming as a good investment (67%) and are proud of their profession as farmers (81%) (see Figure 4.7 for the responses to all of the statements asked).

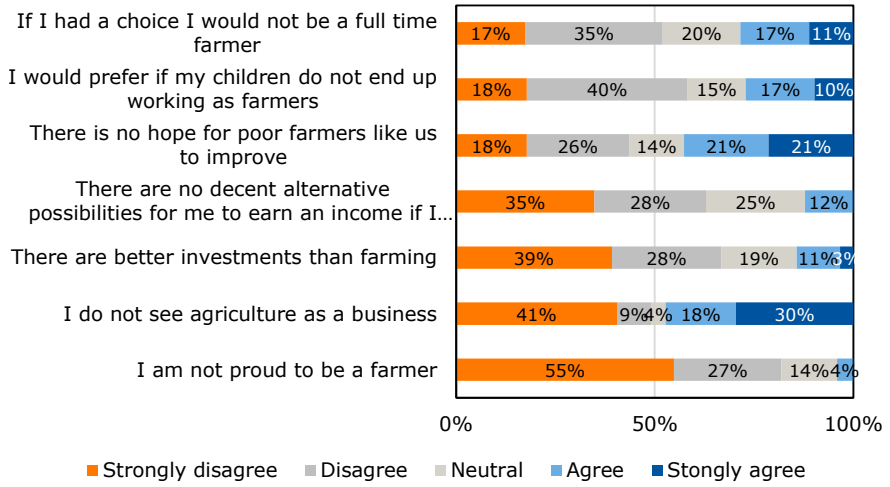

Figure 4.7 Future plans with regards to sugarcane farming of farmers producing sugarcane at the time of the endline (n=385)

5

Agricultural practices

5 Improved agricultural practices and irrigation techniques

Improved agricultural practices are key to FDW's theory of change.
It is assumed good agricultural practices lead to higher production levels, higher productivity, higher farm incomes from sugarcane and increase water efficiency. While this assumption is based on solid experimental proof from an agro-economic point of view (FDW Project Plan Solidaridad 2014 and Catalyst Business Case Report 2014), it is not yet certain this will hold for all farmers targeted by FDW. This chapter presents the agricultural practices and irrigation techniques in 2016, 2018 and 2021 for the sample of 385 farmers. In Chapters 6 and 7 the next steps in the theory of change - productivity and farm income - are elaborated upon.

5.1 Input Use

More farmers started using seed nurseries but two third of farmers still only use less efficient traditional sets.
A key element of the programme was the development of shade houses by Solidaridad and sugar mills in the villages. The use of seedlings saves one month of irrigation while also increasing productivity by minimising plant mortality, and it also saves seed usage (FDW Project plan Solidaridad 2014). Seedlings from seed nurseries were hardly used at the time of the baseline (by 1% of the farmers only). In 2021, farmers producing sugarcane still mostly use traditional setts, but more also farmers started using seed nurseries over time (see Figure 5.1). Farmers who were engaged with the programme early on (before the midline) were not more likely to use seed nurseries. The increase in adoption of seed nurseries over time in mill 3 is significantly stronger than in mill 1. Despite improvements, there is still high potential to introduce the farmers to this practice as only one third of farmers uses it in 2021.

Use of shade houses did not result in an overall increase in use of other variety in planting material.
Another benefit of the shade houses is that farmers are introduced to new varieties of seeds. Anecdotal evidence shows this to be true on occasion (water use report 2022), but this is not yet confirmed at scale by data from our sample. The set variety is in 59% of the cases CO86032, which means that the set variety did not change since the midline, where 60% of the final sample used CO86032. Still not all farmers know what sets they use exactly, as 27% indicates using whatever the mill provided them with at the time of the endline (31% at the midline).

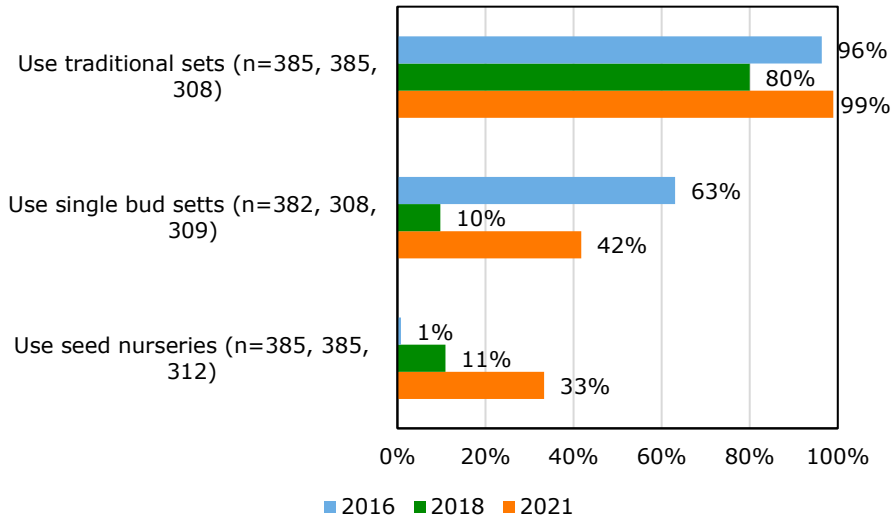

Figure 5.1 Planting material

Input use: percentage of farmers using organic fertilisers decreased

Another key element of the programme relates to promotion of organic fertilisers rather than chemical fertilisers. After an initial increase in organic fertilisers (almost all manure), farmers started using fewer organic fertilisers after 2018. The strong initial increase is also linked to the fact that mills provided organic fertilisers in early stages of the project (based on interviews). Having no access (55%) and no resources (28%) are two common reasons for not using it (anymore). While organic fertiliser was stimulated by the programme, access therefore has a strong influence in its success. Yet 39% of the farmers who indicate not using organic fertilisers indicate that they prefer chemical fertilisers instead, so perhaps some farmers were not as satisfied with the use of organic fertilisers after having tried them. There is no difference between farmers who were engaged with the programme at the time of the midline survey and those who were not. Farmers who did not produce sugarcane at the endline were less likely to use organic fertilisers. The costs associated with the use of organic fertilisers have strongly and significantly increased between the midline and the endline evaluation (see Figure 5.3), which might also explain why people state having no access to or resources for these inputs.

Percentage of farmers using chemical fertilisers remained high and increased for pesticide use.

Figure 5.2 shows the percentage of farmer applying each type of input. Most farmers (98%) still apply chemical fertilisers, although the costs of chemical fertiliser use have increased significantly between 2018 and 2021. However, they do apply it less frequently and (no longer) following guidelines provided by government or mill (see Appendix 10.6). At baseline 24% of farmers followed these guidelines, in the midline 59% and at endline only 1%. This is again linked to lack of resources and availability. In terms of pesticide use, we see, farmers started using more pesticides again by 2021 - after an initial decline between 2016 and 2018 (all chemical). We find that farmers who were engaged with the programme at an early stage were significantly more likely to use pesticides at the time of the midline survey. Farmers who are not producing sugarcane at the endline use significantly more pesticides.

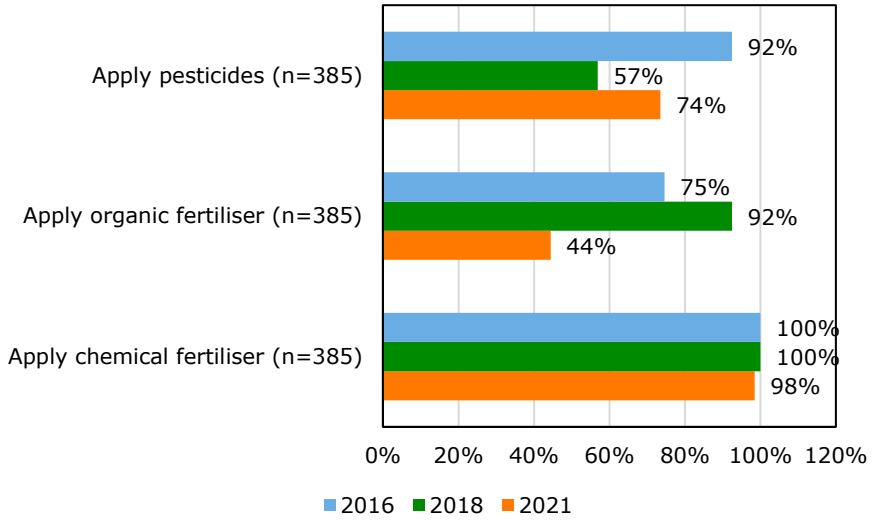

Figure 5.2 Input use

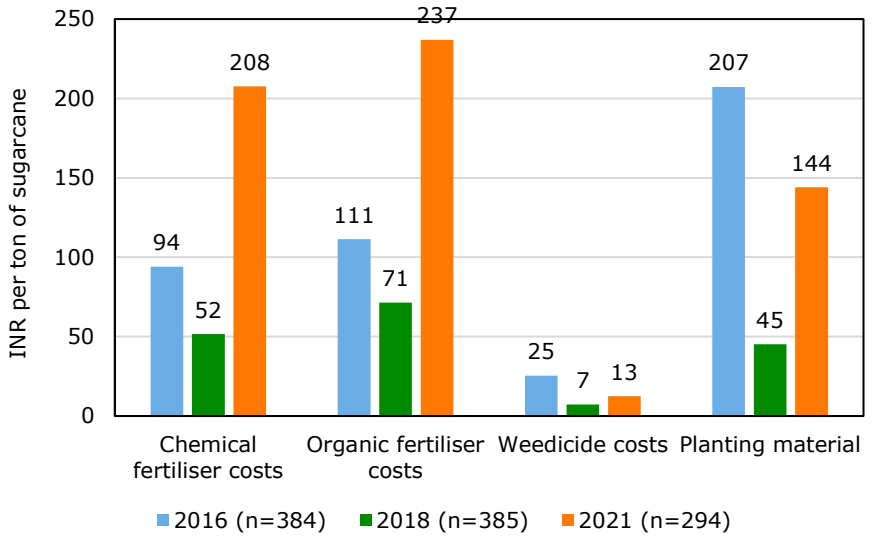

Figure 5.3 Input costs per tonne of sugarcane

5.2 Row spacing, intercropping and trash shredding

Application of correct row-to-row spacing decreased since the midline.
Correct row-to-row spacing is an important agricultural practice and related to higher water efficiency and productivity (water use report 2022). The standard for a good agricultural practice according to Solidaridad is 3 feet with regular irrigation and 4 or more with drip irrigation. At the baseline 55% of farmers applied right row-to-row spacing, and at the time of the midline this share increased to 86%. There is no difference between farmer who were engaged with the programme at an early stage. After the midline evaluation a share of these farmers seemed to have stopped using correct row-to-row spacing, with 64% applying correct row-to-row spacing. It is unclear why we observe this decrease.

Steep increase in the share of farmers applying intercropping; but still small in numbers (14%).
Intercropping is an important element in the training on good agricultural practices, but farmers originally did not seem very interested to be trained in intercropping, and they were barely applying it at all during the baseline (2%) or the midline evaluation (1%). However, at the endline 14% of the farmers was already applying intercropping. The reason why this is not higher is probably related to the need for labour in intercropping as harvesting is done manual (water use report 2022, interview). Given labour shortages in some of the regions intercropping is not a possibility. We also saw increases in general in the share of farmers growing other crops. This might indicate that the decision to start intercropping more often might also be a result of general uncertainties in the sugarcane sector. There is no difference between farmers who were engaged with the programme at an early stage.

Burning of trash getting more common; even though trash shredders were temporarily more available.
Burning the trash after the harvest has negative implication for the organic matter content and water conservation in the soil.[5] The burning of land and trash after harvest is, however, done by even more farmers compared to at the baseline. At this time, 46% was engaged in trash burning, compared to 69% at the midline and 70% at the endline. There is no difference between farmers who were engaged in programme early on and those who were not. We do find however that farmers who do not grow sugarcane are less likely to burn trash, which could be a result of their crop of choice producing less trash. The increase of trash burning in between baseline and midline was remarkable, as farmers also indicated sharp increases in access to trash shredders during the midline (from 1 to 23%). However, by the time of the endline evaluation the access to trash shredders had gone back to 3%.

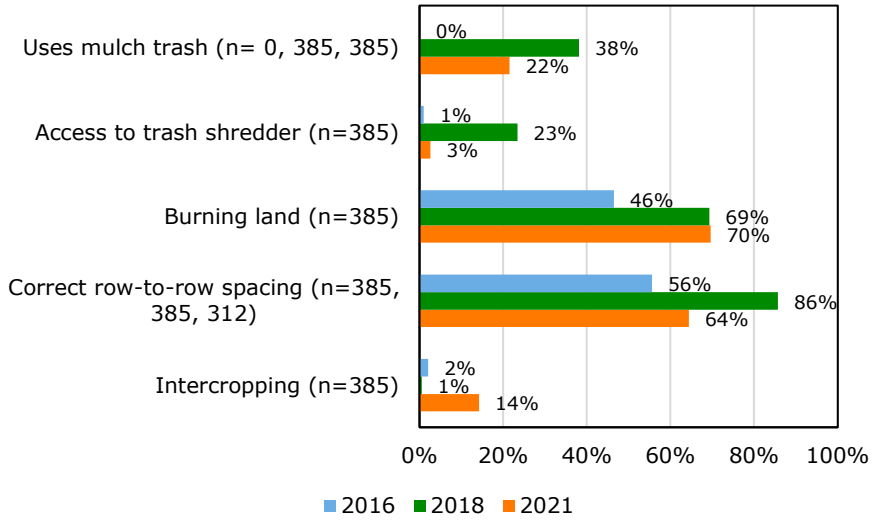

Figure 5.4 Application of good agricultural practices

The practice of trash mulching declined.
An alternative to trash burning is trash mulching. Trash mulching has benefits in terms of waste management, prevention of evaporation of water and weed growth as well as increasing the nutrient content of the soil (water use report 2022). The share of people who indicate using a mulch trash declined from

[5] FDW Project Plan Solidaridad, 2014.

38% at the midline to 22% at the endline. The main reason why people do not use a mulch trash remains that there is no trash shredder in the neighbourhood (42% at the endline, 67% at the midline), but farmers increasingly answer that it is because they do not know how to use them (2% at the midline and 36% at the endline). The decrease in trash mulching could also be explained by the (perceived) risk of fire due to trash mulch as dried matter in case of fire (water use report 2022).

Farmers that are more likely to invest less often burn trash.

Aside from the command area and training, farm or household characteristics may also determine whether or not farmers adopt certain agricultural practices. To investigate this, we run a regression analysis to explain use of burning (yes or no) by the farm and household characteristics. There are a few characteristics influencing the habit of burning. First, we find that if farmers are more willing to invest, they are less likely to burn trash. This make senses as costs are involved in shredding trash instead of burning, so an investment should be made. We also find that farmers who only use plant crops, those who are members of a farmer group, those who earn at least 75% of their income from sugarcane, as well as heads of the household each are less likely to burn trash. However, these effects disappear after correcting for the mills, showing that these indicators are also strongly related to which mill a farmer is associated with.

5.3 Irrigation systems

Irrigation techniques influence water use efficiency and productivity.

Improving irrigation systems is another key concept in the intervention logic which should in the first-place lead to increased water efficiency, but also to higher production levels as leaching of soil nutrients could be prevented with a well applied drip irrigation system. Four types of irrigation systems are applied in the command areas of the mills. Furrow irrigation is the most applied system, which is also the most common method of water delivery in sugarcane growing in India (FDW Project Plan Solidaridad 2014) but has low water efficiency and harms soil in the long run by leaching soil nutrients. Surface-drip irrigation is more water efficient compared to furrow as it eliminates conveyance losses and percolation losses and can boost the yield by more frequent water delivery. Sub-surface drip irrigation is installed in the root zone and drip irrigation with fertigation combines drip irrigation with fertiliser.

Farmers indicate access to water improved; strongly related to increase in rainfall.

We asked the farmers their perception on access to water compared to three years ago. Figure 5.5 shows the statements share of farmers who agreed. The majority of the farmers reported improved access to water, for various reasons: 24% because of access to a canal, 21% because of improved soil conservation efforts and 17% because of other reasons. Only 2% of the farmers reported a deterioration of water availability, which is a strong improvement compared to the midline, where the 69% of the farmers reported a decrease in water availability. In terms of water quality, 52% of the farmers indicated that the quality of their water improved at the time of the endline whereas 46% stated it remained the same. Only 1% claimed the quality of their water declined. The reported change in water availability is strongly related to the mills, with 94% of the farmers associated with the mill in Karnataka indicating no change in rainfall in the last three years and the vast majority of the farmers associated with the mills in Telangana indicating improvements in water availability in the last three years. This strongly matches the changes in rainfall reported in Chapter 2, indicating that water availability most likely largely improved due to changes in rainfall.

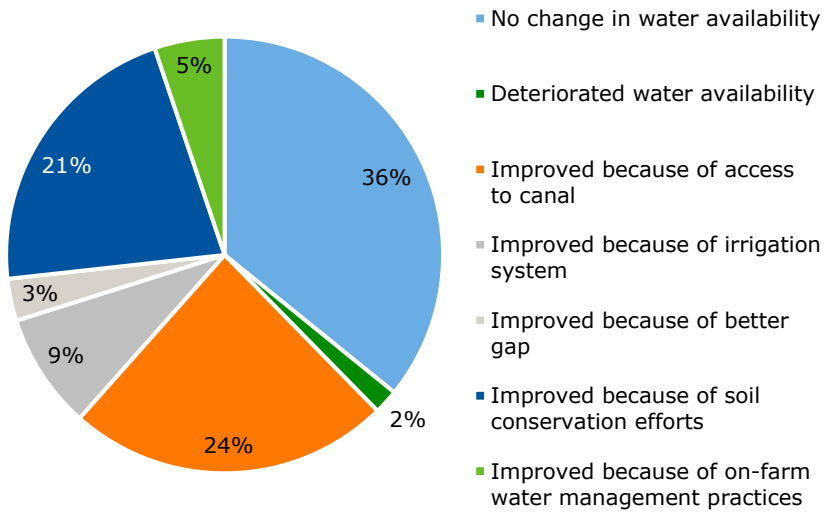

Figure 5.5 Change in access to water at endline compared to 3 years ago

After an initial strong increase in drip irrigation between 2016 and 2018, a decrease in observed between 2018 and 2021.

Figure 5.6 provides an overview of the irrigation systems used by the farmers. Overall, 45% of the farmers used any form of drip irrigation at the time of the baseline compared to 76% at the midline and 57% at the endline. The increase between the baseline and the endline is significant. The largest increase appears to have taken place for surface drip irrigation. Surface drip and drip combined with fertigation are most common in 2021. There is no difference between farmers who were engaged with the programme at an early stage and those who were not. Farmers who do not produce sugarcane at the time of the endline are less likely to be using drip irrigation. This indicates that they either stopped using drip irrigation, or that the farmers who were not yet using drip irrigation were the ones for which it was easier to switch to the production of other crops.

The main source of finance – governance subsidy – is insufficient to overcome lack of resources in increasing or even maintaining level of drip irrigation.

Ninety per cent of the farmers who are currently applying drip irrigation started using it since 2018. Subsidies are the main financial source that finance drip irrigation. The way these subsidies are administered differs by region and influences the ease and risk farmers perceive in applying investing in drip irrigation (see midline report). The results show that this state policy has huge implications for adoption of drip irrigation technology. However, it also shows that subsidies alone are not sufficient given that the share of farmers that use some sort of drip irrigation declined again after the midline. The decrease in use of drip irrigation between midline and endline is partially explained by increased rainfall (less perceived need), shortage of labour in COVID-19 times and overall lack of resources.

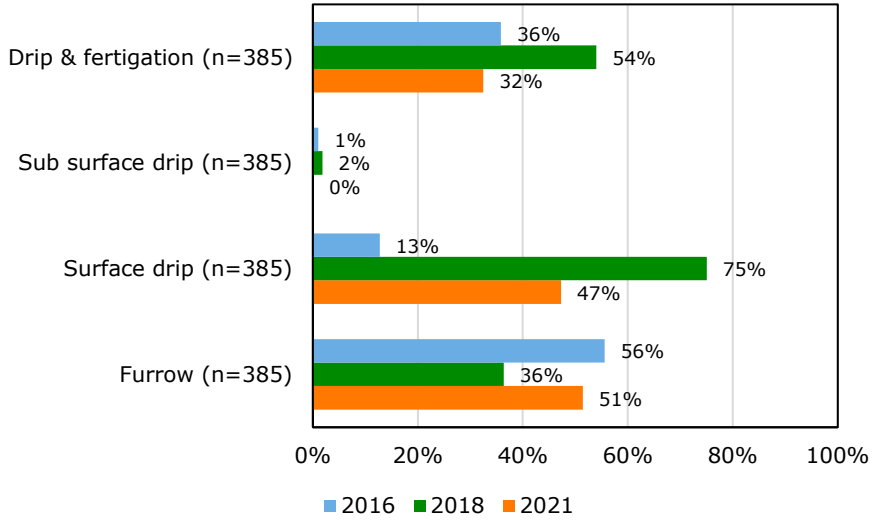

Figure 5.6 Use of irrigation techniques

Despite increasing awareness on the need for maintenance, farmers indicate the condition of drip irrigation systems strongly declined.
Not only did the share of farmers using drip irrigation decline from midline to baseline, the condition of the drip irrigation systems of the farmers that use it, also declined. Whereas only 5% of the farmers indicated that their drip irrigation was in bad condition at the time of the baseline, and 8% at the time of the midline, 47% of the farmers at the endline indicated a poor condition of their drip irrigation system. Some farmers indicate that they now had to purchase the maintenance liquid as it was no longer provided by the mills (water use report 2022). At the same time, farmers have become more aware that they need to maintain their drip irrigation system as the share of farmers who do not maintain it dropped from 11% at the baseline, to 3% at the midline and 1% at the endline. A shift also took place in terms of how this maintenance is done, with 78% of the farmers indicating hiring labour for the maintenance at the baseline to 52% at the midline and 17% at the endline. This might be related to the large lack of labour or the lack of financial resources.

The vast majority of farmers using drip irrigation indicate that the drip jams frequently and that the wires break easily.
When asked to list the key challenges regarding their irrigation system, 83% of the farmers using drip irrigation indicate that the drip jams frequently and 75% reports that the wires break easily. Furthermore, 48% reports that the maintenance of the drip irrigation system is too labour intensive, which might explain the deteriorating condition of the drip irrigation systems. While maintenance kits were purchased as part of the project (FDW report 2020), this did not reach all farmers. The satisfaction with current irrigation system seems to hamper uptake of drip irrigation. All except one of the farmers in our final study sample indicate using their preferred irrigation method, which indicates that they are unlikely to change practices. At the time of the midline this share was also already very high (96%), whereas it was much lower during the baseline (32%).

Education, sugarcane importance, sugarcane area and membership of a farmer group are positively related to adoption of drip irrigation.
Farm or household characteristics may also determine whether or not farmers adopt drip irrigation. Education level, size of land owned used for sugarcane cultivation, and membership in a sugarcane farmer group all increase the likelihood farmers adopt drip irrigation. The education level may increase the awareness of farmers that drip irrigation is necessary in the long term; or may facilitate farmers to implement it. The more land a farmer owns, the higher the probability that the farmer uses drip irrigation. This is in line with the expectation that less land can be a constraint in the application of good agricultural practices or irrigation. The same holds for farmers for whom sugarcane contributes to at least 75% of their income. Finally, farmers that find investing in agriculture less risky also are more likely to invest in drip irrigation, although this result does not hold after correcting for differences between mills.

5.4 Mechanisation

Farmers mechanised fewer activities compared to the midline.
A component of the FDW programme that was added after the start of the programme is entrepreneur training about mechanisation and the provision of equipment. At the time of the midline, 96% of the farmers indicated to have at least one production activity mechanised. By the time of the endline evaluation this dropped to 64%, which is statistically significant after controlling for farm(er) characteristics. The most important reason mentioned by farmers for not mechanising any of their activities is that it is too expensive (mentioned by 95%).

Land preparation and plant protection are most often mechanised.
Figure 5.7 shows the share of farmers that mechanised each activity for each of the activities in terms of mechanisation. At the time of the endline, mechanisation was most often used for land preparation (53% of the farmers) and for plant protection (53%). The strongest declines in mechanisation took place for harvesting, which decreased from 91% at the midline to 13% at the endline and for inter cultivation equipment, which declined from 90% to 40%. As a part of the project, water meters have been introduced to farmers with which they can measure the water content of their soils. After the midline evaluation, the share of farmers using them dropped from 60 to 33%, however. Slight increases in mechanisation were seen for trash incorporators (from 19 to 32%) sugarcane planting (from 4 to 13%) and disc off barrowers (from 1 to 6%). The majority of farmers rents equipment needed. Only for water meters 82% indicates having their own equipment. During one of the

interviews it was mentioned that farm mechanisation would be more successful if farm conditions were also maintained (such as removal of stones from the field).

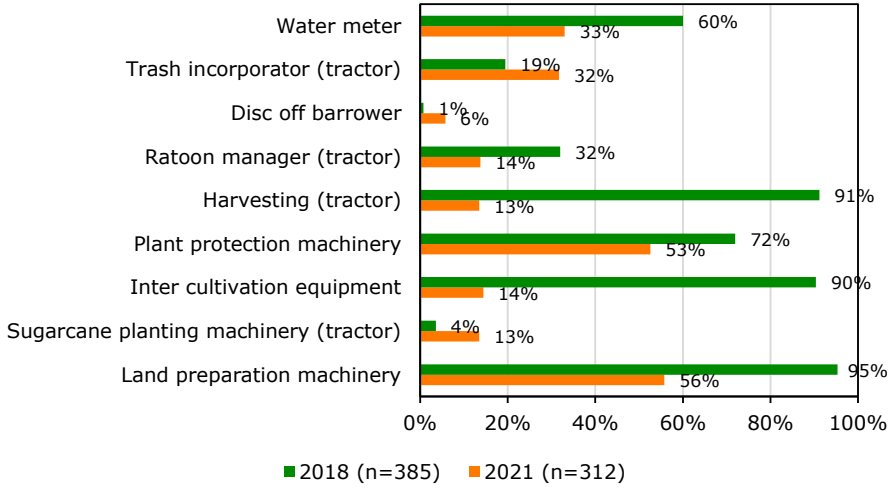

Figure 5.7 Use of mechanisation on different activities

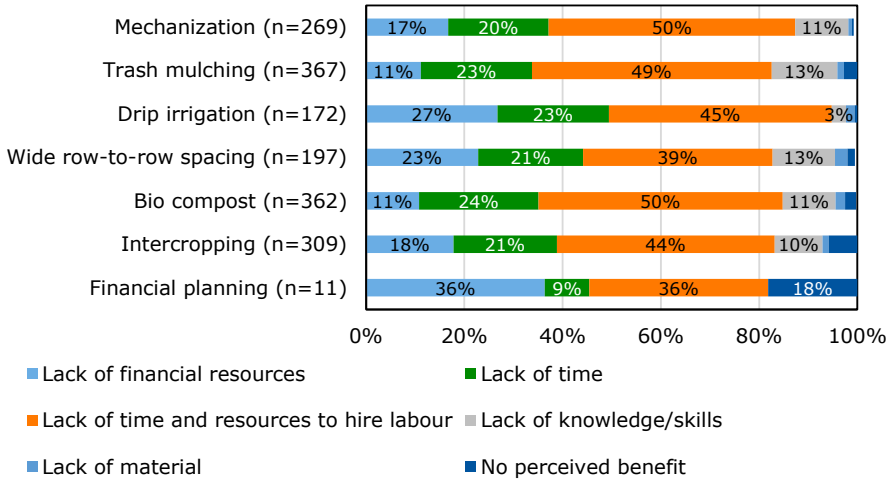

Figure 5.8 Reasons for not applying practices (2021)

5.5 Reasons for not applying practices

Most common reasons for not applying practices at endline are lack of time and resources to hire labour.

We asked farmers whether they are applying specific practices that they learnt about during any assistance, training or demonstration received. For the farmers indicating that they were not applying a specific practice we also asked why they were not applying it even though they remember it. Overall, the reasons for not applying promoted agricultural practices are fairly consistent among the different practices: a lack of time and resources to hire labour are the most important reasons why farmers do not apply the promoted practices (see Figure 5.8).

6

Productivity and costs of sugarcane

6 Productivity and production costs of sugarcane

Improved agricultural practices are to reduce costs and water use and increase quality and productivity.

Following the intervention logic, improved agricultural practices, input use and irrigation systems are the immediate outcomes of the intervention which would lead to the intermediate outcomes of higher crop productivity, lower production cost, lower water use and higher quality and price for the crops. This chapter examines these intermediate outcomes. Another key outcome area of the project has been to reduce water use efficiency. Measuring effects in terms of water use efficiency was not in the scope of this project but monitored by E-LEAF (see water use report 2022).

6.1 Sugarcane productivity

Productivity increased initially but decreased between the midline and the endline.

The productivity per acre is based on owned and leased sugarcane area. In 2016 productivity was 36.6 tonnes per acre, it increased to 37.9 tonnes in 2018 but decreased 33.8 tonnes per acre in 2021 (see Figure 6.1). More specifically, for 30% of the farmers in our final sample the productivity per acre decreased between the midline and the endline. This matches what we find when asking farmers themselves about the change they experienced in sugarcane productivity in recent years. Twenty-eight per cent of the farmers producing sugarcane at the time of the endline indicated experiencing decreases in sugarcane productivity. Fifty-five per cent claimed to not have experienced any changes, and 17% indicated increases. There is no difference between farmers who were engaged with the programme at an early stage and those who were engaged at a later stage.

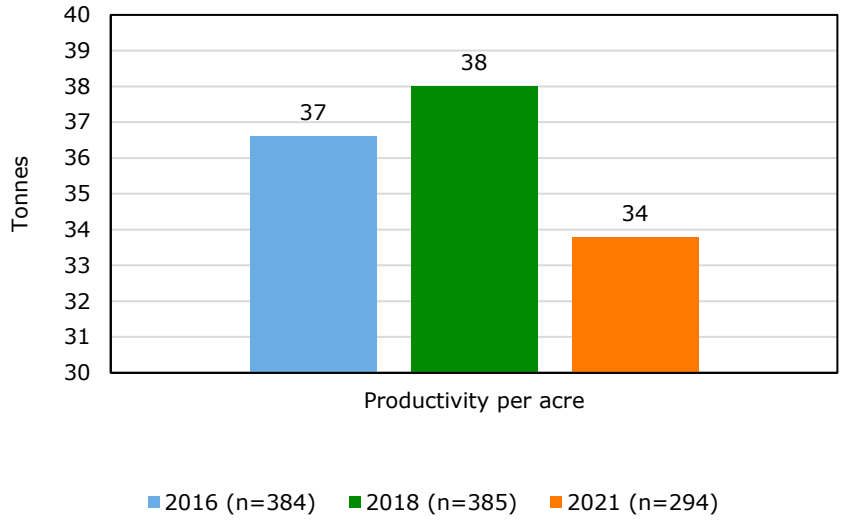

Figure 6.1 Productivity per acre

There is no relation between productivity and several agricultural practices except for trash burning and farmers with higher production costs per tonne of sugarcane have lower productivity.

Drip irrigation (when properly used) is expected to reduce water stress and as such to increase yield through a more frequent and controlled water delivery. We do not find a significant relation between productivity and the use of drip irrigation or other important agricultural practices such as the use of chemicals, except for trash burning. Farmers who burn their land after harvest have lower productivity per acre, and so do farmers who use seed nurseries. The fact that the application of most good agricultural practices was not related to higher sugarcane productivity is also confirmed when looking at the relation between total production costs per tonne of sugarcane and

productivity as we find that farmers with higher production costs per tonne have lower productivity per acre.

Productivity is positively related to a higher dependency on sugarcane but lower for larger sugarcane area and higher levels of education.

We find that owned sugarcane area is negatively and significantly related to productivity, indicating that the smaller the sugarcane area, the more intense the cultivation. The opposite holds for land owned for other crops, the more land is owned for other crops, the higher sugarcane productivity is. Sugarcane productivity is also higher for people for whom sugarcane accounts for at least 75% of their income. As sugarcane farming is the main occupation of these farmers, it could be they invest more in their produce resulting in higher productivity. They might be able to pay more attention to their sugarcane production as they are more dependent on their sugarcane income, compared to farmers who earn more income from other sources. Sugarcane productivity is lower for farmers with higher levels of education, which may be explained by farmers with higher levels of education moving out of agriculture. Furthermore, sugarcane productivity is higher for farmers who are members of a farmer group and lower for bigger households, although these two findings are not robust to estimation methods that correct for differences between mills. As expected, there is also a high degree of correlation between the mills and average productivity.

Main reasons mentioned by farmers for decrease in productivity are the unavailability of labour and late cutting orders.

Out of the farmers who indicated that they experienced decreases in productivity (n=87), 64% indicated it was (among others) because of delayed harvests due to late cutting orders and 49% mentioned it was because of the unavailability of labour. The mills provide the farmers with an order when to harvest based on farm data and collection of yields. It seems farmers have to wait too long which might be a risk for the amount harvested (and quality). Of the farmers who indicated increases in productivity (n=53), the most common reasons mentioned are increased availability of water for irrigation from natural sources (70%), applying better agricultural practices (55%), low occurrence of pest and disease (47%) and using drip irrigation (38%).

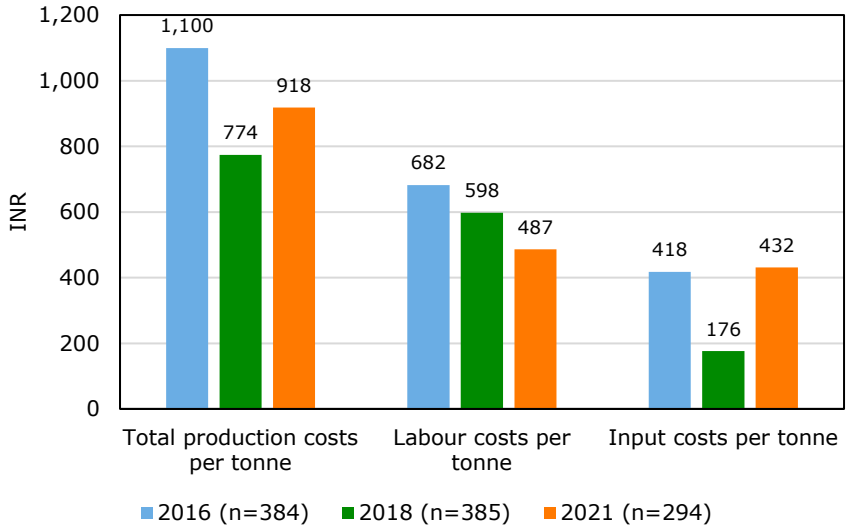

Figure 6.2 Production costs per tonne

6.2 Production costs

Total production costs per tonne decreased over time as a result of labour shortages, not linked to promoted practices.

Production costs were INR 917 per tonne at the endline. This includes costs for planting material, fertilisers, weedicides and hired labour. Own labour costs are not included. These total production costs in 2021 are significantly decreased compared to 2016 but increased compared to 2018. Labour costs per tonne have decreased over time – which is reflection of labour shortage, rather a than a GAP based decision. Other input costs have fluctuated (see Figure 6.2). For the changes over time in costs per tonne of each type of input specifically, see Figure 5.3. There is no difference between farmers who were engaged with the programme at the time of the midline survey and those who were not.

Total production costs per acre remained stable between midline and endline.

The costs per acre decreased from INR 35,845 per acre at the baseline to INR 28,808 per acre in the midline, and then did not significantly change between the midline and the endline. The total production costs per acre were INR 27,154. There is no difference between farmers who were engaged with the programme at an early stage and those who were engaged at a later stage.

Total production costs per tonne lower for farmers with more sugarcane area, for farmers with high sugarcane dependency, and for larger households.

The production costs per tonne of sugarcane are lower for farmers with more sugarcane area, which confirms that farmers with smaller sugarcane area produce it more intensively. Furthermore, the production costs per tonne are also lower for farmers with high sugarcane dependency and for larger households. There are also large differences between mills, with farmers associated with mills 2 and 3 having higher production costs per tonne compared to mill 1 farmers. In terms of agricultural practices, production costs per tonne are higher for farmers using drip irrigation. This is contrary to expectations in the FDW partnership as drip irrigation should save resources in terms of labour and fertiliser use (FDW report 2020). This however does not hold after correcting for differences between mills. Production costs are also higher for farmers only using plant crop, but they are lower for farmers for whom chemical fertiliser costs contributes to a higher share of total production costs.

6.3 Sugarcane price

Sugarcane prices decreased since 2018.

In 2016, farmers received on average INR 2,351 per tonne of sugarcane (see Figure 6.3). This was just above the Fair and Remunerative Price (FRP) of 2016-2017 of INR 2,300 per tonne and well below the State Advised Price (SAP) of INR 2,850 per tonne.[6] The average price received in 2018 increased to INR 2,843, which is above the FRP of 2017-2018 of INR 2,550. In 2021, the price had decreased again to INR 2,613, which was below the FRP of 2020-2021 of INR 2,850 per tonne. Fifty-three per cent of farmers indicate the low price to be a key challenge in sugarcane production (versus 46% in 2018, and 53% in 2016). The low prices in 2019-2020 season are related to the overall challenges in the sugarcane sector around that time (see Section 2.1). One of the mills was closed in 2021, which caused farmers to have to sell their sugarcane to other mills at lower prices. In addition to the price decrease, farmers also were also paid late which influences investments in subsequent years (based on interviews).

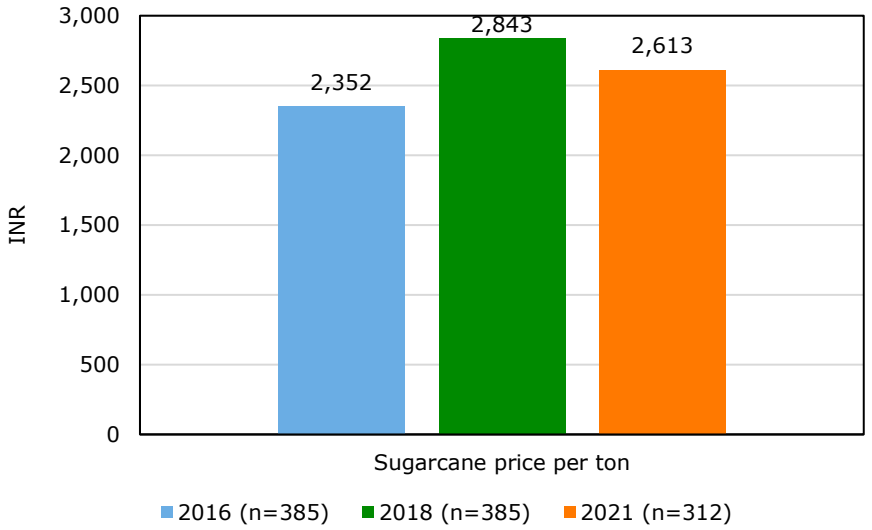

Figure 6.3 Sugarcane price per tonne

[6] http://www.thehindu.com/news/cities/chennai/sugarcane-sap-fixed-at-rs-2850-per-tonne/article8094351.ece

7

Farm income of sugarcane

7 Farm income of sugarcane

Lower production costs, higher prices and yields are expected to increase farm incomes.

The immediate and intermediate outcomes would lead to the ultimate outcomes in the theory of change, which are increased farm incomes and water efficiency of the farmers. This chapter examines total farm incomes from sugarcane, as well as income per acre and per tonne of sugarcane produced of the harvest in 2021.

Average farm income from sugarcane of INR 249,123 increased since 2016.

The average farm income from owned and leased sugarcane land of the farmers at the baseline was INR 156,537, and it rose significantly to INR 380,203 at the midline but decreased again to INR 249,123 at the endline (see Figure 7.1). The term farm income is used instead of profit as family labour and opportunity cost are not considered. This means that the actual margins, profits, are lower. Engagement at the time of the midline was significantly negatively related to changes in farm income, meaning that farmers who had already been engaged by the programme were doing worse in terms of changes in farm income between the baseline and the midline compared to those who did not. In absolute numbers this means that, farm incomes went up for both groups of farmers between baseline and midline. Farmers who already were engaged with the programme at the time of the midline had higher baseline incomes, but farmers who were not yet engaged with the programme surpassed farmers who were in terms of income at the time of the midline.

60% of the farmers indicate not having experienced any changes in farm incomes in the last 3 years.

Even though the farm incomes have significantly decreased since the midline, farmers did not experience it as such. The majority of the famers (60%) indicates not having experienced any changes in their farm incomes. Twenty-two per cent reported decreases and 17% reported increases. In addition, we also asked farmers whether their incomes changed since March 2020 as a result of COVID-19. Exactly 50% of the farmers indicated having experienced decreases in incomes as a result of COVID-19. Furthermore, 29% reported no changes and 22% reported increases.

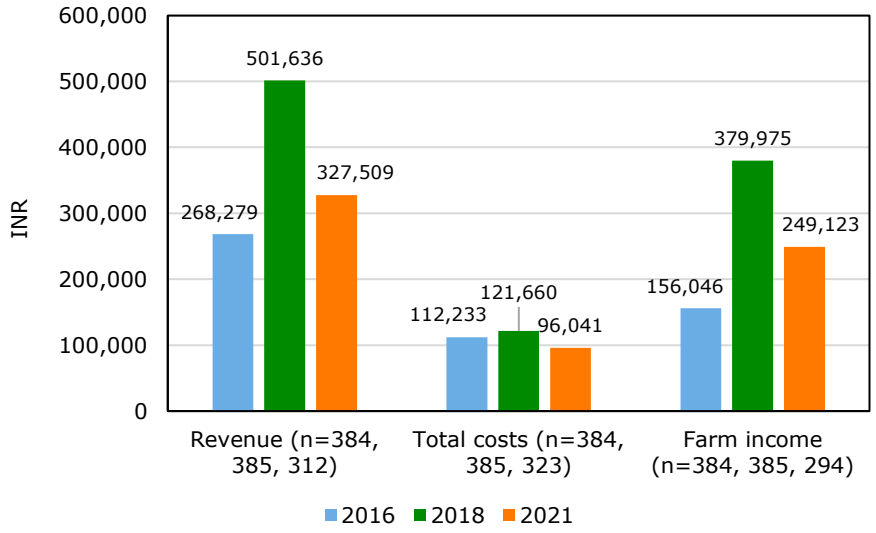

Figure 7.1 Revenue, costs and profits

Demographics and command area influence profitability.

Aside from the expected relation between profitability and productivity, production cost and price, we also see a link to several demographic factors. Being a member of a farmer group is related to higher farm incomes per acre. Farmers with a higher dependency on sugarcane (>75% of their total income) have higher farm incomes per acre and per tonne as well, but this result does

not hold after correcting for differences between the mills. These differences are significant too, with farmers in mills 2 and 3 having higher farm incomes compared to farmers in mill 1. Higher education is related to lower sugarcane farm incomes per ton.

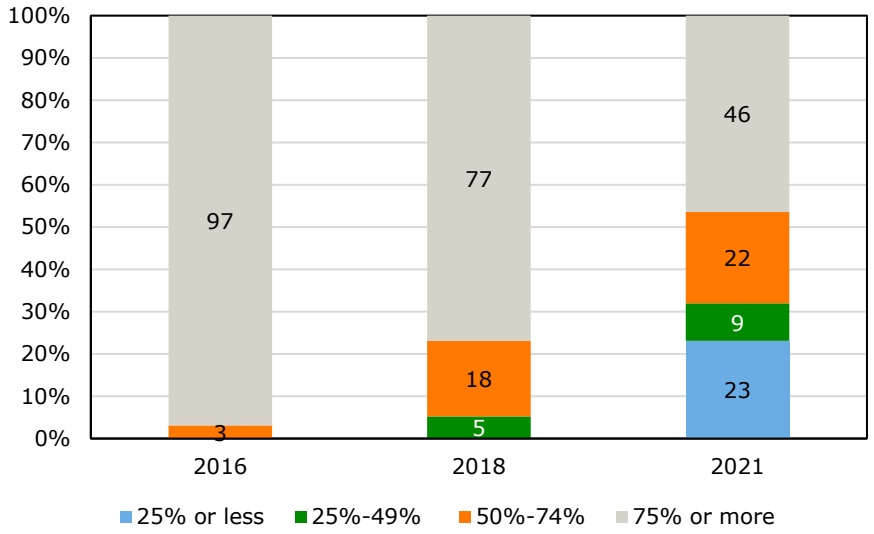

Figure 7.2 Reliance on sugarcane income (n=385)

Farmers are becoming rapidly less reliant on sugarcane.

When asked what percentage of their total household income is coming from sugarcane, we see that farmers are rapidly becoming less dependent on sugarcane. Whereas only a very small minority of the farmers was not largely dependent on sugarcane in 2016 (3% was for less than 75% of their incomes dependent on sugarcane), this rose to 23% at the time of the midline and 54% at the endline (see Figure 7.2). Farmers who were engaged with the programme at the time of the midline survey had significantly lower shares of sugarcane income compared to farmers who were not yet engaged with the program. Besides the farmers who completely moved away from the production of sugarcane, and who now focus on another crop, farmers also seem to be receiving more money from other farm and non-farm sources. The share of farmers who received a small share of their incomes (maximum 25%) from other farm activities initially decreased from 50% at the baseline to 20% at the midline, but then increased again to 56% at the endline. For non-farm income sources this effect is even stronger, from 4% at the baseline, to 43% at the midline and 92% at the endline.

Sugarcane farmers most often receive additional farm income from soybean, cotton and ginger.

Of the people indicating that they are receiving income from other farm activities at the endline, 88% report it is from the production of other crops. For farmers who were still producing sugarcane at the time of the survey (n=152), the most important crops were soybean (45%), cotton (30%) and ginger (28%). For farmers who were not producing sugarcane at the time of the survey (n=65), the majority received income from rice (72%). For non-farm income, the most important source are shops owned by the respondent (37%).

We estimate that 85% of the sugarcane farmers were able to afford a decent standard of living at the time of the endline.

The costs of a decent standard of living following the approach of the global living wage coalition was INR 20,088 for a reference family of 4 people in rural Tamil Nadu in 2021 (Andersen et al., 2022). In terms of geographic location this is the closest benchmark of a living income that is currently available, and we assume that this will be relatively comparable to the living income of sugarcane farmers in our study. Using the farm income from sugarcane production and the share of income that comes from sugarcane production for the farmers who were producing sugarcane at the time of the endline (for those farmers, sugarcane accounted for 68% of their total income), we estimate that about 85% of the sugarcane farmers in our sample achieve an income that allows them to afford a decent standard of living for their household.

8

Conclusions and Recommendations

8 Conclusions and recommendations

The FDW project aimed to enhance sustainability of sugarcane growing and to raise smallholder incomes but was faced with various challenges.
FDW proposed a large-scale roll-out of irrigation techniques and farming practices that have proven to raise water productivity and farm income of sugarcane farming in smallholder settings in India. The implementation of these activities was affected by several challenges including management reforms within the mills as well as COVID-19, which delayed agricultural operations, affected the availability of inputs and disturbed markets and prices. Furthermore, farmers were also strongly impacted by delayed payments from the mills, which also affected the data collection for our study. Despite these challenges the project managed to reach out to thousands of farmers with training through extension services, demonstration plots or farmer field schools, financial literacy, shade house development and service delivery.

Recommendation 1 - do a food system analysis. A food systems approach (FSA) is a useful interdisciplinary conceptual framework for research and policy aimed at sustainable solutions for the sufficient production and supply of healthy food. This framework is also useful for farm system related products that are often influenced by several socio-economic and environmental drivers (see for example van Berkum et al., 2018). In terms of project design and evaluation this means four things. First, to identify drivers of food system activities and root causes of problematic system behaviour. Second, to map the diverse spectrum of economic, social and environmental food system outcomes. Third, to analyse the trade-offs and possible synergies between different food system outcomes. Fourth, point to feedback loops and tipping points in the relation of the food system with other systems. Based on this analysis one can isolate leverage points in the food system that can offer entry points for food system change.

Challenges affected farmers' willingness and ability to invest.
Challenges faced by farmers are also represented in their attitudes towards investments and risks as we see that farmers have become more risk averse in recent years and less fond of investing in agriculture. Besides a lower willingness to invest, farmers also may be less able to invest, as the share of farmers with savings has dropped significantly since the midline.

Recommendation 2 – targeted interventions for different types of farmers. The face of agriculture is changing and to address the same there is a need to provide emphasis on mechanisation and agri-entrepreneur services. But this may not an option for many resource poor farmers. The fact that some farmers may be better able or willing to invest is one of many reasons for targeted interventions. Not all farmers are the same, and hence future interventions need to be adjusted to the realities of different kinds of farmers.

Recommendation 3 – resource poor farmers may require non-commodity focus interventions. For farmers without possibilities to invest in better agricultural practices that require additional financial resources, other focuses for interventions must be prioritised. Similarly, some farmers do not have the potential to eventually earn a living income without structural change. For these farmers, we recommend taking improving their resilience as a starting point for short to medium term interventions. Long term interventions require talking to farmers and their household members, coordination between stakeholders, and accepting that remaining in (sugarcane) crop production is not the best solution for all farmers (Waarts et al., 2021).

A number of practices promoted by the programme have declined in uptake in recent years as a result of shortages of labour and resources.
We find that farmers have become more engaged in farmer groups over time and in terms of agricultural practices that they use seed nurseries more often. Farmers also initially increased the application of organic fertiliser, with a sharp

drop in more recent years, mainly due to a lack of access or resources to it when not provided by the program. The application of pesticides decreased at first but increased again in more recent years, and the use of correct row-to-row spacing increased at first but then decreased again. Intercropping has increased but remains low overall, most likely due to labour shortages. Access to trash shredders increased at first but then decreased again, which also led to a decline in using mulch trash between midline and endline. Even though the burning of trash is discouraged, the practice increased between baseline and midline and remained commonly done. Finally, another key component of the FDW programme was the training on mechanisation and the provision of equipment, but the number of activities mechanised declined between midline and endline, even though labour was scarce. In general farmers who do not apply specific good agricultural practices, even though they are aware of them, state they do not do so because of a lack of time to apply practices, combined with a lack of resources to hire labour.

After an initial surge in adoption of improved irrigation practices, a decline is observed at endline strongly related to increased rainfall, shortage of labour in times of COVID-19 and overall lack of resources.
Drip irrigation was heavily subsidised by the government in the early stages of the project, when farmers were also experiencing large shortages of water. In more recent years a decrease in the usage of drip irrigation was observed, as well as a strong deterioration of the conditions of drip irrigation. Farmers mention that they find the maintenance of drip irrigation too labour intensive, and more farmers have started maintaining their drip irrigation systems themselves, possibly as a result of a lack of affordable hired labour. Other issues experienced when using drip irrigation are that the drip jams frequently and that the wires break easily. These issues, in combination with abundance of rainfall in recent years may discourage farmers to continue using or maintaining their drip irrigation systems properly, which will deteriorate water availability in the future.

No clear link between agricultural practices and productivity, costs or profitability.
According to the intervention logic improved agricultural practices are to reduce costs and increase quality and productivity. In general we do not see an improvement in agricultural practices, and productivity per acre decreased in recent years after an initial increase. When we analyse the relation of the application of specific agricultural practices and productivity, we also do not find a relation between relation between productivity and several agricultural practices except for trash burning, which contradicts our expectations. Revenues and farm incomes also decreased after an initial increase between baseline and midline.

Recommendation 4 – engage farmers in design more strongly. We recommend involving farmers more closely in the design and upscaling of interventions to better meet farmers' needs and possibilities in terms of resources, including efforts to build effective partnerships and carefully manage farmer expectations on the short and long term. Factors that influence adoption (or dis-adoption) can then be tackled more effectively. In doing this representation of all types of farmers (e.g. locations, gender, age, resources) should be ascertained. Topics to be addressed in this process include how to design effective incentives for FBP adoption or planting trees in the long run. Also, we advise to take more time and provide appropriate materials that show implications in terms of time and money spent, as well as expected return on investment, risks and timelines for expected impact.

Decreasing price, sector unrest and shortage of labour increasing shift to other means of income.
Besides lower productivity, also the sugarcane prices decreased after the midline while farmers were also dealing with the effects of COVID, including delayed payments from the mill. These developments have strongly impacted farmers, and many have switched to other crops instead of sugarcane such as rice, or have started growing other crops such as soybean, cotton or ginger. The farmers who stopped growing sugarcane do express an interest in returning to do so in the future. The declining dependency of farmers on sugarcane and the increase in income from other crops or from non-farm sources is beneficial to the resilience of farmers to shocks and should not be discouraged.

Recommendation 5 - consider shocks & farmer resilience. COVID-19 was an example of a shock that strongly affected sugarcane farmers. Although the exact timing and type of shock can never be predicted, it is important to conduct a food systems analysis to get an overview of how specific potential shocks may impact different parts of the food system or the sugarcane supply system. As we have seen, disruptions higher up in the supply system have most strongly affected farmers (e.g. by delays in payments or cutting orders). It is important to better understand these processes so that the effects on

farmers can be minimised in the future. In this regard, it is important to, once again, take different types of farmers in consideration as not all shocks will affect each type of farmer similarly. An example outcome of such an analysis to minimise effects of shocks of farmers may be the promotion of agricultural index insurance, which is a type of insurance that protects farmers from specific production losses if an index (e.g. rainfall) exceeds a certain threshold.

Recommendation 6 - extract value from this evaluation by using data and sharing findings. We advise Solidaridad to extract value from this evaluation by using and sharing the data collected. Moreover, we urge to feedback learning to all levels in the supply chain. This can inspire longer term partnerships and future collaborations in research and design of future interventions.

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10 Appendix

10.1 Intervention logic FDW

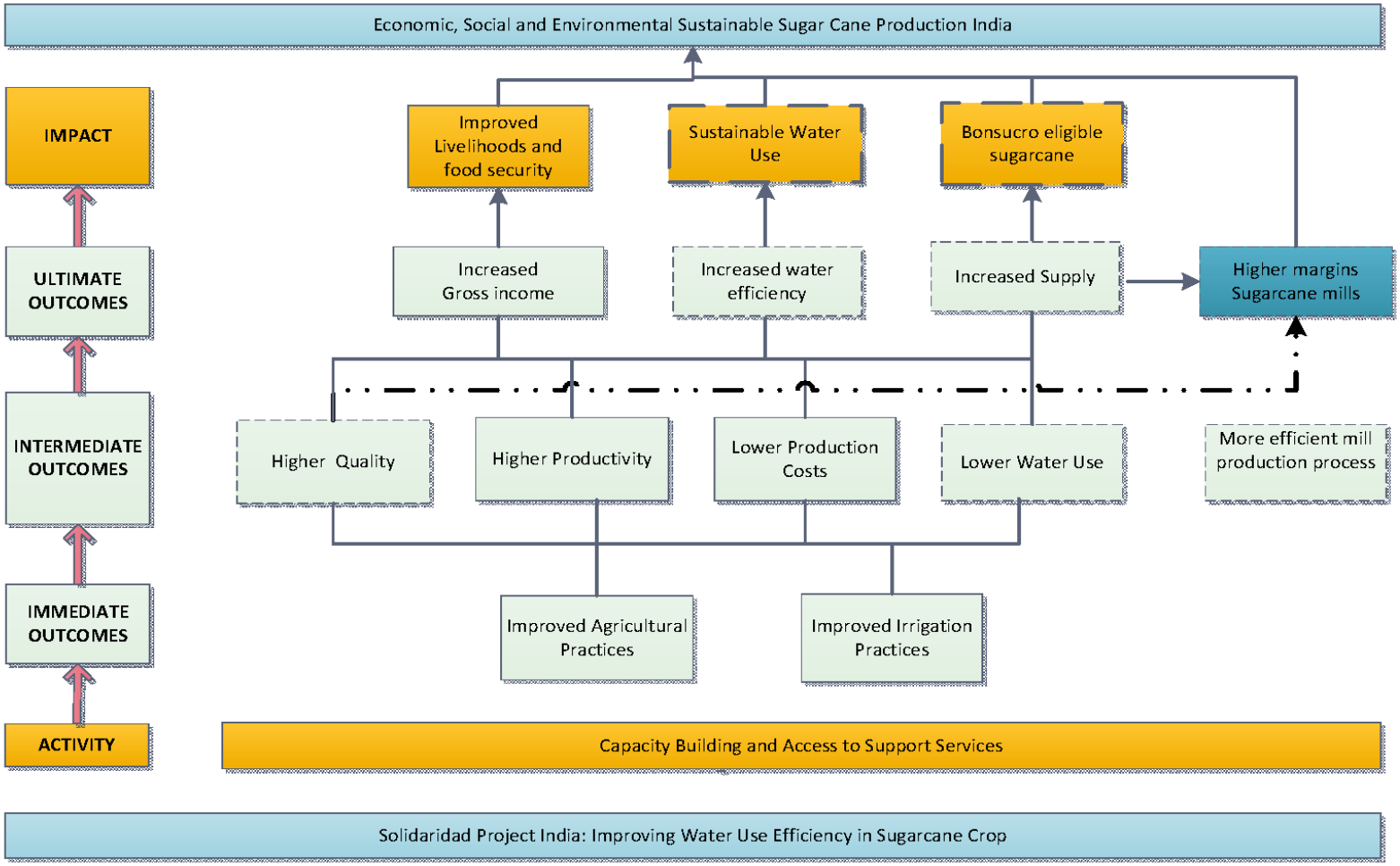

Figure 10.1 Intervention logic FDW at the time of the baseline

10.2 Specific context of mills

Table 10.1 Specific context of mills

Mills	Characteristic soil, water and irrigation
Mill 1	The command area of mill 1 is characterised by red and black sandy loam and medium soils, which allows high water drainage. Its' fairly rich organic nutrient content makes it conducive for sugarcane cultivation and it has 75,000 acres of irrigated area. Average rainfall in the target's catchment region is in range of 650-700 mm. Yield and sugarcane acreage exhibits very low to moderate correlation with rainfall over the past ten years owing to improved irrigation facilities in the region. The area is irrigated via a host of rivers (Hemavati, Cauvery, Lakshmana Tirtha and Shimsha), reservoirs (Krishnarajasagar, Markonahalli and Managala) and a well-branched canal system network. Main irrigation source is KRS Dam through perennial Vishweshwaraih canal system. Irrigated land in Maddur and Mandya talukas constitute nearly 80% and 60% of cultivable land respectively. Accordingly, most of the mill's catchment area is very well irrigated making it suitable for sugarcane cultivation. The primary crops in the region are paddy, ragi and sugarcane, of which paddy and ragi are used largely for domestic consumption. As a result, this is mainly a sugarcane belt with limited competition from other crops. the closest competitor to sugarcane is paddy; Currently, sugarcane is ~1.4x more gross income able than paddy and 1.3x more gross income able than ragi.
Mill 2	The command area of mill 2 in the southern Telangana zone is characterised by red loams (40%) and black soil (60%), both conducive for sugarcane cultivation and it has 250,000 acres of irrigated area. Average rainfall in target's catchment region is around 600 mm. It is sufficient to maintain 750-800 TMC (Thousand Million Cube) of water outflow from the Jurala reservoir which is adequate for sugarcane cultivation. This area is irrigated via 3 rivers (Krishna, Tungabhadra and Bheema). Two significant lift-irrigation projects, to be fed by Jurala dam on river Krishna, are in progress. The Nettanpadu phase I & II, Bhima phase I & II projects on completion are expected to add over 400,000 acres of irrigated area in next 2 to 3 years. This is expected to lead to significant incremental sugarcane availability. Paddy and groundnut are the other major crops cultivated in the irrigated area. Crop economics indicate sugarcane results in 1.2 times more gross income than paddy and groundnut each.
Mill 3	In the command area of mill 3, the annual rainfall has been decreasing. The groundwater depth in most of the zones is already 400 to 500 feet and there is no scope for either deepening existing wells or drilling new wells. Sufficient rainfall is required every year to recharge the groundwater potential; 60% of the soil consists of red laterite, which has very poor water retention capacity and percolation. There are hardly perennial sources for irrigation such as rivers, canals or irrigation schemes. Sixty-eight per cent of the water for irrigation comes from open wells, 22% from bore wells, 3% from rivers and canals and 8% from tanks and lakes and the irrigated area is 29,966 acres.
	Source: data of the mills provided during field visit, April 2016

10.3 Attrition

For mill 2 & 3 we compared key characteristics of farmers who were interviewed at the midline but no longer at the endline with the characteristics of farmers who were still included in the endline evaluation to see whether there are any specific characteristics related to this attrition. We found no significant differences for any of the key characteristics between those two groups, indicating that attrition is seemingly random (see **Table 10.2** Attrition results mill 2 & 3Table 10.2).

Table 10.2 Attrition results mill 2 & 3

	Mean panel data (n=298)	Mean attrition (n=119)	P-value t-test
Gender of respondent: female	0.101	0.126	0.452
Respondent is household head	0.849	0.790	0.146
Number of household members	5.238	5.664	0.078
Received any kind of education	0.785	0.739	0.316
Sugarcane area: owned	4.789	4.336	0.193
Sugarcane area: leased	0.782	0.492	0.133
Other crop area: owned	2.799	2.485	0.493
Other crop area: leased	0.638	0.412	0.463
Years of experience in sugarcane farming	15.45	14.74	0.483
Member of a famer group	0.151	0.176	0.521
Harvest in tonnes	170.4	182.6	0.622
Productivity (tonnes)	38.02	39.42	0.321
Price per tonne (INR)	2928	2921	0.571
Received subsidy	0.960	0.958	0.935
Profit per acre (INR)	81916	83773	0.551
Total costs per acre (INR)	29063	30943	0.120

10.4 Propensity score matching mill 1 farmers

For mill 1 data was collected for different farmers compared to earlier years. Including all of these farmers in the analysis would bias the results, as it would not be evident whether any changes found would be because farmers actually changed something, or just because we are looking at different farmers. Looking at key characteristics, the farmers who were interviewed at the endline strongly differed from farmers who were interviewed in earlier rounds of the survey. In order to select only endline farmers from mill 1 with similar characteristics compared to farmers in the midline data we used nearest neighbour propensity score matching. Figure 10.2 shows the propensity scores of the midline famers ('untreated') as well as those for the endline farmers ('treated'), where the green bars indicate which farmers from the endline survey were dropped because there was no farmer with similar characteristics available within the midline data. In total, 87 out of 251 farmers interviewed at the endline remain and are used for descriptive statistics and analyses. Table **10.3** shows the means for the matched and the unmatched endline farmers on the variables used in the propensity score matching.

Table 10.3 Descriptive statistics for matched and unmatched endline farmers (mill 1)

	Matched (N=87)				Not matched (N=164)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Gender (1= female)	0.10	0.31	0.00	1.00	0.04	0.20	0.00	1.00
Household size (adjusted for change in household size in other mills)	3.68	0.49	2.37	4.37	4.45	0.52	3.37	7.37
Education level (1-7)	4.44	0.69	1.00	6.00	4.55	0.53	3.00	6.00
Owned sugarcane area (acres)	2.72	1.59	0.50	9.00	3.51	2.12	1.00	17.0
Years of experience in sugarcane production (adjusted for years since baseline)	12.0	3.24	0.00	20.0	10.5	2.13	0.00	20.0
Member of farmer group (1=Yes)	0.16	0.37	0.00	1.00	0.32	0.47	0.00	1.00

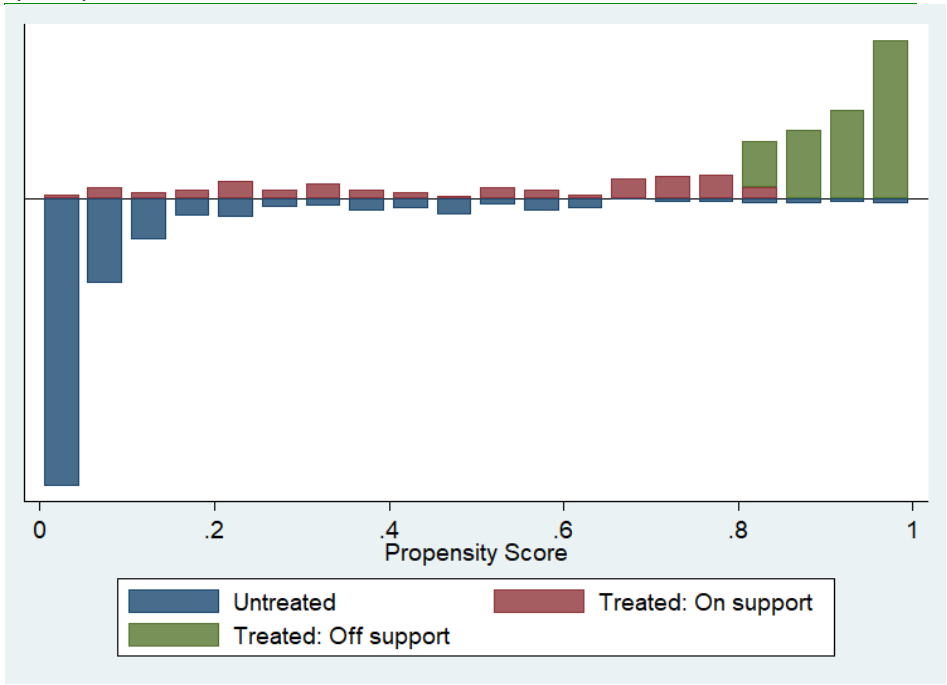

Figure 10.2 Propensity score matching results

10.5 Regression results

Table 10.4 Shows the regression results of the standard linear regression model. The main variable of interest is the interaction term between midline and early engagement, which shows whether farmers with early engagement with the programme had a significantly different change in the indicator of interest between baseline and midline compared to farmers who were not yet engaged with the programme at the time of the midline. The table also shows the coefficients and p-values for other important control variables. Additionally, all models also controlled for gender of the respondent, whether the respondent is the household head or not, household size, owned sugarcane area, leased sugarcane area, years of experience in sugarcane, whether the farmer is a member of a farmer group or not as well as the farmers' willingness to invest and risk attitude.

Table 10.4 Regression results

Outcome variable	Early engagement*midline		Early engagement		Midline		Endline		Mill 2		Mill 3		No sugarcane (2021)	
	coef	p value	coef	p value	coef	p value	coef	p value	coef	p value	coef	p value	coef	p value
Uses seed nurseries	0.042	0.546	0.067	0.180	0.115	0.000	0.366	0.000	0.048	0.158	0.182	0.000		
Uses pesticides	0.377	0.000	-0.111	0.068	-0.356	0.000	-0.146	0.000	0.199	0.000	-0.056	0.080	0.121	0.025
Uses chemical fertilisers	-0.001	0.968	-0.002	0.897	-0.004	0.483	-0.018	0.004	-0.007	0.402	-0.002	0.748	-0.016	0.130
Uses organic fertilisers	-0.067	0.454	0.052	0.415	0.186	0.000	-0.237	0.000	-0.240	0.000	-0.311	0.000	-0.226	0.000
Weedicide costs per tonne	16.3	0.214	-11.9	0.209	-19.5	0.000	-13.3	0.009	7.476	0.244	9.383	0.064		
Chemical fertiliser costs per tonne	-4.243	0.906	25.5	0.324	-24.4	0.063	155	0.000	75.5	0.000	89.0	0.000		
Organic fertiliser costs per tonne	-1.658	0.994	19.9	0.905	94.8	0.261	229	0.011	98.6	0.384	222	0.013		
Planting material costs per tonne	38.4	0.353	-21.2	0.478	-165	0.000	-49.2	0.002	115	0.000	45.4	0.005		
Applies intercropping	0.020	0.697	-0.013	0.720	-0.009	0.618	0.139	0.000	-0.057	0.020	-0.072	0.000	-0.066	0.040
Uses appropriate row to row spacing	-0.045	0.612	0.057	0.370	0.302	0.000	0.120	0.000	0.277	0.000	0.511	0.000		
Burns land after harvest	-0.127	0.134	0.080	0.190	0.191	0.000	0.207	0.000	-0.831	0.000	-0.259	0.000	-0.065	0.230
Has access to a trash shredder	0.196	0.001	-0.026	0.512	0.237	0.000	0.035	0.103	-0.060	0.050	-0.128	0.000	0.040	0.279
Uses drip irrigation	-0.049	0.524	0.035	0.528	0.320	0.000	0.229	0.000	0.577	0.000	0.795	0.000	-0.518	0.000
Productivity	-4.592	0.154	0.882	0.703	2.882	0.014	-2.578	0.041	-6.593	0.000	-11.2	0.000		
Labour costs per tonne	51.3	0.319	-64.8	0.080	-81.3	0.000	-187	0.000	-20.7	0.411	-9.963	0.617		
Labour costs per acre	-384	0.852	-2277	0.124	-55.4	0.941	-6766	0.000	-5087	0.000	-7815	0.000	-10262	0.000
Other input costs per tonne	35.5	0.604	4.744	0.923	-222	0.000	78.5	0.003	266	0.000	199	0.000		
Other input costs per acre	-735	0.569	420	0.651	-5,313	0.000	122	0.802	4234	0.000	1,927	0.000	-69.7	0.935
Total costs per tonne	86.8	0.406	-60.1	0.425	-303	0.000	-109	0.008	245	0.000	189	0.000		
Total costs per acre	-1,119	0.690	-1,857	0.358	-5,368	0.000	-6,644	0.000	-853	0.528	-5,889	0.000	-10,332	0.000
Profit	-81,667	0.031	23,494	0.388	151,759	0.000	30,913	0.037	6,472	0.727	-37,712	0.010		
Sugarcane dependency	-0.105	0.003	0.001	0.977	-0.039	0.002	-0.161	0.000	0.062	0.000	-0.041	0.002	-0.589	0.000

10.6 Descriptive statistics

Table 10.5 Descriptive statistics of key indicators for overall sample

Programme engagement	Mean baseline	N baseline	Mean mid term	N mid term	Mean endline	N endline
I have/had access to a demonstration plot on sugarcane cultivation			5%	385	62%	385
I receive(d) assistance from the extension worker for the mill			9%	385	10%	385
I receive(d) assistance from a lead farmer			69%	36	41%	385
I received training on good agricultural practices in sugarcane production, on irrigation methods, techniques and maintenance, on farm mechanisation, on trash shredding or on financial literacy.	0%	385	3%	385	10%	385
Remember topic from programme engagement: Financial planning					44%	385
Remember topic from programme engagement: Intercropping					18%	385
Remember topic from programme engagement: Bio compost					5%	385
Remember topic from programme engagement: Wide row spacing					17%	385
Remember topic from programme engagement: Drip irrigation					53%	385
Remember topic from programme engagement: Trash mulching					4%	385
Remember topic from programme engagement: Mechanisation					30%	385
Remember topic from programme engagement: Other					1%	385
Applies information learnt in engagement on: Financial planning					93%	168
Applies information learnt in engagement on: Intercropping					46%	68
Applies information learnt in engagement on: Bio compost					30%	20
Applies information learnt in engagement on: Wide row spacing					87%	67
Applies information learnt in engagement on: Drip irrigation					93%	205
Applies information learnt in engagement on: Trash mulching					14%	14
Applies information learnt in engagement on: Other					60%	115
Wants further training	100%	385	100%	336	73%	385
Farm(er) characteristics	**Mean baseline**	**N baseline**	**Mean mid term**	**N mid term**	**Mean endline**	**N endline**
Gender of respondent	10%	385	10%	385	10%	385
Respondent is household head	84%	385	84%	385	88%	385
Number of household members	4.9	385			5.7	385
Received any kind of education	95%	385	82%	385	84%	385
Likelihood of falling below the 2.50$ a day poverty line (PPP 2005)	63.5	385	50.2	385		
Is member of a farmer group	18%	385	15%	385	25%	385
Total area used for sugarcane	3.6	385	4.9	385	3.9	385
Total area used for other crops	1.4	385	2.9	385	3.1	385
Sugarcane area: owned	3.4	385	4.2	385	3.7	385
Other crop area: owned	1.4	385	2.3	385	2.7	385
Sugarcane area: leased	0.2	385	0.6	385	0.2	385
Other crop area: leased	0.0	385	0.6	385	0.3	385
Total area owned	4.8	385	6.5	385	6.4	385

Supply to the mill in tonnes	114	384	173	385	52	312
Total tonnes harvested			148	385	125	312
Productivity per acre	36.6	384	37.9	385	33.8	294
Price received per tonne	2,351	385	2844	385	2613	312
Taken out loan in past year	76%	385	95%	385	54%	385
Did you follow a training on financial literacy in the past 2-3 years?			28%	385	3%	385
Household has savings	64%	385	88%	385	45%	385
Household received a subsidy	43%	385	75%	385	2%	385
Subsidy for: surface drip irrigation	9%	166	96%	288	88%	8
Subsidy for: sub surface drip irrigation	2%	166	1%	288	13%	8
Subsidy for: Other irrigation system, specify	57%	166	0%	288	0%	8
Subsidy for electricity	28%	166	67%	288	0%	8
Subsidy for water pump	8%	166	2%	288	0%	8
Subsidy for fertiliser	30%	165	0%	288		0
Key challenges	**Mean baseline**	**N baseline**	**Mean mid term**	**N mid term**	**Mean endline**	**N endline**
Key challenges: Unavailability of labour	78%	385	98%	385	97%	385
Key challenges: Unavailability of agri inputs	37%	385	24%	385	34%	385
Key challenges: No resources to buy agri inputs	32%	385	10%	385	42%	385
Key challenges: Unavailability of water for irrigation	76%	385	77%	385	7%	385
Key challenges: My drip irrigation is in bad condition	26%	385	7%	385	5%	385
Key challenges: Attack of diseases and insect pest	40%	385	26%	385	17%	385
Key challenges: Poor quality of soil	27%	385	29%	385	3%	385
Key challenges: No facility for soil testing	41%	385	46%	385	7%	385
Key challenges: Delay in getting cutting order	57%	385	41%	385	56%	385
Key challenges: Low price of sugarcane	54%	385	46%	385	53%	385
Key challenges: (No) electricity/blackouts	5%	385	2%	385	2%	385
Key challenges: Delay in payment for produce from the mill			14%	385	92%	385
Key challenges: Transportation issues of produce to the mill					84%	385
Agricultural practices	**Mean baseline**	**N baseline**	**Mean mid term**	**N mid term**	**Mean endline**	**N endline**
Use single bud setts	63%	382	10%	308	42%	309
Use seed nurseries	1%	385	11%	385	33%	312
Uses chemical fertiliser	100%	385	100%	385	98%	385
Uses organic fertiliser	75%	385	92%	385	44%	385
Source organic fertiliser: own farm	74%	287	73%	356	85%	171
Source organic fertiliser: other farmers	29%	287	58%	356	38%	171
Source organic fertiliser: mill	10%	287	16%	356	4%	171
Source organic fertiliser: government	1%	287	4%	356	1%	171
Applies pesticides	92%	385	57%	385	74%	385
Applies chemical pesticides	66%	385	22%	385	73%	385
Applies organic pesticides	0%	385	2%	385	0%	385
Applies both chemical and organic pesticides	26%	385	33%	385	0%	385

Applies pesticides preventively	69%	95	16%	197	46%	189
Applies pesticides curatively	81%	152	31%	241	63%	277
Applies pesticides preventively and curatively	85%	196	41%	279	17%	123
Intercropped at least one crop with sugar	2%	385	1%	385	14%	385
Used appropriate row to row spacing for irrigation system used	55%	385	86%	385	64%	312
Ploughs using a tractor	0%	385	0%	385	0%	385
Burns land after harvest	46%	385	69%	385	70%	385
Access to trash shredder	1%	385	23%	303	3%	385
Owns a trash shredder	100%	4	1%	385	2%	385
Uses a mulch trash	0%	0	38%	385	22%	385
Used irrigation system: furrow	55%	385	36%	385	51%	385
Used irrigation system: surface drip	13%	385	75%	385	47%	385
Used irrigation system: sub surface drip	1%	385	2%	385	0%	385
Used irrigation system: drip combined with fertigation	36%	385	54%	385	32%	385
Uses preferred irrigation system	32%	385	96%	385	100%	385
Uses any form of drip irrigation	45%	384	77%	385	57%	385
Adopted or changed any practices in the past 5 years to improve water efficiency					9%	385
Count of activities mechanised			4.63	385	2.39	312
Costs and income	**Mean baseline**	**N baseline**	**Mean mid term**	**N mid term**	**Mean endline**	**N endline**
Revenue per acre	85,366	384	107,569	385	88,646	294
Estimated income share from sugarcane production					56	385
Estimated income share from other crops					35	385
Estimated income share from non-farm activities					9	385
Total costs of planting material per tonne produced	207	384	45	385	144	294
Total costs of chemical fertiliser per tonne produced	93	384	52	385	208	294
Total costs of biological fertiliser per tonne produced	112	384	71	385	237	294
Total costs of weedicide per tonne produced	25	384	7	385	13	294
Total costs of pesticides per tonne produced					18	294
Input costs per tonne (excl. labour)	417	384	176	385	432	294
Labour costs per tonne	682	384	599	385	487	294
Total costs per tonne	1,099	384	775	385	918	294
Total production costs per acre	35,840	384	28,811	385	27,422	379
Total farm income (revenue - production costs)	156,558	384	379,870	385	249,123	294
Total costs	112,429	384	121,689	385	96,041	323
Profit per acre	49,526	384	78,758	385	60,359	294
Profit per tonne	-2,387	384	-2,613	385	1,710	291
Labour costs per acre	23,410	384	22,420	385	15,016	379
Input costs per acre	12,430	384	6,391	385	12,406	379

Table 10.6 Descriptive statistics of key indicators for mill 1 farmers

Programme engagement	Mean baseline Mill 1	N baseline Mill 1	Mean mid term Mill 1	N mid term Mill 1	Mean endline Mill 1	N endline Mill 1
I have/had access to a demonstration plot on sugarcane cultivation			7%	87	55%	87
I receive(d) assistance from the extension worker for the mill			28%	87	3%	87
I receive(d) assistance from a lead farmer			96%	24	48%	87
I received training on good agricultural practices in sugarcane production, on irrigation methods, techniques and maintenance, on farm mechanisation, on trash shredding or on financial literacy.	0%	87	6%	87	0%	87
Remember topic from programme engagement: Financial planning					99%	87
Remember topic from programme engagement: Intercropping					11%	87
Remember topic from programme engagement: Bio compost					0%	87
Remember topic from programme engagement: Wide row spacing					6%	87
Remember topic from programme engagement: Drip irrigation					2%	87
Remember topic from programme engagement: Trash mulching					0%	87
Remember topic from programme engagement: Mechanisation					1%	87
Remember topic from programme engagement: Other					0%	87
Applies information learnt in engagement on: Financial planning					94%	86
Applies information learnt in engagement on: Intercropping					0%	10
Applies information learnt in engagement on: Bio compost					0%	0
Applies information learnt in engagement on: Wide row spacing					0%	5
Applies information learnt in engagement on: Drip irrigation					0%	2
Applies information learnt in engagement on: Trash mulching					0%	0
Applies information learnt in engagement on: Other					0%	1
Wants further training	100%	87	100%	63	100%	87
Farm(er) characteristics	**Mean baseline Mill 1**	**N baseline Mill 1**	**Mean mid term Mill 1**	**N mid term Mill 1**	**Mean endline Mill 1**	**N endline Mill 1**
Gender of respondent	8%	87	8%	87	10%	87
Respondent is household head	82%	87	82%	87	99%	87
Number of household members	3.7	87			4.3	87
Received any kind of education	1	87	95%	87	99%	87
Likelihood of falling below the 2.50$ a day poverty line (PPP 2005)	50.4	87	39.5	87		
Is member of a farmer group	44%	87	15%	87	16%	87
Total area used for sugarcane	3.6	87	2.5	87	2.7	87
Total area used for other crops	1.0	87	0.9	87	0.6	87
Sugarcane area: owned	3.1	87	2.4	87	2.7	87
Other crop area: owned	1.0	87	0.5	87	0.6	87
Sugarcane area: leased	0.5	87	0.1	87	0.0	87
Other crop area: leased	0.0	87	0.4	87	0.0	87
Total area owned	4.1	87	2.9	87	3.3	87
Supply to the mill in tonnes	163	87	75	87	136	87

Total tonnes harvested			73	87	135	87
Productivity per acre	46.5	87	37.5	87	50.6	87
Price received per tonne	2273	87	2555	87	2628	87
Taken out loan in past year	55%	87	100%	87	8%	87
Did you follow a training on financial literacy in the past 2-3 years?			21%	87	6%	87
Household has savings	87%	87	98%	87	92%	87
Household received a subsidy	51%	87	2%	87	3%	87
Subsidy for: surface drip irrigation	0%	44	50%	2	67%	3
Subsidy for: sub surface drip irrigation	2%	44	50%	2	33%	3
Subsidy for: Other irrigation system, specify	0%	44	0%	2	0%	3
Subsidy for electricity	98%	44	0%	2	0%	3
Subsidy for water pump	27%	44	0%	2	0%	3
Subsidy for fertiliser	95%	44	0%	2		0
Key challenges	**Mean baseline Mill 1**	**N baseline Mill 1**	**Mean mid term Mill 1**	**N mid term Mill 1**	**Mean endline Mill 1**	**N endline Mill 1**
Key challenges: Unavailability of labour	62%	87	98%	87	99%	87
Key challenges: Unavailability of agri inputs	26%	87	44%	87	79%	87
Key challenges: No resources to buy agri inputs	47%	87	7%	87	82%	87
Key challenges: Unavailability of water for irrigation	52%	87	86%	87	11%	87
Key challenges: My drip irrigation is in bad condition	36%	87	3%	87	6%	87
Key challenges: Attack of diseases and insect pest	57%	87	16%	87	3%	87
Key challenges: Poor quality of soil	46%	87	20%	87	8%	87
Key challenges: No facility for soil testing	34%	87	43%	87	8%	87
Key challenges: Delay in getting cutting order	67%	87	55%	87	32%	87
Key challenges: Low price of sugarcane	53%	87	34%	87	15%	87
Key challenges: (No) electricity/blackouts	5%	87	1%	87	3%	87
Key challenges: Delay in payment for produce from the mill			0%	87	78%	87
Key challenges: Transportation issues of produce to the mill					75%	87
Agricultural practices	**Mean baseline Mill 1**	**N baseline Mill 1**	**Mean mid term Mill 1**	**N mid term Mill 1**	**Mean endline Mill 1**	**N endline Mill 1**
Use single bud setts	7%	87	16%	87	99%	87
Use seed nurseries	3%	87	7%	87	0%	87
Uses chemical fertiliser	100%	87	100%	87	100%	87
Uses organic fertiliser	100%	87	99%	87	71%	87
Source organic fertiliser: own farm	95%	87	94%	86	100%	62
Source organic fertiliser: other farmers	15%	87	80%	86	2%	62
Source organic fertiliser: mill	20%	87	2%	86	0%	62
Source organic fertiliser: government	3%	87	13%	86	0%	62
Applies pesticides	99%	87	99%	87	23%	87
Applies chemical pesticides	63%	87	38%	87	23%	87
Applies organic pesticides	0%	87	2%	87	0%	87

Applies both chemical and organic pesticides	36%	87	59%	87	0%	87
Applies pesticides preventively	94%	18	90%	10	0%	67
Applies pesticides curatively	93%	15	97%	29	1%	68
Applies pesticides preventively and curatively	98%	56	98%	50	22%	86
Intercropped at least one crop with sugar	1%	87	0%	87	29%	87
Used appropriate row to row spacing for irrigation system used	51%	87	52%	87	1%	87
Ploughs using a tractor	0%	87	0%	87	0%	87
Burns land after harvest	92%	87	95%	87	98%	87
Access to trash shredder	0%	87	53%	87	2%	87
Owns a trash shredder	0%	0	5%	87	2%	87
Uses a mulch trash	0%	0	47%	87	1%	87
Used irrigation system: furrow	95%	87	100%	87	100%	87
Used irrigation system: surface drip	5%	87	8%	87	0%	87
Used irrigation system: sub surface drip	0%	87	2%	87	0%	87
Used irrigation system: drip combined with fertigation	1%	87	1%	87	0%	87
Uses preferred irrigation system	99%	87	99%	87	100%	87
Uses any form of drip irrigation	6%	87	11%	87	0%	87
Adopted or changed any practices in the past 5 years to improve water efficiency					0%	87
Count of activities mechanised			3.43	87	1.63	87
Costs and income	**Mean baseline Mill 1**	**N baseline Mill 1**	**Mean mid term Mill 1**	**N mid term Mill 1**	**Mean endline Mill 1**	**N endline Mill 1**
Revenue per acre	105,859	87	95,890	87	132,969	87
Estimated income share from sugarcane production					78	87
Estimated income share from other crops					6	87
Estimated income share from non-farm activities					16	87
Total costs of planting material per tonne produced	99	87	46	87	108	87
Total costs of chemical fertiliser per tonne produced	103	87	61	87	57	87
Total costs of biological fertiliser per tonne produced	44	87	26	87	59	87
Total costs of weedicide per tonne produced	8	87	9	87	8	87
Total costs of pesticides per tonne produced					14	87
Input costs per tonne (excl. labour)	251	87	141	87	237	87
Labour costs per tonne	591	87	629	87	635	87
Total costs per tonne	842	87	770	87	872	87
Total production costs per acre	37,258	87	27,948	87	43,866	87
Total farm income (revenue - production costs)	241,970	87	136,416	87	243,368	87
Total costs	128,952	87	56,441	87	112,760	87
Profit per acre	68,601	87	67,941	87	89,103	87
Profit per tonne	-3,120	87	-1,204	87	1,756	87
Labour costs per acre	26,261	87	22,967	87	31,999	87
Input costs per acre	10,997	87	4,982	87	11,866	87

Table 10.7 Descriptive statistics of key indicators for mill 2 farmers

Programme engagement	Mean baseline Mill 2	N baseline Mill 2	Mean mid term Mill 2	N mid term Mill 2	Mean endline Mill 2	N endline Mill 2
I have/had access to a demonstration plot on sugarcane cultivation			1%	84	18%	84
I receive(d) assistance from the extension worker for the mill			0%	84	7%	84
I receive(d) assistance from a lead farmer			0%	0	81%	84
I received training on good agricultural practices in sugarcane production, on irrigation methods, techniques and maintenance, on farm mechanisation, on trash shredding or on financial literacy.	0%	84	6%	84	7%	84
Remember topic from programme engagement: Financial planning					92%	84
Remember topic from programme engagement: Intercropping					11%	84
Remember topic from programme engagement: Bio compost					6%	84
Remember topic from programme engagement: Wide row spacing					5%	84
Remember topic from programme engagement: Drip irrigation					11%	84
Remember topic from programme engagement: Trash mulching					2%	84
Remember topic from programme engagement: Mechanisation					5%	84
Remember topic from programme engagement: Other					2%	84
Applies information learnt in engagement on: Financial planning					99%	77
Applies information learnt in engagement on: Intercropping					44%	9
Applies information learnt in engagement on: Bio compost					60%	5
Applies information learnt in engagement on: Wide row spacing					50%	4
Applies information learnt in engagement on: Drip irrigation					67%	9
Applies information learnt in engagement on: Trash mulching					0%	2
Applies information learnt in engagement on: Other					50%	4
Wants further training	100%	84	100%	84	17%	84
Farm(er) characteristics	**Mean baseline Mill 2**	**N baseline Mill 2**	**Mean mid term Mill 2**	**N mid term Mill 2**	**Mean endline Mill 2**	**N endline Mill 2**
Gender of respondent	8%	84	8%	84	8%	84
Respondent is household head	95%	84	95%	84	95%	84
Number of household members	4.7	84			4.8	84
Received any kind of education	98%	84	73%	84	98%	84
Likelihood of falling below the 2.50$ a day poverty line (PPP 2005)	59.6	84	52.7	84		
Is member of a farmer group	25%	84	42%	84	79%	84
Total area used for sugarcane	4.2	84	4.4	84	2.6	84
Total area used for other crops	1.2	84	4.8	84	3.0	84
Sugarcane area: owned	4.2	84	3.5	84	2.5	84
Other crop area: owned	1.2	84	3.5	84	2.6	84
Sugarcane area: leased	0.0	84	0.8	84	0.1	84
Other crop area: leased	0.0	84	1.3	84	0.4	84
Total area owned	5.5	84	7.0	84	5.1	84
Supply to the mill in tonnes	101	84	220	84	148	28

Total tonnes harvested			64	84	150	28
Productivity per acre	25.6	84	52.6	84	31.1	28
Price received per tonne	2565	84	2873	84	2723	28
Taken out loan in past year	98%	84	85%	84	15%	84
Did you follow a training on financial literacy in the past 2-3 years?			77%	84	4%	84
Household has savings	99%	84	90%	84	6%	84
Household received a subsidy	39%	84	88%	84	1%	84
Subsidy for: surface drip irrigation	24%	33	100%	74	100%	1
Subsidy for: sub surface drip irrigation	0%	33	0%	74	0%	1
Subsidy for: Other irrigation system, specify	64%	33	0%	74	0%	1
Subsidy for electricity	6%	33	3%	74	0%	1
Subsidy for water pump	0%	33	0%	74	0%	1
Subsidy for fertiliser	3%	32	0%	74		0
Key challenges	**Mean baseline Mill 2**	**N baseline Mill 2**	**Mean mid term Mill 2**	**N mid term Mill 2**	**Mean endline Mill 2**	**N endline Mill 2**
Key challenges: Unavailability of labour	64%	84	100%	84	98%	84
Key challenges: Unavailability of agri inputs	58%	84	49%	84	65%	84
Key challenges: No resources to buy agri inputs	69%	84	20%	84	62%	84
Key challenges: Unavailability of water for irrigation	88%	84	20%	84	13%	84
Key challenges: My drip irrigation is in bad condition	58%	84	10%	84	2%	84
Key challenges: Attack of diseases and insect pest	64%	84	21%	84	65%	84
Key challenges: Poor quality of soil	33%	84	43%	84	2%	84
Key challenges: No facility for soil testing	27%	84	56%	84	2%	84
Key challenges: Delay in getting cutting order	20%	84	52%	84	17%	84
Key challenges: Low price of sugarcane	29%	84	60%	84	17%	84
Key challenges: (No) electricity/blackouts	2%	84	1%	84	1%	84
Key challenges: Delay in payment for produce from the mill			1%	84	90%	84
Key challenges: Transportation issues of produce to the mill					64%	84
Agricultural practices	**Mean baseline Mill 2**	**N baseline Mill 2**	**Mean mid term Mill 2**	**N mid term Mill 2**	**Mean endline Mill 2**	**N endline Mill 2**
Use single bud setts	51%	81	21%	14	32%	25
Use seed nurseries	0%	84	6%	84	0%	28
Uses chemical fertiliser	100%	84	100%	84	96%	84
Uses organic fertiliser	85%	84	94%	84	15%	84
Source organic fertiliser: own farm	63%	71	96%	79	100%	13
Source organic fertiliser: other farmers	17%	71	3%	79	0%	13
Source organic fertiliser: mill	15%	71	35%	79	0%	13
Source organic fertiliser: government	0%	71	1%	79	0%	13
Applies pesticides	100%	84	100%	84	100%	84
Applies chemical pesticides	18%	84	11%	84	100%	84
Applies organic pesticides	1%	84	0%	84	0%	84

Applies both chemical and organic pesticides	81%	84	89%	84	0%	84
Applies pesticides preventively	100%	2	100%	20	100%	82
Applies pesticides curatively	0%	0	0%	0	0%	0
Applies pesticides preventively and curatively	100%	82	100%	64	100%	2
Intercropped at least one crop with sugar	5%	84	1%	84	6%	84
Used appropriate row to row spacing for irrigation system used	46%	84	88%	84	93%	28
Ploughs using a tractor	0%	84	0%	84	0%	84
Burns land after harvest	6%	84	4%	84	20%	84
Access to trash shredder	4%	84	0%	2	8%	84
Owns a trash shredder	100%	3	0%	84	6%	84
Uses a mulch trash	0%	0	98%	84	4%	84
Used irrigation system: furrow	54%	84	48%	84	69%	84
Used irrigation system: surface drip	46%	84	88%	84	1%	84
Used irrigation system: sub surface drip	0%	84	0%	84	0%	84
Used irrigation system: drip combined with fertigation	23%	84	33%	84	33%	84
Uses preferred irrigation system	18%	84	89%	84	100%	84
Uses any form of drip irrigation	46%	84	88%	84	35%	84
Adopted or changed any practices in the past 5 years to improve water efficiency					11%	84
Count of activities mechanised			6.15	84	593%	28
Costs and income	**Mean baseline Mill 2**	**N baseline Mill 2**	**Mean mid term Mill 2**	**N mid term Mill 2**	**Mean endline Mill 2**	**N endline Mill 2**
Revenue per acre	65,433	84	15,0865	84	85,851	28
Estimated income share from sugarcane production					35	84
Estimated income share from other crops					63	84
Estimated income share from non-farm activities					1	84
Total costs of planting material per tonne produced	320	84	59	84	220	28
Total costs of chemical fertiliser per tonne produced	140	84	58	84	97	28
Total costs of biological fertiliser per tonne produced	127	84	74	84	128	28
Total costs of weedicide per tonne produced	32	84	8	84	11	28
Total costs of pesticides per tonne produced					32	28
Input costs per tonne (excl. labour)	600	84	196	84	461	28
Labour costs per tonne	682	84	595	84	265	28
Total costs per tonne	1,281	84	791	84	727	28
Total production costs per acre	30,531	84	41398	84	22,696	81
Total farm income (revenue - production costs)	146,965	84	473198	84	347,903	28
Total costs	112,813	84	161913	84	67,906	39
Profit per acre	34,902	84	109468	84	71,743	28
Profit per tonne	-1,905	84	-4641	84	2,132	27
Labour costs per acre	16,943	84	31244	84	8,259	81
Input costs per acre	13,588	84	10154	84	14,438	81

Table 10.8 Descriptive statistics of key indicators for Mill 3 farmers

Programme engagement	Mean baseline Mill 3	N baseline Mill 3	Mean mid term Mill 3	N mid term Mill 3	Mean endline Mill 3	N endline Mill 3
I have/had access to a demonstration plot on sugarcane cultivation			7%	214	81%	214
I receive(d) assistance from the extension worker for the mill			6%	214	13%	214
I receive(d) assistance from a lead farmer			17%	12	22%	214
I received training on good agricultural practices in sugarcane production, on irrigation methods, techniques and maintenance, on farm mechanisation, on trash shredding or on financial literacy.	0%	214	1%	214	15%	214
Remember topic from programme engagement: Financial planning					2%	214
Remember topic from programme engagement: Intercropping					23%	214
Remember topic from programme engagement: Bio compost					7%	214
Remember topic from programme engagement: Wide row spacing					27%	214
Remember topic from programme engagement: Drip irrigation					91%	214
Remember topic from programme engagement: Trash mulching					6%	214
Remember topic from programme engagement: Mechanisation					51%	214
Remember topic from programme engagement: Other					1%	214
Applies information learnt in engagement on: Financial planning					0%	5
Applies information learnt in engagement on: Intercropping					55%	49
Applies information learnt in engagement on: Bio compost					20%	15
Applies information learnt in engagement on: Wide row spacing					97%	58
Applies information learnt in engagement on: Drip irrigation					95%	194
Applies information learnt in engagement on: Trash mulching					17%	12
Applies information learnt in engagement on: Other					61%	110
Wants further training	100%	214	100%	189	85%	214
Farm(er) characteristics	**Mean baseline Mill 3**	**N baseline Mill 3**	**Mean mid term Mill 3**	**N mid term Mill 3**	**Mean endline Mill 3**	**N endline Mill 3**
Gender of respondent	11%	214	11%	214	11%	214
Respondent is household head	81%	214	81%	214	81%	214
Number of household members	5.5	214			6.6	214
Received any kind of education	93%	214	81%	214	72%	214
Likelihood of falling below the 2.50$ a day poverty line (PPP 2005)	70.4	214	53.5	214		
Is member of a farmer group	5%	214	5%	214	7%	214
Total area used for sugarcane	3.4	214	6.0	214	4.9	214
Total area used for other crops	1.6	214	2.9	214	4.1	214
Sugarcane area: owned	3.3	214	5.3	214	4.6	214
Other crop area: owned	1.6	214	2.5	214	3.6	214
Sugarcane area: leased	0.1	214	0.8	214	0.3	214
Other crop area: leased	0.0	214	0.4	214	0.4	214
Total area owned	4.8	214	7.8	214	8.3	214
Supply to the mill in tonnes	100	213	194	214	0	197

Total tonnes harvested			212	214	117	197
Productivity per acre	36.9	213	32.3	214	26.0	179
Price received per tonne	2299	214	2949	214	2591	197
Taken out loan in past year	76%	214	97%	214	88%	214
Did you follow a training on financial literacy in the past 2-3 years?			12%	214	2%	214
Household has savings	42%	214	83%	214	41%	214
Household received a subsidy	42%	214	99%	214	2%	214
Subsidy for: surface drip irrigation	8%	89	95%	212	100%	4
Subsidy for: sub surface drip irrigation	2%	89	1%	212	0%	4
Subsidy for: Other irrigation system, specify	83%	89	0%	212	0%	4
Subsidy for electricity	2%	89	91%	212	0%	4
Subsidy for water pump	1%	89	3%	212	0%	4
Subsidy for fertiliser	8%	89	0%	212		0
Key challenges	**Mean baseline Mill 3**	**N baseline Mill 3**	**Mean mid term Mill 3**	**N mid term Mill 3**	**Mean endline Mill 3**	**N endline Mill 3**
Key challenges: Unavailability of labour	89%	214	98%	214	96%	214
Key challenges: Unavailability of agri inputs	33%	214	7%	214	2%	214
Key challenges: No resources to buy agri inputs	11%	214	7%	214	19%	214
Key challenges: Unavailability of water for irrigation	82%	214	95%	214	2%	214
Key challenges: My drip irrigation is in bad condition	10%	214	8%	214	5%	214
Key challenges: Attack of diseases and insect pest	23%	214	32%	214	4%	214
Key challenges: Poor quality of soil	16%	214	27%	214	0%	214
Key challenges: No facility for soil testing	50%	214	44%	214	9%	214
Key challenges: Delay in getting cutting order	67%	214	31%	214	80%	214
Key challenges: Low price of sugarcane	64%	214	45%	214	83%	214
Key challenges: (No) electricity/blackouts	7%	214	2%	214	1%	214
Key challenges: Delay in payment for produce from the mill			25%	214	99%	214
Key challenges: Transportation issues of produce to the mill					95%	214
Agricultural practices	**Mean baseline Mill 3**	**N baseline Mill 3**	**Mean mid term Mill 3**	**N mid term Mill 3**	**Mean endline Mill 3**	**N endline Mill 3**
Use single bud setts	91%	214	6%	207	18%	197
Use seed nurseries	0%	214	14%	214	53%	197
Uses chemical fertiliser	100%	214	100%	214	99%	214
Uses organic fertiliser	60%	214	89%	214	45%	214
Source organic fertiliser: own farm	65%	129	54%	191	74%	96
Source organic fertiliser: other farmers	44%	129	71%	191	67%	96
Source organic fertiliser: mill	2%	129	14%	191	6%	96
Source organic fertiliser: government	0%	129	1%	191	1%	96
Applies pesticides	87%	214	23%	214	84%	214
Applies chemical pesticides	86%	214	20%	214	83%	214
Applies organic pesticides	0%	214	2%	214	0%	214

Applies both chemical and organic pesticides	1%	214	0%	214	0%	214
Applies pesticides preventively	63%	75	1%	167	13%	40
Applies pesticides curatively	80%	137	22%	212	83%	209
Applies pesticides preventively and curatively	52%	58	0%	165	0%	35
Intercropped at least one crop with sugar	1%	214	0%	214	12%	214
Used appropriate row to row spacing for irrigation system used	60%	214	99%	214	88%	197
Ploughs using a tractor	0%	214	0%	214	0%	214
Burns land after harvest	44%	214	85%	214	78%	214
Access to trash shredder	0%	214	12%	214	0%	214
Owns a trash shredder	100%	1	0%	214	0%	214
Uses a mulch trash	0%	0	11%	214	37%	214
Used irrigation system: furrow	40%	214	6%	214	25%	214
Used irrigation system: surface drip	3%	214	98%	214	85%	214
Used irrigation system: sub surface drip	2%	214	2%	214	0%	214
Used irrigation system: drip combined with fertigation	55%	214	84%	214	45%	214
Uses preferred irrigation system	10%	214	98%	214	100%	214
Uses any form of drip irrigation	60%	213	99%	214	88%	214
Adopted or changed any practices in the past 5 years to improve water efficiency					12%	214
Count of activities mechanised			4.52	214	2.23	197
Costs and income	**Mean baseline Mill 3**	**N baseline Mill 3**	**Mean mid term Mill 3**	**N mid term Mill 3**	**Mean endline Mill 3**	**N endline Mill 3**
Revenue per acre	84,856	213	95,323	214	67,542	179
Estimated income share from sugarcane production					55	214
Estimated income share from other crops					36	214
Estimated income share from non-farm activities					8	214
Total costs of planting material per tonne produced	208	213	40	214	150	179
Total costs of chemical fertiliser per tonne produced	71	213	45	214	298	179
Total costs of biological fertiliser per tonne produced	133	213	89	214	341	179
Total costs of weedicide per tonne produced	30	213	6	214	15	179
Total costs of pesticides per tonne produced					18	179
Input costs per tonne (excl. labour)	413	213	183	214	522	179
Labour costs per tonne	720	213	588	214	449	179
Total costs per tonne	1,133	213	771	214	971	179
Total production costs per acre	37,355	213	24,222	214	22,457	211
Total farm income (revenue - production costs)	125,455	213	442,211	214	236,468	179
Total costs	105,529	213	132,427	214	94,228	197
Profit per acre	47,502	213	71,101	214	44,608	179
Profit per tonne	-2,278	213	-2,390	214	1,623	177
Labour costs per acre	24,796	213	18,734	214	10,608	211
Input costs per acre	12,559	213	5,488	214	11,849	211

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