Doubling sugarcane farmers' income by 2022 – strategies and way forward for sugarcane Farmers

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Doubling farmers' income for sugarcane farmers

1. Introduction

India is the largest consumer of sugar in the world and next to Brazil, second largest producer of sugar in the world. Next cotton, sugarcane is the second important industrial crop in the country cultivated in about five million hectares. Growth in cane area and sugar production in the country during last eight decades had been spectacular. Cane area witnessed a fourfold increase from an area of about 1.17 m ha in 1930-31 to 4.93 million ha during 2015-16. During this period the yield also has improved substantially from 31 t/ha to 70.7 t/ha. Correspondingly, sugarcane production increased from 37 million tonnes to 348.44 million tonnes and from 0.12 million tonnes in 1930-31, sugar production touched 27.9 million tonnes during 2015-16. Sugar recovery also showed an improvement from 9.05% to 10.61%. Number of sugar factories in operation went up from 29 to over 526 during 2015-16. In India, sugarcane is grown under varied agro-climatic conditions. Crop faces various biotic and abiotic stresses that impact the productivity in a significant way. Major disease affecting crop is red rot prevalent throughout the country, which has been largely managed through the deployment of resistant varieties. Decades of sugarcane research form a strong technological base for making these achievements feasible. Equally both farmers and industries benefitted and reaped rich dividends from the technological breakthroughs which helped them to overcome various challenges and limiting factors.

Sugar requirement is expected to grow substantially in the coming years due to the population growth which increases per capita consumption and changing consumer preferences towards variety of dishes, value added food products, high demand for beverages and indigenous sweets. Sugarcane is also emerging as a multi-faceted crop backing to production of sugar, ethanol, electricity, paper and other allied products. Consequently, overall demand for sugarcane for its varied uses will increase significantly. However, area under the crop is not likely to increase in phase with the demand and therefore, increased demand for sugar is to be met only through vertical growth in sugarcane productivity and sugar recovery. Thus sugar sector demands for steady increase in sugarcane production thorough sustained growth which provides ample opportunities to increase the farmers' income through optimal resource use and adoption of relevant and potential technologies by the farmers.

A critical analysis of various issues to be addressed for ensuring growth sustainability and increasing income level to cane farmers revealed the presence of following ground realities across the country:

Continued mono-cropping of sugarcane without crop rotation and organic recycling for several decades have depleted soil fertility considerably. It is reported that there is an estimated loss of 4.5 to 7.9% in sugarcane yield due to soil degradation in India. Soil productivity has come down due to the degradation of the physical and chemical properties and decline in rhizosphere microbial activities. Decline in soil organic carbon content has been very apparent over the years affecting productivity. Sugarcane is cultivated in about 7-8 lakh hectares under saline and alkaline soils. Though the crop is moderately tolerant to salinity, losses are significant.

Climate change effect has got significant effect influence over the sugarcane production system across the country with frequent draughts, floods and diseases. Approximately, 2.97 lakh ha of sugarcane area are prone to drought, affecting the crop growth leading to 30-50% reduction in yield. Floods and water logging are serious problems in Eastern UP, Bihar, Orissa, Coastal Andhra Pradesh and parts of Maharashtra. Approximately 2.13 lakh ha of sugarcane area are flood/water logging prone in different states. Water logging affects all stages of crop growth and can reduce germination, root establishment, tillering and growth which will lead to reduced yield.

Major diseases like smut, wilt and yellow leaf disease (YLD), are need to be managed effectively through tissue culture-based seed nursery programme combined with virus-indexing. Pests, particularly borer pests, continue to be a threat to sugarcane productivity and efforts for management of pests through behavioural, chemical and biological methods have been partially successful.

Increasing cost of cane cultivation is another major factor for deceasing farm income in the recent past. Sugarcane requires 300 to 350 man labourers for its crop season. Decreasing working hours per unit of labour, quality of labour hours and ever increasing wages had increased production cost.

Through promoting resource conservation crop production technologies such as precise irrigation methods, site specific fertilizer application, and supporting farmers with timely weather forecast, weather and crop advisories, ICT based technology back stopping and

farmer centric credit system and site specific insurance scheme it is possible to overcome the emerging challenges prevailing in the cane production system.

Emerging crop scenario in sugarcane is a multidimensional one in terms of demand, production constraints, opportunities and technology landscape. To achieve doubling of farmers' income, strategic planning becomes absolutely essential taking into consideration the core issues cane cultivation to be addressed, resources availability, investments to be made, technological requirements etc. Draft outline of this paper is an effort to visualise the emerging scenario and make a quantitative assessment of the sectorial needs and to evolve production targets to achieve doubling of farmers' income in a specified timeframe of 2022 in the country.

The policy orientation is organised into three parts. The first part gives the details about current cost of production and income to farmers across the country. Second part deals with various improvements and production scenarios required to meet the desired objective of doubling farmers' income and finally policy options and action points for doubling farmers' income in the country.

Cost of Sugarcane production and income to farmers

It is important to know the current level of farmers' income and opportunities available in the sugarcane farming to increase the profitability of farmers across the country to frame appropriate action plan and course of action that can be suggested for implementation. Among all other things, Cost of production (CoP) is one of the important factors in determining Fair and Remunerative Price (FRP) of sugarcane. Commission for Agricultural Costs and Prices (CACP) uses the cost estimates furnished by DES, Ministry of Agriculture and Farmers Welfare under comprehensive scheme (CS) for studying the cost of cultivation of principal crops in India. Since, CS data is generally available with a time lag of two years, it needs to be projected for the ensuing crop year 2016-17 *i.e.* sugar season 2017-18 state-wise and all-India level. These projected cost estimates are factored into formulation of price policy recommendations.

The Commission has projected CoP estimates for sugar season 2017-18, based on actual estimates for the latest three years *viz*. 2012-13 to 2014-15 for major cane growing states. These projections capture movement in overall input cost separately for the crop year 2016-17. An assessment of overall movement in input cost likely for the crop year 2016-17 with reference to each of the three consecutive years ending with 2014-15 is made by constructing the Composite Input Price Index (CIPI) based on latest prices of different inputs like human labour, bullock labour, machine labour, seeds, fertilizers, manures, insecticides and irrigation charges

sourced from Labour Bureau, State Governments, Office of the Economic Adviser (OEA), Ministry of Commerce and Industry, Fertilizers Association of India (FAI) etc. Based on CIPI thus constructed, the Commission has projected CoP for 2017-18 sugar season and the same is given hereunder at Table-1.It can be inferred from the table-1 that the cost of cultivation ranges from Rs 172 in Karnataka (lowest) to Rs 278 in Haryana which is the highest. The challenge here is how to address this wide gap I the cost of cultivation and increase the profitability in the states like Tamil nadu where the average yield of the state is already crossed 100t/ha. On one hand the strategy need to address the issues like reducing the cost of cultivation and on the other hand to achieve the possible potential yield under farmers' condition. Simultaneously we need to explore the opportunities for income generation potential of the crop in terms of other potential areas like fuel, fodder and value addition.

Table-1. Calculation of farmers income based on CACP Data - 2017 -18

States	Cost /Quintal	SAP at 2017-18/Quintal	Average yield (Q/ha)	Income (Rs./Quintal)	Farmers income (Rs./ha)
Andhra Pradesh	213	260.0	776	47.00	36,472
Haryana	278	305.0	732	27.00	19,764
Karnataka	172	261.5	880	90.00	78,760
Maharashtra	183	273.3	797	90.00	71,969
Tamil Nadu	212	285.0	1041	87.00	75,993
Uttar Pradesh	234	280.0	618	46.00	28,428
Uttarakhand	222	280.0	594	58.00	34,452

Source: Base data was drawn from Commission for Agricultural Costs and Prices (CACP)

Using the base data given at Table-1 on the projection and estimates, cost of production, revenue and income for all India was calculated and given in the Table 2.

Table.2. Average yield, cost of production and farmers income of sugarcane crop

Item	Average yield (t/ha)	Cost of production (C)/tonne of cane	Cost of production (C)/ (Rs./ha)	Fair and remunerative price (Rs.)/tonne	Farmers revenue (Rs./ha)	Income earned by farmers (Rs./tonne)	Income earned by farmers (Rs./ha)
All India	71.0	2,270	16,1170	2,550	18,1170	280	19,880

Source: CACP Calculations based on data received under DES, Ministry of Agriculture and Farmers Welfare.

It can be considered that a sugarcane farmer on an average need to spend Rs 1.61 lakh for sugarcane cultivation in one ha of land and expected to earn about Rs.19,880/ha as net profit across the country. Profit margin available for farmers is low because of increase in cost of production and stagnated crop yield. The feasibility of doubling the net profit from Rs 19,880/ha to Rs.39760 by 2022 therefore need explore the issues like constraints faced by the farmers, technological options available for interventions, socio-political and economic issues to be addressed, capacity development, building of grass root level supportive infrastructure for farming etc. in a holistic way to integrate the precise resources for synergistic effect. In order to critically understand the potential profit opportunity available for the sugarcane farmers a critical analysis of inter-crop Price Parity was attempted and discussed here under.

Inter-Crop Price Parity

To appraise inter crop price parity, the CACP computes per hectare returns of different crops that substitutes for each other. On critical examination of the details of inter-crop price parity analysis for the four important remunerative crops namely sugarcane, paddy, wheat and cotton revealed (Annexure-I) that relative returns for sugarcane in reference to other three crops is higher. It is observed that sugarcane is the most profitable crop vis-à-vis its competing crops like wheat, paddy and cotton. Net returns as percent of cost turns out to be 52 percent in sugarcane during 2012-13 to 2014-15 at all India level compared with paddy (12 percent), cotton (15 percent) and wheat (27 percent). It is an important factor that compared to wheat or rice sugarcane is a crop of 12 months duration and the crop cycle on an average is about three times more that of wheat and paddy. Therefore, the returns have been normalized for time duration and returns per month have been derived for these competing crops. It is observed that per

hectare gross returns for sugarcane at all-India level is generally higher or close to those of wheat and paddy, even after adjusting the crop duration.

Though, income of the sugarcane is comparatively higher than other competing crops, we can observe disparity in income among sugarcane farmers in the country (Annexure 1). It can be observed from the details given in the table at Annexure-I that farmers' income has recorded lowest in Uttar Pradesh, Uttarakhand and Andhra Pradesh and maximum was realised in Tamil Nadu, Maharashtra and Karnataka. Whereas, out of total cane area cultivated 40 per cent area is in UP state and the state realised lowest income. Considering all the above facts and figures, three possible means/strategies were discussed keeping in mind the low income group of states and also the requirements of the farmers in the states where already higher income/return is achieved. An overview of the criteria to be considered, objectives to be addressed and approaches to be followed for reaching the goal of doubling the famers' income across the cane producing states are given here under at Table 3.

Table 3 Approaches for achieving the goal of doubling farmers' income

Criteria	Objectives	Approaches
Increasing the yield and Recovery	To increase the income per hectare	Cultivation of suitable Varieties and use of cutting edge technologies like in land preparation, soil and water management, fertility management, selection of disease free planting materials, sett treatments, use of tools and machinaries for prevention of harvest loss etc
Resource conservation	To reduce the cost of cultivation	Maximisation of resource use efficiency for cost reduction and optimisation of resource use. Use of resource conservation technologies, INM, precision farming techniques, augmenting bio-resources in the farm and less external input and sustainable farming practices.

Managing loss due to biotic and abiotic stress, climate change effects	Prevention of crop loss due to diseases and other stressors.	Effective disease management, use of IPM practices, periodical weather advisory and crop advisory during draught and flood, combating climate change effects through technological interventions and monitoring and surveillance of insects ,pests and diseases across the county for their elimination and minimisation of crop loss through integrated approaches.
Capacity Building and Reaching the unreached	Improving the farmers' capacity and ensuring the availability and accessibility of recommended technologies by the farmers	Establishing and strengthening linkages at all levels of research-extension-farmer-industry continuum and organising farmers group and field school for horizontal spread of technologies and use of ICT

2. Strategy of Improving Cane yield and Sugar recovery

2.1 Increasing Sugarcane Yield

The yield-gap analysis revealed huge gap between the potential and feasible yield in sugarcane under research station condition, which is and the actual yield obtained under farmers' field. Current average yield in our country is hardly 21% of the technical and economic yield potential of the sugarcane crop (339.42t/ha). The yield gap is as high as 80t/ha in the tropical and 65 t/ha in sub-tropical regions of the country (Annexure IV). Wide gap exists between the potential yield and the yield realized at present across the country.

CACP recommends a Fair and Remunerative Price (FRP) for sugarcane to be Rs. 255/qtl. at 9.5 percent recovery level for 2017-18 sugar season. With every increase in recovery by 0.1 percentage point, the FRP will increase by Rs. 2.68/qtl (Annexure II). The average sugar recovery was 10.60 during 2015-16. Disparity in yield and sugar recovery significantly affects income of the sugarcane farmers in the country (Annexure III). So, increasing yield and sugar recovery with the assumption of cost of cultivation and output price remains constant. The warranted growth of yield and sugar recovery to double income of the farmers in 2022 was given in the Tables 4 and 5.

Table: 4. Current yield and warranted yield and expected income by 2022 in India

Unit	Base line yield (t/ha) at 2016-17	Warranted yield growth (t/ha) at 2022	Income earned by the farmers at base year (Rs./ha)	Expected income at 2022 (Rs./ha) by increased yield
All India	71.0	78.8	19,880	39,760

2.2 Sugar recovery

Every 0.1 % increase in sugar recovery is equivalent one unit yield improvement in term of revenue and cane yield. Increasing yield coupled with sugar recovery will be really pragmatic approach to double the farmers' income by 2022. The base line sugar recovery, expected sugar recovery and yield equivalent were given in the Table 5.

Table: 5. Current level of sugar recovery, yield equivalent and expected income by 2022

Item	Base line recovery (t/ha)	Expected recovery (% cane) at 2022	Yield equivalent (t/ha)	Expected income at 2022 (Rs./ha) by increased sugar recovery
All India	10.60	11.0	4.0	10,200

2.3. Combination of yield and sugar recovery

Increasing yield over 10 % of the existing yield with the span of five years will be a daunting task due to various biotic and abiotic stresses influencing sugarcane production system. Nevertheless, increasing yield of 50 % of the targeted yield (75t/ha) with 0.4 unit improvement in sugar recovery shall be possible with adoption of suitable varieties along with production cum protection technologies recommended by ICAR- SBI for the sugarcane horizon of our country (Table 6). Consequently, short and medium term plan of action was chalked out and discussed below.

2.4. Strategies for yield and recovery improvement

Current scenario with respect to sugarcane in the past two to three decades in the country has remained static with respect to production, productivity and sugar recovery. The concern is that yield remained unchanged since 20 years. Though better varieties and crop production technologies have been developed over the years, their impact has not been duly reflected in the overall productivity. The potential of the existing varieties and technologies remains indisputable, since record yields of 290 t/ha have been achieved by innovative farmers using the existing varieties and technologies. Apart from the fact that the technology adoption remains at low levels in major sugarcane growing states. Since scope for improvement in sub-tropical India very much possible the technological recommendations to increase the yield and recovery for sub-tropical and tropical states are given here under at Table: 6 and 7 respectively.

Table: 6 Recommended technological interventions for increasing yield and Recovery in Sub-tropical states.

Technological	Recommended Technologies	Problems addressed and Expected Out Come
Varieties	Co 87263, Co 89029, Co 98014, Co 0118, Co 0232 and Co 0233 Co 0238, Co 0237, Co 0239, Co 0124, Co 05009, Co 05011, Co 06034 and Co 09022	➢ High yielding and high sugar recovery variety. ➢ Yield improvement is 15t/ha is higher than existing variety. ➢ Improvement of sugar recovery is more than 1 unit ➢ Ideal for sub –tropical climatic conditions.
Planting system	Settling transplanting technique (STT) Trench planting	➢ 12,500 settlings per hectare are required in case of bud chip planting against 50000 setts for conventional method. ➢ Saving considerable amount of seed materials. ➢ Bud chip gave a sprouting and survival of more than 80% plantlets. ➢ Trench method of sugarcane planting produces significantly higher cane yield. ➢ Saves water because trenches are irrigated and not whole field. ➢ Trench system of planting in saline soils and salt water irrigated areas recorded improved yields of around 15%.
Nutrient Management	Split application of N and K fertilizers; two or three splits, band application	Sugarcane is a long duration crop having huge biomass production potential demands large amounts of water, nutrients and sunlight. It is

	covering with soil and irrigation	always better to apply manures and fertilizers based on soil test recommendations.
	Need based micronutrient fertilization: Fe and Zn	Crop yields are drastically reduced when the nutrient concentration fall below the critical limits.

2.4.1 Sub-tropical India

Adoption of new improved variety for cane yield and sugar recovery - variety Co 0238

Co 0238 was evaluated at seven locations under the AICRP (Sugarcane) during 2006-08 in North West Zone (NWZ). It ranked as number one for cane yield (81 tonnes/ha) in comparison to CoJ 64, a well-known early maturing variety of North West Zone (NWZ). The jaggery of Co 0238 is of first grade quality with light yellow colour. This variety is moderately resistant to the prevalent races of red rot pathogen.

This variety has spread in the field at a much faster rate as it combines both high cane yield and better juice quality and hence is being preferred by both farmers and sugar mills. Since 2012-13, the area under Co 0238 has been increasing at a faster rate in all the five major sugarcane growing states, viz. Uttar Pradesh, Bihar, Punjab, Haryana and Uttarakhand in sub-tropical India. Though, this variety was released and notified for NWZ, however, it has crossed the boundaries of the zone to reach Eastern UP, Bihar, Madhya Pradesh and Odisha. During 2016-17, about 34% of the total cane area (26,26,030 ha) in North India was cultivated by Co 0238 (8,91,196 ha). Punjab had the maximum coverage (62.8 % area) followed by Haryana (39.45 %), UP (35.47%), Uttarakhand (17%) and Bihar (11.6%).

The advantage with early-maturing varieties is that farmers can get high recovery from November and all through the crushing season. The UP government has fixed a state advised price (SAP) of Rs 315 per quintal for early-maturing cane, as against Rs 305 for general varieties. Adoption of early maturing varieties fetches additional income without incurring extra expenses.

Farmers have also gained higher yields from this variety. Before Co 0238, the cane varieties cultivated in northern India were all ‘medium-thin’, with the average diameter of each stick at 2-2.25 cm. Co 0238, by contrast, is ‘medium-thick, whose individual cane sticks have

a diameter range of 2.5 to 3 cm. Even the average reported yields of 80 tonnes hectare for Co 0238 work out 15-20 tonnes more than that for CoS 767, till recently the most widely cultivated cane variety in UP state. Similarly, sugar recovery was higher by 1.5% due to Co 0238. So, farmers could earn additional income to farmers from Rs 47,250 to Rs 63,000 per hectare. Adoption of this variety Co 0238 would double the farmers' income before 2022 with proper management practices which is prescribed during varietal release and package of practices.

2.4.2 Popular Sugarcane variety for Tropical India - Co 86032 (Nayana)

Sugarcane variety Co 86032, released for commercial cultivation in the Peninsular Zone in 2000. This is most popular sugarcane variety in the tropical India. Variety Co 86032 is being cultivated over 65 per cent of the cane area in Tamil Nadu and over 50 per cent of the cane area in the states of Karnataka, Maharashtra and Gujarat and sizable cane area in Andhra Pradesh and Orissa. This is a very rare instance of a single crop variety is cultivated almost entire cultivated area in a state as in Tamil Nadu.

Co 86032 (Nayana) variety notified for commercial cultivation in the Peninsular Zone in 2000. The variety has proved to be suited for almost all situations in the peninsular India. Co 86032 has contributed significantly in sustaining high productivity in the states viz., Tamil Nadu, Karnataka, Maharashtra and Gujarat. Productivity in these states were constantly high compared to other states (Annexure IV). Average yield in these states was 84.3 t/ ha which is almost 19% higher than national average.

There was tremendous increase in sugar production as well as sugar recovery in tropical India. Sugar recovery was improved from 0.5 to 1.0 unit. It has contributed for average yield improvement of over 10 t/ha with recovery improvements of 0.5 units. However, in recent past, yield and sugar recovery were reduced due to varietal degeneration. Disease free healthy seed material is immediate need for reviving yield and sugar recovery in tropical India.

Under Indian scenario, diseases viz. mosaic and YLD are the serious viral diseases. These diseases occur in all sugarcane growing regions and varieties under cultivation exhibit varying intensities of diseases. YLD is caused by sugarcane yellow leaf virus (SCYLV). Due to vegetative propagation, these viral pathogens along with other non-fungal pathogens causing RSD and GSD gradually increase in their load in sugarcane over generations. Such a high population of different pathogens cause a decline in the performance i.e. loss in vigour of sugarcane varieties and this progressive decline in crop performance, referred to as 'varietal degeneration'. Due to this, longevity of many elite sugarcane varieties was reduced earlier. Variety degenerates faster and its potential comes down in due course of time.

It is estimated that severe infection of the virus reduces cane yield by 30 to 50 % and juice yield by 34%. Tissue culture derived planting materials (virus free setts) always maintained a better crop stand than the affected fields which had conventional planting materials. Recently a farmer who planted popular variety Co 86032 free from diseases has recorded a yield of 100 tonnes per acre at Vellode in Erode Dt. in Tamil Nadu. The recommended technologies for increasing yield and Recovery in Sub-tropical states are given here under in Table7.

Table: 7 Recommended technological interventions for increasing yield and Recovery in tropical states.

Technological	Recommended Technologies	Problems addressed and Expected Out Come
Varieties	Co 85004, Co 86032, Co 86249, Co 87025, Co 87044, Co 8371, Co 91010, Co 94008, Co 99004, Co 2001-13, Co 2001-15, Co 0218, Co 0403, Co 06027, Co 06030 and Co 09004	➢ High yielding and high sucrose and tolerant to red rot. ➢ Variety has proved to be suited for almost all situations in the peninsular India. ➢ Co 86032 has contributed significantly in sustaining high productivity in the states viz., Tamil Nadu, Karnataka, Maharashtra and Gujarat.
Planting system	Wide row planting	➢ Facilitates better spacing ➢ Conducive for intercropping ➢ Ideal for mechanisation of farm operations and mechanical harvesting.
Nutrient Management	Soil testing and adoption of Integrated Plant Nutrient System	➢ Soil test based fertilizer application takes into consideration the fertility status of the soil and ensures balanced fertilizer use.
Ratoon management	Ratoon management device	➢ Ratooning is more profitable as compared to plant crop.

		➢ Land preparation, planting operation and seed are not required. ➢ Saves Rs. 15000 –Rs. 20000 of cost of cultivation.

3. Strategies to reduce cost of cultivation

High cost of cultivation of sugarcane has resulted in reduced profits for farmers and has lead to diversification towards cultivation of other remunerative crops. Sugarcane is a labour and input intensive crop which remains in the field for more than a year. Cost of cultivation of sugarcane has gone up significantly due to the increase in cost of labour and inputs. Labour availability for major operations like harvesting also has become scarce due to migration of labourers seeking urban employment. Development of varieties and technologies suited for mechanization has become imperative now under the circumstances. The steep rise in cost of production, non- availability of labour in adequate numbers and in time for harvesting and high cost of inputs are eroding the profits and untimely operations has affected yield and sugar recovery which indirectly led poor realisations from sugarcane crop.

There is a labour shortage and wage rates have been increasing rapidly in the recent years. Therefore, it is high time to respond to this situation by promoting mechanization of planting and harvesting operations. Farmers in UP observed that planters were being used to plant sugarcane which has resulted in higher yields with less input cost. Given that labour availability is becoming a major constraint and farm wages are rising, mechanization of sugarcane cultivation is becoming a dire necessity.

Modern sugarcane machinery and labour saving devices were introduced at large scale to reduce dependency of labour and complete the farm operation in time. Mechanical operations proved that it was superior to manual operations. It reduced cost of production and enable efficient utilization of resources with better work output. Furrow method of irrigation requires about 320 man-hour as against drip irrigation requires of only 40 man-hours. Now it is inevitable to use modern sugarcane machinery, which is now available in the-country such as sugarcane planters, mechanical weeders and imported harvesters. Although their initial price is very high but advantages accrued in their use are much more. All these factors along with rising cost of cultivation, has necessitated to illustrate cost saving measures and reduction of cost of cultivation are given below.

3.1. Land Preparation

Sugarcane crop requires well prepared seed bed. In sugarcane production tillage is done with the help of nine tyne spring loaded cultivator mould board plough, disc plough, heavy disc harrow, duck foot tillers, rotavators, blade tracers, land planer, bund former, trencher, ridger, furrower and other local tillage tools whereas, in conventional method, bullock pair was used to prepare the seed bed. The studies show that the cost involved in conventional methods is Rs 14000/ha including 320 man-h with 46 bullock pair hour/ha, while in mechanized system (Rs.10,300/ha) (Annexure V). It has reduced Rs 3,800/ha and large amount labour hours.

3.2 Weeding

Sugarcane requires number of intercultural operations for weed control, moisture conservation, microbial action and creation of better environment for overall growth of the plant. After emergence, weeding is done with the help of animal or tractor operated cultivators. Manual weeding with sickle is a very common practice. It is cost about Rs. 6,400/ha (Annexure 5). Use of self-propelled rotary weeder and lightweight power tillers, tractor with ridgers and discs are being followed for intercultural and earthing up of sugarcane. Multipurpose tractor operated equipment are also being used for this purpose. Cost of mechanical weeding and inter culture is about Rs 3,250/ha. It saved about 50 % of the expenses as compared to manual weeding.

3.3 Earthing Up

After weeding, the soil has to be recouped to prop up the sugarcane plant. It is done with the help of male labours with spade. Manual operations with spade are a very common practice, it cost about Rs 8750/ha (Annexure V). Due to labour scarcity, farmers are using bund famer which cost about Rs 3,250/ha. The farmer could save about Rs. 5500/ ha by employing machinery.

3.4 Irrigation

Number of irrigations to sugarcane crop varies among the states and between regions within the state. Number of irrigation varies depending upon rainfall pattern/climatic conditions, soil types and source of irrigation water.

On an average, the number of the irrigation is 35–40 in tropical India. In drip irrigation, the labour saving hours about 10 times higher than furrow method of irrigation (Annexure VI). In addition, it helps farmers to apply fertiliser through irrigation water (fertigation). Some innovative farmers are operating their electric motors by using mobile to switch on/off whenever it is required. This complete mechanisation cum automation saved 40 man days/ha.

Since drip system was highly subsidised, mechanised irrigation is being adopted without any obstacles.

3.5 Harvesting

Harvesting of sugarcane under contract mode is a common practice. Harvesting requires maximum man days among all the cultural operations. It involves base cutting, detrashing, detopping and bundle making followed by loading and transport. Mechanical harvesting was first introduced in 1996–97 by Sakthi Sugars (at Erode, Tamil Nadu) to cope up labour scarcity, high harvesting cost and to avoid delay in cane harvesting during peak season. It saved labour, cost and timely harvesting the crops (Annexure VII). It is estimated about 10% of the cane area at Tamil Nadu were brought under mechanical harvesting since 2014–2015. Area under mechanical harvesting need to be increased to 50% at 2021–2022 sugar season to reduce cost of cultivation.

3.6 Ratoon Management

Ratooning is a regular practice in sugarcane cultivation. Ratooning is more profitable as compared to plant crop as land preparation, planting operation and seed are not required. About 60% of sugarcane area is under ratoon crop. After harvesting, the field was left with sugarcane trash and crop residues. The trash was burned to clear the fields due to labour scarcity. To avoid burning of the trash, trash shudders was introduced to powder the trash. It paved a way for in situ trash mulching. In case of manual sugarcane harvesting, bottom portion of sugarcane is left out in the soil. Using the stubble shaver, stubble shaving is being done (Rs 1,500/ha). For manual stubble shaving, the farmer has to incur 100 labour hour and incurs a cost of about Rs.4,200/ha (Annexure V). In case of mechanical harvesting, sugarcane is harvested from the bottom portion, hence stubble shaving may not be required. Cost of mechanical stubble shaving is about 50 % lesser than manual practices followed for ratooning of sugarcane.

4 .Strategy for Enhancing Input Use Efficiency for productivity improvement and cost reduction

4.1 Settlings Transplanting Technique (STT)

Conventional planting of sugarcane with three budded setts requires about 8-9 t/ha planting material. There is possibility of utilizing bud chips and single budded settlings as seed material. Only 12,500 settlings per hectare are required in case of bud chip planting. Using bud chips and raising settlings in a nursery can save 80 per cent of the seed material compared to three budded setts. Methodologies for taking bud chips, treatment with insecticide and fungicide, storability, transport, raising of settlings in polythene bags/plug trays and their survival and establishment in field were standardized. Bud chip gave a sprouting and survival of more than 80% plantlets following two weeks of storage in transit. This is relatively less expensive and labour saving technique and is reliable method for multiplication of breeders' seed as well as promising seed stocks. After removal of bud chips, left out cane could be efficiently utilized for extracting juice for any purpose. Advancement of crop age of 30 to 40 days will be there due to transplanting settlings. Innovative applications for mechanically removing the bud chips by pedal operated bud chipping machine, pneumatic bud chipping machine, motorized bud chipping machine and transplanting the bud chip settlings mechanically by tractor drawn transplanter were developed by ICAR-SBI and CIAE. Sugarcane bud chip transplants (3000-5000/acre) are a low cost alternative to setts.

4.2 Soil Test Based Plant Nutrition System

Soil test based fertilizer application takes into consideration the fertility status of the soil and ensures balanced fertilizer use. Adopting fertilizer prescription based on soil test minimizes the risk of uneconomic use of fertilizer. Soil testing is a prerequisite to know nutrient imbalances in soil and apply required amount of nutrients to correct such imbalances and optimize crop nutrition. Soil test based fertilizer recommendation approach considers soil nutrient deficiencies and corrective measures for achieving optimum yield. There is wide variation in availability of nutrients. It varies between regions, soil types and between fields. Therefore it is best to follow 'field-based' approach to decide about the dosage. This needs information on soil available nutrient status, variety to be grown (high yielding or moderate yielding), soil reaction, availability of organic manures etc. Soil samples from the field concerned may be drawn and testing is done through soil testing laboratories of the agricultural departments or any other reliable agencies and recommendation is obtained.

Recommendation so obtained may be modified to some extent based on the variety to be grown or the addition of organic matter to be applied. In case of variety to be grown is different from the usual one in the sense that it is high yielding with high response to the higher dosage, an increase over recommendation derived through soil testing may be done. Information available about such varieties from the research stations or extension agencies about their fertilizer response should be used for this purpose. Recommended dosage may be reduced in case it has to be supplemented through other source. One of the important advantages of this approach is farmers have the options to relate their resources with a desired level of yield target. Choosing appropriate target and application of required amount of plant nutrient ensure the most judicious and balanced fertilization and also helps to sustain soil productivity and crop production. Targeted yield concept thus, strikes a balance between fertilizing crop and soil.

In order to reduce the cost of cultivation and also to keep the soil health and fertility in better condition to sustain productivity, there is an urgent need to find out some alternate sources of nutrients. Application of green manures, farm wastes and factories wastes along with bio-fertilizers are found to be useful in supplementing the in-organic fertilizers and also maintain cane productivity as well as soil fertility. In the light of ever increasing prices coupled with increasing demand of chemical fertilizer and depleting soil fertilizer necessitates integrated use of organic (renewable) and inorganic (non-renewable) sources of nutrient for sustainable crop production and better soil health. Therefore, there is a need for improvement of input use efficiency through proper integration of chemical fertilizer with organic manure, by balanced nutrition of crop. Soil test based integrated plant nutrient system has been contributed substantially to this package. Blanket recommendation may be applied only when other means of assessing exact dosage is not available.

4.3 Location specific variety

Performance of a variety is the major factor that decides success of sugarcane agriculture. Choice of correct set of varieties for a particular agro-climatic location is very vital in reaping best possible harvest, given other crop production and protection inputs in required measures. While some farmers are able to produce higher yield and productivity, many others are left with sub optimal crop yield. Choice of right varieties is focal point of achieving higher productivity. ICAR Sugarcane Breeding Institute is bestowed with the greatest job of developing varieties/facilitating all sugarcane research stations to breed varieties. At present 23 research centers located in almost all major sugarcane growing regions of the country take

part in the sugarcane breeding programmes and identify new clones for testing in different locations of five agro-climatic zones under the AICRP. There are enough location specific improved sugarcane varieties for higher yield and better sugar recovery are available at ICAR-SBI and respective research stations. Adoption of suitable varieties will be helpful in enhancing farmers' income and better living standards for farmers.

4.4 Wide row planting and inter-cropping with short duration pulses and vegetables

Harvesting of sugarcane in India is being done by human labourers. As this operation involves drudgery, availability of human labour for harvesting is gradually dwindling and wage rate is increasing in a sustained manner. Therefore, development of mechanical sugarcane harvester suitable for Indian conditions is the need of the hour. To facilitate the use of harvesters, row spacing needs to be increased to at least 120 cm. Adoption of wide rows would facilitate intercropping during initial stages of sugarcane growth, which will generate additional income for the sugarcane farmers. When sugarcane is grown adopting closer row spacing of about 90 cm, it takes about three months for closing in the canopy while it takes longer time under wide row spacing. The availability of more space and sunlight for a longer duration under wide rows facilitates growing of intercrops without any adverse effect on sugarcane. Under wide rows, as the availability of growth resources increases like solar radiation and space is more, medium canopied high yielding varieties of crops can be raised as intercrops. The yield and additional returns from intercrops will also be more compared to intercrops grown in closed spaced sugarcane.

Growing of legumes as intercrops can also result in improvement in soil fertility. Legumes could fix atmospheric nitrogen under favorable condition and it may become available to associated sugarcane crop. Generally short duration crops which can be harvested before the final earthing up are recommended. Green gram, black gram, soy bean, sunhemp, daincha, potato garlic, onion and pulses could be raised as intercrops in sugarcane. The expected net income is in the range of 10,000 to 40000 per acre by growing intercrops. Market led vegetables cultivation as intercrop will be highly remunerative to the sugarcane farmers. With vegetable intercropping, farmers will get additional income which will help to increase his total income from the farm.

4.5 Healthy seed

A good seed in sugarcane is defined as sett obtained from a healthy crop. It should be free from pests and diseases should have a good germination of more than 85%. Genetic purity of a variety which plays a pivotal role in sugarcane and sugar production should be maintained. Production and availability of quality seed of sugarcane is important to sustain the varietal potential for quick spread of varieties and management of diseases and pests. The use of poor quality seed over years has resulted in varietal degeneration. In sugarcane seed production, equal emphasis is being accorded to seed cane as well as tissue culture plants obtained through micro-propagation. Settlings can be raised either through nursery beds or polythene bags or settlings trays using bud chips or single bud setts.

A low cost technology for exchange of cane seed and seed multiplication material using bud chips was developed at SBI, Coimbatore. This low cost seed technology is helpful for breeder seed production as well as commercial cane production. High quality genetically pure, disease free breeder seed cane of promising notified varieties of sugarcane, micro-propagated tissue culture plants, mother culture flasks and bud chip transplants were provided to farmers and sugar factories for initiating and implementing a quality seed production and distribution system that created a marked impact on the productivity and quality of sugarcane. Micro-propagated plants have been well accepted by sugar factories and farmers all over country because of its uniform productivity, free from disease, vigorous growth and high yield.

4.6 Irrigation Management

Sugarcane is cultivated in India under widely varying conditions of soil types, rainfall pattern, temperature regimes and water availability. Water requirement of sugarcane varies from 1200 to 2500 mm depending on yield level, crop duration and climatic conditions. Water requirement varies from 1200-1800 mm in the subtropical zone while it is 1600-2500 mm in tropical belt except Maharashtra. Sugarcane performs well when soil moisture close to field capacity. It has been found that for sugarcane irrigation is to be given at 50% depletion of available soil moisture during the vegetative phase (from planting to 270 days after planting) and at 75% depletion of soil moisture during the maturity phase (from 270 days after planting to harvest).

Drip system of irrigation also known as trickle irrigation is useful to economies water use in sugarcane. There are two types of drip irrigation system like surface drip system and sub-surface drip system. In the surface drip system, the water carrying lateral pipes are placed on the soil surface close to the plant and the emitters fixed at regular intervals discharge water

at required rates. In the subsurface system water carrying lateral pipes are buried in the soil, in the root zone and water is delivered in trickles.

4.7 Water conservation technologies

Trash can be removed to the bunds and then applied to the fields after the initial ratooning operations are completed. Trash mulching is particularly useful in extreme cases of weather conditions. Mulching also suppresses weed growth besides conserving moisture. Wherever water is scarce, number of irrigations can be reduced by trash mulching and thus water can be saved. Experiments have shown that irrigation interval can be extended to 15-20 days by trash mulching compared to 8-10 days interval in medium textured soils. Besides conserving soil moisture by reducing the evaporation from soil surface, mulching also moderates soil temperature helps in improving germination, better tiller survival and check weeds growth. In a multi-location trial in Tamil Nadu, 36% higher germination was observed under trash mulching compared to control when sugarcane was planted during hot weather period. This ultimately led to 20% higher stalk population and 10% higher cane yield. At Coimbatore, soil temperature was reduced by 2.1°C under trash cover, creating a more favourable environment for crop growth. Trash mulching at 3t/ha immediately after ratooning results in conservation of soil moisture resulting in better development of roots and increased cane yields in a ratoon crop.

Composting of trash is another way of conserving it. Sugarcane Breeding Institute has developed a rapid trash composting technique for decomposition of trash. Trenches with convenient width and length can be formed near boundary of sugarcane field. During de-trashing and harvesting trashes and tops are kept in layers in the trenches. One kg of cultures (*Trichoderma viride* and *Pleurotus*) 7.5 kg of urea + 50-75 kg of fresh cow dung for every tonne of trash are to be applied to every layer. Frequent watering is to be done for maintaining moisture content. Compost will be ready within 10-12 weeks for use. This trash compost can be done in both pit and heap methods. Trash compost has the nutrient content of 0.8% N, 0.25% P and 0.7% K with C: N ratio of 22:1. Trash can also be composted along with press-mud.

In the case of ratoons, trash can be aligned *in situ* in the furrows with help of rakes and compressed either by stamping or any other convenient ways and soil removed while stubble shaving and off baring operations has to be applied. Further, microbial culture is added to facilitate decomposition and irrigation water is applied. The method was experimented at Coimbatore and there was improvement in ratoon yield. Distinct advantage of trash mulching

over trash burning was demonstrated at Sugarcane Research Station Anakapalle. About 5-10 tonne more cane yield was obtained in the trash mulched plots. Planting setts with composted coir pith and trash application gave significantly higher yield than without trash and composted coir pith application.

4.8 Plant protection measures

Sugarcane eco system is comparatively less prone to economics yield loss if it's properly managed at farmers' level. A large number of pests and diseases attack sugarcane. To manage any pest or disease the best approach is an integrated approach involving cultural, mechanical, biological and chemical methods, employed in appropriate combination depending upon the pest or disease, the gravity of problem and economics. Integrated disease management (IDM) or integrated pest management (IPM) are best management practices to avoid productivity losses in sugarcane production.

4.9 Mechanisation of farm operations

In the conventional system, for cultivating sugarcane in an acre (0.4 ha) of land about 1170 man hours and 130 bullock pair hours are required, which is laborious hence it not only increases drudgery but also cost of production. Moreover, due to attractive job offers&wages in non-farm sectors, labourers are reluctant to work in sugarcane farms. Cost of cultivation excluding cost on family labour and fixed costs is around Rs. 150000 per acre; approximately 45-48% of the total cost goes to payment on human labour and only 15-16% is spent on machinery including transport. To increase net returns from sugarcane cultivation, there is a need incorporate cost effectiveness in the production system.

Mechanization is the immediate option through which there is possibility of minimizing expenditure on human labour. Mechanization has brought about significant improvement in agricultural productivity in developed countries. Taking into consideration the time, precision of field operations, increased input use efficiency and productivity per unit, there is a need to making sugarcane cultivation at least a semi-mechanized one by popularizing machinery like sugarcane cutter planter, inter-culture implements, tractor-mounted-sprayers and harvesters which are available in the country. If the initial cost of machinery is high, then it can be hired on co-operative basis.

Tractor drawn cane planters are technically better and economically viable. Agricultural departments and sugar mills in the country are either having or promoting use machinery like trench opener, pit digger and cane planter-cum-seeder. These machines can be

hired and used by farmers. Multipurpose inter-culture equipment would reduce 1/3rd of the total cost incurred on manual labour. Tine cultivator and earthing up ridger needs to be popularized among farmers. With synergistic efforts of stake holders, it is hoped that goal of complete mechanization in sugarcane cultivation would be tool to achieve desired objective of cost minimisation and doubling-up of farm profit.

Table: 8 Recommended technological interventions for enhancing input use efficiency for productivity improvement

Technological	Recommended Technologies	Problems addressed and Expected Out Come
Land preparation	Laser leveller	➢ Traditional methods of levelling are cumbersome, time consuming and less accuracy. Precise levelling in short period of time is another advantage of laser levelling. Better distribution of water which will save around 20-25 % of irrigation water.
Variety	Location specific variety	➢ Choice of correct set of varieties for a particular agro-climatic location is very vital in reaping best possible harvest, given other crop production and protection inputs in required measures
	Healthy seed	➢ A good seed in sugarcane is defined as sett obtained from a healthy crop. It should be free from pests and diseases should have a good germination of more than 85%. Genetic purity of a variety which plays a pivotal role in sugarcane and sugar production should be maintained.
Planting system	Settlings Transplanting Technique (STT)	➢ Conventional planting of sugarcane with three budded setts requires about 8-9 t/ha

		planting material. There is possibility of utilizing bud chips and single budded settlings as seed material. Only 12,500 settlings per hectare are required in case of bud chip planting. Using bud chips and raising settlings in a nursery can save 80 per cent of the seed material compared to three budded setts.
	Inter-cropping with short duration pulses and vegetables	➢ Growing of legumes as intercrops can also result in improvement in soil fertility and additional income to the farmers ➢ Green gram, black gram, soy bean, sunhemp, daincha, potato garlic, onion and pulses could be raised as intercrops in sugarcane. ➢ Additional income to farmers within short span of 65-90 days.
Water Management	Drip system of irrigation	➢ About 40 % saving water and 25% increase in the yield ➢ It reduces labour requirement for irrigation. ➢ Effective application of inorganic fertilizers. ➢ Improvement in sugar recovery.
	Water conservation technologies	➢ Mulching also suppresses weed growth besides conserving moisture. Wherever water is scarce, number of irrigations can be reduced by trash mulching and thus water can be saved.
Soil health management	Improving SOM content: Trash composting and bio-compost application	➢ Maintains the soil fertility and sustainability of sugarcane productivity

	Reclamation of soil salinity and alkalinity	➢ Increase the resource use efficiency and crop productivity
	Diagnosis of subsurface hard pan and chisel ploughing	➢ Soil compaction can be a serious and unnecessary form of soil degradation that can result in increased soil erosion and decreased crop production. Compaction of soil is the compression of soil particles into a smaller volume, which reduces the size of pore space available for air and water.
Plant protection measures	Integrated Pest Management (IPM)	➢ Sugarcane eco system is comparatively less prone to economics yield loss if it's properly managed at farmers' level. To manage any pest or disease the best approach is an integrated approach involving cultural, mechanical, biological and chemical methods.
Farm mechanisation	Mechanisation of farm operations	➢ Mechanization is the immediate option through which there is possibility of minimizing expenditure on human labour. ➢ Timely intercultural operations ➢ Saves considerable amount of labour ➢ Reduces cost of cultivation ➢ Improvement in cane yield and sugar recovery

5. Regional/state wise approach for doubling farmers' income

Sugarcane is being cultivated about 5 million ha. Though, it is cultivated more than 20 states &UT's, more than 90 % of the cane area cultivated is seven states (Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Punjab, Haryana and Bihar). Nevertheless, information on cost of production and farmer revenue and income was available six major major sugarcane states barring Bihar. Accordingly, doubling farmers' income was devised for tropical and sub-tropical India and deliberation was given below.

5.1 Plan of action for Tropical India

Tropical states possesses higher cane yield and better sugar recovery due to favourable climatic and socio economic status of cane farmers. Maharashtra, Karnataka and Tamil Nadu are leading sugarcane producers along with Gujarat and Andhra Pradesh. Considering homogeneity of production scenario in the region, ways and means to doubling farmer's income was summed up here.

Tamil Nadu ranks first in yield, similarly Karnataka and Maharashtra ranked second and third in India. Average level of productivity and net income is 80t/ha and Rs.70000/ha respectively. To double income of the farmers, yield has to be increased to 100 t/ha with assumption of *Ceteris paribus* condition. Increasing yield to achieve objective is daunting task, but, it is not beyond target. There are farmers who is harvesting more than 150 t/ha in tropical India with the popular variety Co 86032 and maximum yield recorded by the variety Co 86032 was more than 250 t/ha in the recent times in tropical India. Yield and sugar recovery improvement could be possible by addressing the following constraints faced by the sugarcane farmers in this region.

i). Cultivation of tissue culture derived seeds/setts of popular variety Co 86032

ii). Mechanisation of farm operations

iii). Implementation of micro irrigation along with fertigation

iv). Mechanised harvesting

v). Ratoon management

5.2 Plan of action for sub-tropical India

Stagnant cane yield and low sugar recovery became identity of sugar mills in sub-tropical India. There was a challenge to break this jinx with large scale adoption of technological interventions. Income of farmers at sub-tropical is comparatively low due to low yield realisation in comparison with yield potential. Sugarcane is cultivated conventionally and introduction of modern technologies is need of the hour for doubling farmers' income in this

region. Some of the proven varieties and technologies which are developed exclusively to sub-tropical India are explained to achieve desired objective.

5.2.1 Adoption of high yielding and better sugar recovery varieties

Continuous efforts of hybridisation and selection process, it was possible to select many clones with juice quality better than the best standard variety CoJ 64. These clones were Co 98014, Co 0237, Co 0238 and Co 0239. All these clones were better than the standard CoJ 64. These clones were evaluated in All India Coordinated Research Project (AICRP) in the North West Zone. In AIRCP trials also these clones showed better juice quality and cane yield than standard varieties. Based on performance with respect to cane yield, juice quality and red rot resistance in AICRP(S) experiments conducted at 10 locations in North Western Zone, Co 98014, Co 0118, Co 0238 and Co 0239 have been released as early varieties by the Central Varietal Release Committee for commercial cultivation.

Based on superior performance in All India Coordinated Research Project (Sugarcane) experiments with respect to cane yield, juice quality, resistance to red rot disease and tolerance to major insect pests Co 98014 (Karan 1), Co 0118 (Karan 2), Co 0238 (Karan 4) and Co 0239 (Karan 6) have been released for commercial cultivation as early varieties during 2007 – 2010.

Adaptability trials conducted at sugar mills under local conditions in Haryana, Uttarakhand, UP and Bihar also indicated superiority of these clones over other varieties under cultivation in respective sugar mills. Performance of Co 0238 was found better in all above states under varying environmental conditions. Co 98014 was found better under water logging conditions. Co 0118 and Co 0239, which are best combinations of cane yield and juice quality, varied in their performance in different states.

Among all varieties in the recent past, Co 0238 (Karan 4) is a high yielding and high sugar content variety which was evolved at the Sugarcane Breeding Institute, Regional Centre, Karnal. An early maturing variety for commercial cultivation in North-West Zone (NWZ) comprising states of Haryana, Punjab, Western and Central Uttar Pradesh, Uttarakhand and Rajasthan was widely accepted in this region. Adoption of this variety would increases yield and sugar recovery significantly increase farmers income was realised in sub-tropical India.

5.2.2 Trench method of planting

Trench method of sugarcane planting produces significantly higher cane yield. Trenches are made with help of sugarcane trench planter machine or trenchers. This method also saves water because trenches are irrigated and not whole field. As compared to furrow method, there is increased germination percentage and number of tillers. Tractor-drawn sugarcane planter is a very suitable device for planting cane in trenches. All early maturing

varieties (Co 0238, Co 0118 and etc.) are well suited for trench method of planting. Adoption of trench method would enhance cane yield by 15-20 t/ha. It is highly recommend adopting trench method to increase farmers' income along with popular varieties in the region.

5.2.3 Post-harvest losses

Cane supply system prevailing in sub-tropical India has some serious drawbacks and this adversely affects growers and sugar industry. Besides other factors, which undermine cane quality, recurrent cut-to-crush delay in cane supplies is one of the major factors in pulling down sugar recovery. In many sugar mills, time lag between harvesting to milling of cane ranges between 2 to 5 days, entailing huge losses in recoverable sugar due to deterioration and souring of harvested cane. Biological losses of sucrose as a result of inversion, organic acid, ethanol and polysaccharides formation in harvested cane and upstream milling process are largely responsible for low sugar recovery.

Climatic variability of sub-tropical India also influences pre and post-harvest losses and it is estimated that nearly 15-20 percent of total sucrose present in freshly harvested cane is lost during transit. There is a vast difference between agronomic and technical sucrose content in sugarcane delivered to the mills which is mainly due to biological losses. Post-harvest losses remained major concern as it greatly impairs sugar recovery. Timely harvesting, reducing time of travelling of cane to mill gate would significantly improves sugar recovery and farmers income.

5.2.4 Diversification

Sugar industry being rural based provide opportunity for further diversification in milk processing and diary technology. Many problems (low cane yield and sugar recovery, shortage of pulses, oil seeds and etc,) related to sugarcane agriculture can be solved by popularising autumn planting with intercrops like pulses, oilseeds, vegetables etc. in sub-tropical India. For achieving this target, the sugar industries have to help the farmers by ensuring the marketing of intercrops. Options such as dairy farming and value addition will provide income to meet out daily consumption needs besides by products of sugarcane could be well utilized by this synergy associations.

5.2.5 Mechanised farm operations would enhance income of farmers in sub-tropical India. Adoption above discussed course of actions will sustain farmers' income and reaching goal of doubling income of farmers in sub- tropical region.

6. Policy options

6.1 Juice to ethanol

Sugarcane has been projected as the crop for the future contributing to the production of not only sugar but biofuel and bioenergy as well. Ethanol is a proven and environmentally safe alternative to fossil fuel and the use of ethanol in transport industry is ever increasing. The World Energy Council (WEC) expects that the transport fuel demand in next 15 years will come mainly from developing countries such as China and India where demand will grow by 200-300%. By a modest estimate the demand for petrol is likely to double to 34 million tonnes by 2030, considering the projected growth in commercial and domestic transport sectors.

The import of crude oil to meet this requirement is likely to impact the country's economic growth seriously and alternatives have to be found. Besides, the country should achieve the mandated emission levels by 2050, which is possible only through the reduction in the consumption of carbon fuels. At present, blending of petrol with 5% ethanol is mandatory in the country which is a gross mismatch when compared with Brazil, where vehicles are operated with either 25% ethanol blend or 100% ethanol. In India also a policy shift towards higher ethanol utilization in energy sector is unavoidable. At present ethanol is produced exclusively from molasses as direct conversion of sugarcane juice to ethanol is not permitted. To meet the growing demand for ethanol as a biofuel and other industrial and commercial use, the molasses route may not be adequate. Excess sugar production in the country also provides reason to produce ethanol directly from sugarcane juice. It would help more realisation for sugarcane particularly in years of excess sugar production resulting in lower sugar prices and this would ultimately lead to increase in farmers' income.

6.2 Value added products

Sugar sector has to be conceived as an energy hub producing not only sugar but also value-added by-products such as ethanol from molasses and power from bagasse. Apart from being the most important and commonly used sweetener, sugar is also a raw material for the production of a host of industrial chemicals and nearly 10,000 technically feasible products have been developed from sucrose at laboratory and pilot plant scale. Some of the important products with industrial applications derived from sugar are acetic acid, citric acid, citrates, lactic acid, lactates, glutamate, sysine, xylitol, acetone/ butanol, 2,3 butanediol and Polyhydroxybutyrate (PHB).

Thus the crop offers a wide range of options to be exploited suitably in coming years. For this the 'sugar factories' have to transform themselves into 'Agro Processing Complexes' producing a wide range of products apart from sugar. Cane agriculture also needs to diversify as per the industry needs into 'sugarcane plantations', 'energy plantations' and 'sugarcane bio

farms', growing sugarcane for different purposes. In the research front also there are effective tools available now that were not available previously. The modern tools of omics, bioinformatics and transgene technology can redefine the varietal development process and tailor varieties as per needs. The geospatial technology, nanotechnology and ICT will be potential tools for developing effective crop production and crop protection technologies.

Another potential emerging area that is the use of sugarcane as a platform for molecular farming. High biomass potential and multiple ratoonability of sugarcane can be exploited as a bio-factory to produce high value molecules like therapeutics, vaccines, vitamins, industrial enzymes etc. on large scale. This is possible by developing technologies for expressing the genes of interest in sugarcane and targeting their storage into vacuoles which will facilitate easy extraction and purification of the products from juice.

6.3 diversification

Growers in the sugarcane industry have been struggling under financial pressure for several years. One option to improve farm viability might be to diversify farm enterprise income. Choice Modelling, an economic valuation technique, was used to explore the trade-offs growers make between different attributes of diversification, and how their choices may be related to certain socio-economic characteristics. Application of the technique involved surveys of cane growers in three regions of Central Queensland. This is a novel approach to assessing grower intentions that has the potential to reveal detailed information about influences on grower choices.

There are a variety of possible diversification options for sugarcane growers in the Central Queensland area, some sharing similar characteristics to sugarcane. For example, a variety of small pulses and horticultural crops may have similar characteristics such as reasonably low production costs and relatively quick returns.

6.4 Drip irrigation and Fertigation

Today, production of sugarcane crop is complex process and depends on use and combination of different inputs such as labour, land, capital, management practices and other various factors. The variations in use and combination of various factors of production affect

the sugarcane yield. Farmers experience difference in sugarcane yield that is the result of using varying level and combination of inputs. Furthermore, there is a broad gap in the yields of farmer's field and experimental stations showing the suboptimal use of inputs.

Resource use efficiency is of paramount importance, as they provide readily information relating to probable effects of resource use on yield of particular crop. Farmers' resources need to be organized and used efficiently so as to produce maximum output. The problem of inefficient use of production resources such as water and nutrients and reduced profit in sugarcane production has been the greatest obstacle and of great concern to increased production. The efficient use of resources would reduce the cost of production and further enhance sugarcane production profitability.

Water requirement is the total amount of water needed for raising a crop successfully. In the case of sugarcane, it includes the amount of water for meeting the needs of evapo-transpiration and metabolic activities (known as consumptive use), losses during application of water and water needed for land preparation as pre-planting irrigation. It has been estimated that, in India, on an average, sugarcane requires about 20,000 kilo litres of water per hectare for its cultivation. In India sugarcane is an irrigated crop; and from 1980 to 2006 irrigation coverage has increased from 80 per cent to 93 per cent of the total sugarcane-cultivated area. Sugar-producing regions have more than 80 per cent groundwater irrigation through deep-well pumping. The Inter-Governmental Panel on Climate Change has projected that global mean annual surface air temperature is likely to increase in the range 1.8–4.0°C by the end of this century. Rising temperatures associated with climate change will also affect water resources by decreasing snow cover and accelerating the rate of snow melt. Under the climate-change scenario, delayed and/or uncertain onset of the southwest monsoon will also have a direct bearing not only on rainfed crops, but also on water storage putting additional stress on water availability for irrigation. However, we have to cope with the situation of depleting water resources using the technology for economizing water and effective utilization of limited water availability. This may be accomplished through cultivation of less water-requiring/drought-tolerant varieties, applying irrigation at critical stages of growth/ proper utilization of limited water availability; methods of irrigation economizing water like skip furrow/ alternate furrow irrigation and drip irrigation and preventing water loss as evaporation from soil surface (trash mulching).

Natural soil fertility is low in most areas cultivated with sugarcane; the use of chemical fertilizers to increase productivity has become a common practice among farmers. The recommendations vary from state to state depending upon the soil type, crop duration, yield level and irrigated / rain-fed conditions. The fertilizer doses recommended are generally higher in tropical states (100 to 450 kg N/ha) compared to subtropical states (100 to 225 kg N/ha)**.** However, this practice has also contributed to raise the cost of production and the excess of applications may cause serious environmental problems. Nitrogen, for example, when applied in excess in sandy and poorly structured soils in high rainfall conditions, can easily be lost by leaching, contaminating groundwater. When fertiliser N is applied to soil it is generally not used efficiently, with crops assimilating not more than 50 per cent of the N added as fertiliser. Adoption of balanced and judicious use of all needed nutrients can help improve cane productivity and enhance sugar recovery by rendering resistance against biotic and abiotic stresses, and better synthesis and storage of sugar.

Nutritional efficiency is the ability that the cultivar has to incorporate and use the nutrient in the production of economic yield biomass. Sugarcane cultivars differ on the absorption and use of nutrients. Thus, it is possible to select efficient cultivars in use of nutrients, reducing the risks of environmental contamination and, above all, the cost of production. Use of granular or liquid formulations, controlled release fertilizers and products containing urease and nitrification inhibitors, site specific nutrient management, split application, foliar application, variable rate fertilizer application and fertigation are the ways to improve nitrogen use efficiency. About 10 to 20 per cent of applied phosphorus is utilized, much less than those of other nutrients like nitrogen and potassium. It is estimated that 85 to 90 per cent of inorganic P added to the soil becomes unavailable to plants in the year of application. Phosphorus fertilization should be managed to improve absorption by the plant, decrease soil adsorption, and consequently improve phosphorus usage by the crop. In case of sugarcane the entire quantity of phosphorus is applied as basal along with furrows and incorporated. Potassium is usually applied in splits along with nitrogen as top dressing to improve uptake of nutrients and reduce the loss.

6.4.1 Improving water use efficiency

- Cultivation of less water-requiring/drought-tolerant varieties,

- Applying irrigation at critical stages of growth/ proper utilization of limited water availability; methods of irrigation economizing water like skip furrow/ alternate furrow irrigation and drip irrigation
- Preventing water loss as evaporation from soil surface (trash mulching).

6.4.2 Improving Nutrient use efficiency

Generally under farmers' field conditions, the use efficiency of applied nitrogenous fertilizers is very low and ranges from 30 - 40 %. The major pathways of nitrogen losses are leaching of nitrates, volatilization of ammonia from soil and crop tops and denitrification as nitrogen oxides. Average recoveries of applied N for different sources of fertilizers was reported to be in the following order: ammonium sulphate (27.3%) > potassium nitrate (23.0) > urea (19.0%) while for soil types the order was loamy sand (25.9%) > loam (20.5%).

- Adoption of proper method of fertilizer application - essential to minimize the loss of nutrients from the soil and to increase fertilizer use efficiency
- Fertilizers should be placed close to the root zone to enable the roots to derive immediate benefits
- Placement can be made by making 8 - 10 cm deep furrows on either side of the cane rows and then covering them
- Proportion of fertilizer nitrogen recovered in the crop was 33 % when urea was buried in the soil, but it was only 18 % when urea was broadcast
- Soil application at K at 75 per cent of the recommended dose as basal along with 25 per cent of the recommended dose of K as foliar application at 90 DAP resulted in appreciable increase in millable cane count and cane yield
- Potassium application beyond 90 days after ratooning (DAR) either through soil or foliar application did not show any significant effects on cane yield and juice quality
- Ring-pit method of cultivation enhances the fertilizer use efficiency as compared to the conventional method of planting
- About 20 per cent of N can be saved in ring-pit method of cultivation.

6.5 Socio economic analysis for improving farmers Income

All these prosperous ideas and strategies have inherent techno-economic constraints in executing plan of action at micro level. There are problems and obstacles faced by the cane growers are listed here.

- Shrinking resource base
- Changes in demand and consumption pattern
- Changes in farming systems including increasing diversification to high-value crops
- Declining public investments
- International developments- WTO (subsidies, price competency and trade)
- Climate change (global warming, seasonal variations, changes in rainfall pattern and increasing occurrence of natural disasters).

6.6 PESTLE Analysis for creating Enabling Environment:

Various factors that influence the sugarcane farming and the farmers in their day to day activities to be taken into consideration while planning for doubling their income.

Political	Economic	Social	Technological
Current pricing and payment delays. Market surplus and export policy. Inadequate investment in farming sector.	High cost of cultivation. Non availability of labour and poor mechanization opportunity.	Demographic and changing consumer preferences. Fragmentation of land holdings.	Inadequate availability of quality planting materials. Inadequate linkages with research organisations and extension personnel.
International demand for sugar. Quality standards and poor market forecasts.	Poor opportunity for diversification. Poor value addition and entrepreneurial approach.	Migration from rural to urban. Labour demand in non agricultural sector s increasing.	Non availability of broad based extension support and door support services.
Poorly managed cooperative sugar mills. Laws prohibiting killing of wild animals like wild boars.	Inadequate financial support, cash flow, fluctuating market and non revision of sugar price. Pending payments from sugar factories.	Negative attitude towards farming and migration of younger generation from farming to non farming occupation.	Lack of farmer farmer interaction and FIGs ib sugarcane for organizing farmer led extension programmes.

Addressing these emerging challenges would require a new approach which as to be distinct from the earlier approach. Sugarcane research and extension therefore need to emphasize the following new dimensions in the present era:

- Focus on gene revolution, emphasizing application of biotechnology- tissue culture for multiplication of elite germplasm, GM crops, marker assisted breeding etc
- Emphasize use of bio fertilizers, bio pesticides and bio remediation of ground water
- Address issues like sustainability, resource integration and technology integration as the primary focus
- Apply precision farming and mechanization for optimal use of precious resources and human labour
- Strengthening linkage with industry, market driven production and favourable cane support price.
- Increase application of cutting edge technologies
- Thrust on mechanisation, and farmer friendly tools, machinaries and devices
- Highlight quality in addition to increase in quantity
- Protect IPR and farmers' rights
- Integrate agro-enterprises with sugarcane production and application of advances in information technology.

Force field analysis: Understanding for Way forward for Doubling the income through sugarcane farming

Driving Forces ⟶	**Restraining Forces** ⟵
✓ Good Varietal performance in terms of yield and recovery. ✓ Remunerative price for produce and timely payment. ✓ Adequate technology back stopping ✓ Capacity building and farmer led extension. ✓ Strong linkage and partnership between research-extension-farmer and industry continuum. ✓ Industry backing and support. ✓ Remunerative and stability compared to other agricultural crops.	✓ Water and labour crisis. ✓ High cost of cultivation. ✓ Disease incidences and lodging. ✓ Wild animal menace. ✓ Lack of mechanization and small tools and machineries. ✓ Fragmentation of land holdings. ✓ Climate change effect. ✓ Quality planting materials. ✓ Lack of farmer field school and FIGs in sugarcane. ✓ Non availability of credit and crop insurance

6.7 Strengthening technology delivery system:

The technology delivery system in sugarcane production system needs to gear up their capacity in terms of manpower, expertise, finance, structure, institutional linkages and the kinds of methods, approaches and delivery system they employ. The issues to be taken up for strengthening the delivery system are;

(i) Farmers empowerment and farmer organizations development

(ii) Institutional linkages, convergence and Partnership issues

(iii) Technology backstopping, application, integration, ICT use and management

(iv) Frontier areas of extension, HRD and skill development

(v) Policy issues related to minimum support price, timely payment and emphasis on diversification through fuel and energy sector using byproducts.

Technology delivery system should focus on:

- Capacity development of farmers and entrepreneurs on quality standards and phyto sanitary requirements.
- Fair Average Quality Standards (FAQ) for sugarcane products for higher returns to famers.
- Market intelligence through information technology and cyber extension.
- Sensitization training to middle level cane development officers and extension functionaries to improve their technical and professional knowledge and skills.
- Educating the farming community and the industry, the anticipated implications of the WTO agreement and lend a helping hand in building confidence and converting the challenges into opportunities in global trade.
- Emphasis on Good Agricultural Practices (GAP) for farmers and Good Manufacturing Practices (GMP) for industries.
- Facilitating adoption of improved knowledge on production, value addition and marketing by farmers.
- Farmer organizational development including leadership development and supporting farmer organizations to take up new initiatives (technology application, networking, financing and marketing through supporting producer companies.

6.8 ICT and Knowledge Dissemination in Sugarcane Production

The most important role of ICT in Agricultural development is fostering a knowledge intensive sustainable livelihood security system in rural areas. Since ICT can enable us to reach the unreached and include the excluded information, knowledge and skill empowerment

communication and information hold the key to the 21st century. An inclusive knowledge society requires the effective harnessing ICT to combat poverty and foster development. The issues of importance in the information led knowledge dissemination are: (i) access (ii) content and (iii) Capacity Building.

Access: The access to information and knowledge is impeded for much of our population die to poverty, illiteracy and violation. Linkages among professional partners are essential to reach those who are unreached and especially those who are under greatest risk of being left out of the knowledge societies.

Content: The farmers need locally relevant information, in the right language, to meet their immediate needs, and it may be more useful to promote more information sharing between local institutions than bringing in new information from outside. It is therefore important to promote information as a catalyst for community initiatives and encourage the adaptation of new technologies within decentralized and locally owned processes.

Capacity Building: It is needed at all levels to equip farmers and extension functionaries towards effective use of ICT in acquiring and dissemination of knowledge. Support is to be provided in terms of training for the use of ICT, establishment of rural knowledge centres, appropriate linkages with research institutes for continuous content updating. Training in information collection, storage and dissemination including the use of innovative formats based on the local culture is a must.

In the future, market determined production is likely to be basis of all agricultural operations. In such a scenario, real time and up to date information regarding market prices, insurance, logistics, warehousing, commodity trading, pesticide and other allied activities and resources, becomes indispensable to the farmers. The market led agriculture is possible through information based extension support system provided through information communication technologies at his door steps.

7. Way Forward

ICAR - SBI had been successful in fulfilling research needs of crop more than hundred years through timely varietal and technological interventions in our country. 'Co' and 'Co-allied' varieties which is cultivated over 98% of cane area have played a significant role in sustaining and expanding cane area and sugar production. Looking ahead, a medium term planning precisely visualizing improvement of farmers' income was chalked out. This will serve as basic frame work for "doubling farmers' income" subject to on course correction as situation warrants. ICAR-SBI has prepared medium term strategies as a roadmap for achieving production targets taking into consideration of above facts. This approach is theme based and problem solving mode through multidisciplinary approach. Major focus will be on:

- ✓ Adoption location specific improved sugarcane varieties.
- ✓ Cultivation of tissue culture derived healthy seeds/setts of popular varieties.
- ✓ Large scale adoption of settling transplanting technique.
- ✓ Mechanisation and improving resource use efficiency
- ✓ Deployment of micro irrigation and need based irrigation schedule for sugarcane
- ✓ Adoption of proper crop protection technologies to minimise crop losses due to diseases, pests and nematodes.
- ✓ Market led intercropping in sugarcane
- ✓ Crop and product diversification.
- ✓ Market intelligence based sugarcane production system.
- ✓ Conservation of natural resources to ensure sustainability of sugarcane cultivation
- ✓ Technology transfer through effective communication system.

Effort to integrate improved varieties with newer technologies in a mutually complementing way leading to technological innovations that will drive doubling of farmers' income by 2022 without shortfall in sugarcane production system.

Annexures

Annexures -1

S. No.	Crop	Cost A2	Cost A2+FL	Cost C2	GVO	Gross Returns over A2		Gross Returns over A2+FL		Net Returns		Per Month Gross Returns over A2 (Rs./ha.)	Per Month Gross Returns over A2+FL (Rs./ha.)	Per Month Net Returns (Rs./ha.)
		Rs./ha.				Rs./ha. (Col.6-Col.3)	Percent (Col.7/ Col.3* 100)	Rs./ha. (Col.6-Col.4)	Percent (Col.9/ Col.4 *100)	Rs./ha. (Col.6-Col.5)	Percent (Col.11/ Col.5 *100)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Sugarcane														
1	All-India	61985	76429	118746	180556	118571	191	104127	136	61810	52	9881	8677	5151
2	UP	36853	51150	90898	153014	116161	315	101864	199	62116	68	9680	8489	5176
3	Kar	54336	66616	109394	174732	120396	222	108117	162	65338	60	10033	9010	5445
4	Mah	111359	127264	176753	236205	124846	112	108940	86	59452	34	10404	9078	4954
Paddy														
1	All-India	25179	33631	47547	53242	28063	111	19611	58	5696	12	7016	4903	1424
2	Pun	30983	36013	62313	87006	56023	181	50993	142	24692	40	14006	12748	6173
3	Har	29633	37156	60828	91310	61677	208	54154	146	30482	50	15419	13538	7620
4	AP	36219	42466	66088	75060	38841	107	32594	77	8972	14	9710	8149	2243
5	UP	21563	29522	43024	51255	29692	138	21733	74	8232	19	7423	5433	2058
6	Kar	36003	42183	60514	78069	42066	117	35886	85	17554	29	10516	8971	4389

Cotton														
1	All-India	37266	46208	64931	74519	37253	100	28311	61	9588	15	9313	7078	2397
2	Guj	34929	44670	61160	80688	45759	131	36018	81	19527	32	11440	9005	4882
3	Mah	43583	51672	68740	71689	28106	64	20017	39	2949	4	7027	5004	737
Wheat														
1	All-India	22742	28879	45814	58340	35598	157	29461	102	12527	27	8900	7365	3132
2	Pun	25587	28184	52169	72748	47160	184	44564	158	20579	39	11790	11141	5145
3	Har	25364	33380	58462	74251	48887	193	40871	122	15789	27	12222	10218	3947
4	UP	24191	30338	46774	53370	29179	121	23032	76	6595	14	7295	5758	1649
5	Mah	28442	34677	46122	46814	18372	65	12137	35	692	2	4593	3034	173

Annexure.II: FRP Recommended and its Linking with Recovery rate (RR), Sugar Season 2017-18

(Rs./qtl)

Basic Recovery Rate	FRP linked with RR	Basic Recovery Rate	FRP linked with RR
9.5	255.00	11.6	311.28
9.6	257.68	11.7	313.96
9.7	260.36	11.8	316.64
9.8	263.04	11.9	319.32
9.9	265.72	12.0	322.00
10.0	268.40	12.1	324.68
10.1	271.08	12.2	327.36
10.2	273.76	12.3	330.04
10.3	276.44	12.4	332.72
10.4	279.12	12.5	335.40
10.5	281.80	12.6	338.08
10.6	284.48	12.7	340.76
10.7	287.16	12.8	343.44
10.8	289.84	12.9	346.12
10.9	292.52	13.0	348.80
11.0	295.20	13.1	351.48
11.1	297.88	13.2	354.16
11.2	300.56	13.3	356.84
11.3	303.24	13.4	359.52
11.4	305.92	13.5	362.20
11.5	308.60	NA	NA

RR: Recovery Rate

Source: Commission for Agricultural Costs and Prices (CACP)

Annexure :III. Calculation of farmers income based on CACP Data - 2017 -18

States	Cost (C2)/Quintal	SAP at 2017-18/Quintal	Average yield (Q/ha)	Income (Rs./Quintal)	Farmers income (Rs./ha)
Andhra Pradesh	213	260.0	776	47	36472
Haryana	278	305.0	732	27	19764
Karnataka	172	261.5	880	90	78760
Maharashtra	183	273.3	797	90	71969
Tamil Nadu	212	285.0	1041	87	75993
Uttar Pradesh	234	280.0	618	46	28428
Uttarakhand	222	280.0	594	58	34452

Source: Base data was drawn from Commission for Agricultural Costs and Prices (CACP)

Annexure : IV. Average yield, sugar recovery SAP/FRP of major cane growing states

S. No	States	Average yield	Sugar recovery	State advised price (SAP)/FRP 2017-18
1	Andhra Pradesh	77.6	9.62	230 (FRP)
2	Bihar	51.9	9.14	230 (FRP)
3	Gujarat	69.4	10.64	NA
4	Haryana	73.2	9.75	305
5	Karnataka	88.0	10.89	2615
6	Madhya Pradesh	43.8	9.94	230 (FRP)
7	Maharashtra	79.7	11.44	2733
8	Punjab	73.1	9.43	295
9	Tamil Nadu	104.1	8.79	285
10	Uttar Pradesh	61.8	9.53	280
11	Uttarakhand	59.4	9.19	280

Annexure: V. Average man hours for conventional and mechanised farm operations (reference state: Tamil Nadu)

Operation	Labour requirement of Conventional method (labour- hrs)	Cost of operation in conventional method (Rs./ha)	Labour requirement of mechanised operation (machine-hrs)	Cost involved in mechanised cultivation (Rs./ha)
Preparatory tillage	320	14000	17	10200
Manuring	40	1500	40	1500
Irrigation	320	14000	40	1750
Earthing up	200	8750	5	3250
Weeding	240	6000	05	3250
Harvesting	1000	60000	10	47500
Total	2180	104250	233	67450

Annexure VI . Economics of furrow and drip method of irrigation in Tamil Nadu

Particulars	No. of irrigation	Labour hours Used (labour hours)	Water saved (%)	Yield (t/ha)
Conventional method	35-40	350	-----	105
Drip irrigation	40	40	30	110

Note: (Average of plant and ratoon crop)

Annexure VII. Economics of manual and mechanical harvesting in Tamil Nadu 2017 – 2018

Method of harvesting	Labour employed	Cost (Rs /ha)
Manual	100	60000
Mechanical harvester	2	47500