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Ministry of Agriculture &
Farmers Welfare

Report of the Committee for Doubling Farmers' Income

Volume VIII

"Production Enhancement through Productivity Gains"

Production & Productivity is linked to Market Inputs, Field Inputs, Farming Practices and Directly Impacts on the Value Realised

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Document prepared by the Committee for Doubling Farmers' Income,
Department of Agriculture, Cooperation and Farmers' Welfare,
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Foreword

The country has witnessed a series of concerted discussions dealing with the subject of agriculture. In 1926, the Royal Commission of Agriculture was set up to examine and report the status of India's agricultural and rural economy. The Commission made comprehensive recommendations, in its report submitted in 1928, for the improvement of agrarian economy as the basis for the welfare and prosperity of India's rural population. The urban population was about 11 per cent of the whole, and demand from towns was small in comparison. The Commission notes, that communication and physical connectivity were sparse and most villages functioned as self-contained units. The Commission encompassed review of agriculture in areas which are now part of Pakistan, Bangladesh and Myanmar. The net sown area in erstwhile British India was reported as 91.85 million hectares and cattle including buffaloes numbered 151 million. Almost 75 per cent of the cultivated area was under cereals and pulses, with rice and wheat occupying 46 per cent of the net sown area. The area under fruits and vegetables was about 2.5 per cent and that under oilseeds and non-food crops was about 20 per cent. In the ensuing years, as well known, the country underwent vast changes in its political, economic and social spheres.

Almost 40 years later, free India appointed the National Commission on Agriculture in 1970, to review the progress of agriculture in the country and make recommendations for its improvement and modernisation. This Commission released its final report in 1976. It refers to agriculture as a comprehensive term, which includes crop production together with land and water management, animal husbandry, fishery and forestry. Agriculture, in 1970 provided employment to nearly 70 per cent of the working population. The role of agriculture in the country's economic development and the principle of growth with social justice, were core to the discussions. The country was then facing a high population growth rate. After impressive increase in agricultural production in the first two Five Year Plans, a period of stagnancy set in and the country suffered a food crisis in the mid-1960s. The report in fifteen parts, suggested ample focus on increased application of science and technology to enhance production.

Thirty years hence, the National Commission for Farmers was constituted in 2004 to suggest methods for faster and more inclusive growth for farmers. The Commission made comprehensive recommendations covering land reforms, soil testing, augmenting water availability, agriculture productivity, credit and insurance, food security and farmers competitiveness. In its final report of October 2006, the Commission noted upon ten major goals which included a minimum net income to farmers, mainstreaming the human and gender dimension, attention to sustainable livelihoods, fostering youth participation in farming and post-harvest activities, and brought focus on livelihood security of farmers. The need for a single market in India to promote farmer-friendly home markets was also emphasised.

The now constituted DFI (Doubling Farmers' Income) Committee besides all these broad sectoral aspects, invites farmers' income into the core of its deliberations and incorporates it as the fulcrum of its strategy. Agriculture in India today is described by a net sown area of 141 million hectares, with field crops continuing to dominate, as exemplified by 55 per cent of the area under cereals. However, agriculture has been diversifying over the decades. Horticulture now accounts for 16 per cent of net sown area. The nation's livestock population counts at more than 512 million. However, economic indicators do not show equitable and egalitarian growth in income of the farmers. The human factor behind agriculture, the farmers, remain in frequent distress, despite higher productivity and production. The demand for income growth from farming activity, has also translated into demand for government to procure and provide suitable returns. In a reorientation of the approach, this Committee suggests self-sustainable models empowered with improved market linkage as the basis for income growth of farmers.

India today is not only self-sufficient in respect of demand for food, but is also a net exporter of agri-products occupying seventh position globally. It is one of the top producers of cereals (wheat & rice), pulses, fruits, vegetables, milk, meat and marine fish. However, there remain some chinks in the production armoury, when evaluated against nutritional security that is so important from the perspective of harvesting the demographic dividend of the country. The country faces deficit of pulses & oilseeds. The availability of fruits & vegetables and milk & meat & fish has increased, thanks to production gains over the decades, but affordability to a vast majority, including large number of farmers too, remains a question mark.

The impressive agricultural growth and gains since 1947 stand as a tribute to the farmers' resilience to multiple challenges and to their grit & determination to serve and secure the nation's demand for food and raw material for its agro-industries.

It is an irony, that the very same farmer is now caught in the vortex of more serious challenges. The average income of an agricultural household during July 2012 to June 2013 was as low as Rs.6,426, as against its average monthly consumption expenditure of Rs.6,223. As many as 22.50 per cent of the farmers live below official poverty line. Large tracts of arable land have turned problem soils, becoming acidic, alkaline & saline physico-chemically. Another primary factor of production, namely, water is also under stress. Climate change is beginning to challenge the farmer's ability to adopt coping and adaptation measures that are warranted. Technology fatigue is manifesting in the form of yield plateaus. India's yield averages for most crops at global level do not compare favourably. The costs of cultivation are rising. The magnitude of food loss and food waste is alarming. The markets do not assure the farmer of remunerative returns on his produce. In short, sustainability of agricultural growth faces serious doubt, and agrarian challenge even in the midst of surpluses has emerged as a core concern.

Farmers own land. Land is a powerful asset. And, that such an asset owning class of citizens has remained poor is a paradox. They face the twin vulnerabilities of risks & uncertainties of production environment and unpredictability of market forces. Low and fluctuating incomes are a natural corollary of a farmer under such debilitating circumstances. While cultivation is boundarised by the land, market need not have such bounds.

Agriculture is the largest enterprise in the country. An enterprise can survive only if it can grow consistently. And, growth is incumbent upon savings & investment, both of which are a function of positive net returns from the enterprise. The net returns determine the level of income of an entrepreneur, farmer in this case.

This explains the rationale behind adopting income enhancement approach to farmers' welfare. It is hoped, that the answer to agrarian challenges and realization of the aim of farmers' welfare lies in higher and steady incomes. It is in this context, that the Hon'ble Prime Minister shared the vision of doubling farmers' income with the nation at his Bareilly address on 28th February, 2016. Further, recognizing the urgent need for a quick and time-bound transformation of the vision into reality, a time frame of six years (2016-17 to 2022-23) was delineated as the period for implementation of a new strategy.

At the basic level, agriculture when defined as an enterprise comprises two segments – production and post-production. The success of production as of now amounts to half success, and is therefore not sustainable. Recent agitations of farmers (June-July 2017) in certain parts of the country demanding higher prices on their produce following record output or scenes of farmers dumping tractor loads of tomatoes & onions onto the roads or emptying canisters of milk into drains exemplify neglect of other half segment of agriculture.

No nation can afford to compromise with its farming and farmers. And much less India, wherein the absolute number of households engaged in agriculture in 2011 (119 million) outpaced those in 1951 (70 million).Then, there are the landless agricultural labour who numbered 144.30 million in 2011 as against 27.30 million in 1951. The welfare of this elephantine size of India's population is predicated upon a robust agricultural growth strategy, that is guided by an income enhancement approach.

This Committee on Doubling Farmers' Income (DFI) draws its official members from various Ministries / Departments of Government of India, representing the panoply of the complexities that impact the agricultural system. Members drawn from the civil society with interest in agriculture and concern for the farmers were appointed by the Government as non-official members. The DFI Committee has co-opted more than 100 resource persons from across the country to help it in drafting the Report. These members hail from the world of research, academics, non-government organizations, farmers' organizations, professional associations, trade, industry, commerce, consultancy bodies, policy makers at central & state levels and many more of various domain strengths. Such a vast canvas as expected has brought in a kaleidoscope of knowledge, information, wisdom, experience, analysis and unconventionality to the treatment of the subject. The Committee over the last more than a year since its constitution vide Government O.M. No. 15-3/2016-FW dated 13th April, 2016 has held countless number of internal meetings, multiple stakeholder meetings, several conferences & workshops across the country and benefitted from many such deliberations organized by others, as also field visits. The call of the Hon'ble Prime Minister to double farmers' income has generated so much of positive buzz around the subject, that no day goes without someone calling on to make a presentation and share views on income doubling strategy. The Committee has been, therefore, lucky to be fed pro-bono service and advice. To help collage, analyse and interpret such a cornucopia of inputs, the Committee has adopted three institutes, namely, NIAP, NCAER and NCCD. The Committee recognizes the services of all these individuals, institutions & organisations and places on record their service.

Following the declaration of his vision, the Hon'ble Prime Minister also shaped it by articulating 'Seven Point Agenda', and these have offered the much needed hand holding to the DFI Committee.

The Committee has adopted a basic equation of Economics to draw up its strategy, which says that net return is a function of gross return minus the cost of production. This throws up three (3) variables, namely, productivity gains, reduction in cost of cultivation and remunerative price, on which the Committee has worked its strategy. In doing so, it has drawn lessons from the past and been influenced by the challenges of the present & the future.

In consequence, the strategy platform is built by the following four (4) concerns:

- Sustainability of production
- Monetisation of farmers' produce
- Re-strengthening of extension services
- Recognizing agriculture as an enterprise and enabling it to operate as such, by addressing various structural weaknesses.

Notwithstanding the many faces of challenges, India's agriculture has demonstrated remarkable progress. It has been principally a contribution of the biological scientists, supplemented by an incentivizing policy framework. This Committee recognizes their valuable service in the cause of the farmers. It is now time, and brooks no further delay, for the new breed of researchers & policy makers with expertise in post-production technology, organization and management to take over the baton from the biological scientists, and let the pressure off them. This will free the resources, as also time for the biological scientists to focus on new science and technology, that will shift production onto a higher trajectory - one that is defined by benchmark productivities & sustainability. However, henceforth both production & marketing shall march together hand in hand, unlike in the past when their role was thought to be sequential.

This Report is structured through 14 volumes and the layout, as the readers will appreciate, is a break from the past. It prioritizes post-production interventions inclusive of agri-logistics (Vol. III) and agricultural marketing (Vol-IV), as also sustainability issues (Vol-V & VI) over production strategy (Vol. VIII).The readers will, for sure value the layout format as they study the Report with keenness and diligence. And all other volumes including the one on Extension and ICT (Vol. XI), that connect the source and sink of technology and knowledge have been positioned along a particular logic.

The Committee benefited immensely from the DFI Strategy Report of NITI Aayog. Prof. Ramesh Chand identified seven sources of growth and estimated the desired rates of growth to achieve the target by 2022-23. The DFI Committee has relied upon these recommendations in its Report.

There is so much to explain, that not even the license of prose can capture adequately, all that needs to be said about the complexity & challenges of agriculture and the nuances of an appropriate strategy for realizing the vision of doubling farmers' income by the year of India's 75th Independence Day celebrations.

The Committee remains grateful to the Government for trusting it with such an onerous responsibility. The Committee has been working as per the sound advice and counsel of the Hon'ble Minister for Agriculture and Farmers' Welfare, Shri Radha Mohan Singh and Dr. S.K. Pattanayak, IAS, Secretary of the Department of Agriculture, Cooperation and Farmers' Welfare. It also hopes, that the Report will serve the purpose for which it was constituted.

12th August, 2017

Ashok Dalwai
Chairman, Committee on
Doubling Farmers' Income

About Volume VIII

The eighth volume of the Report of the Committee on Doubling Farmers' Income (DFI) examines productivity led production growth, keeping mindful that farmers must be able to benefit from technologies and practices that allow them to create value in a more optimal manner. Production enhancement, as a result of productivity gains, optimises on resources deployed, minimises ecological stresses and also reduces per unit cost of production.

This volume discusses these various aspects for the major agricultural sectors. Productivity on crops comes about from changed cultivation practices, i.e., selection of appropriate planting material, applying optimal inputs for soil and plant health, efficiencies during irrigation and tending phase, suitable staggering of sowing and harvest, inter-cropping and enhancing the cropping intensity on land. To achieve this, a wide variety of technology, information, tools and scientific practices are brought into use. In case of livestock and fisheries sectors, productivity enhancement can come from breeding, feeding, health care and other application of animal sciences. The result of such efforts is that the production is optimal to the effort and resources used.

Productivity enhancement not only adds to production, but can also contribute to release farmers' time, land and other resources, freeing these for other productive activities. Consequently this in turn, can offer the farming enterprise the option to diversify into other activities in the supply chain. Farm level productivity therefore, can bring additional gains by allowing the farmers' enterprise to partake in the marketing and other allied activities and capture value from a market led agricultural value system. These secondary, off-field or near-farm activities are also explained in Volume-III. The important aspects on input management are detailed in Volume-VII which also relate to sustainability, which is discussed earlier in Volumes V and VI. Productivity is therefore, intrinsically linked with the earlier volumes, and the consequent gains in production has to be directly co-related to marketing and monetisation.

This volume touches upon the selected agricultural sectors and examines aspects related to cereals, pulses, oilseeds, horticulture, livestock & fishery, sericulture and some commercial crops. The following Volume-IX will take the discussion forward on Secondary Agricultural activities.

Ashok Dalwai

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Doubling Farmers' Income

Volume VIII

"Production Enhancement through Productivity Gains"

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Setting the Context

Redesigning crop geometry & commodity matrix

Production is the final output resulted from the efforts of farmers. The produce is the fungible material that a farmer seeks to monetise, for generating returns on the efforts and costs undertaken. The value realised depends not only on the market demand but also on the productivity achieved in the course of production. Productivity allows for production at lower per unit cost, and is critical to farmers' income.

0.1 Background

Assets, tools, labour and capital are the key elements that take material inputs and convert into agricultural output. Land is the primary asset in case of all terrain-based farming, for field crops, orchards, plantations, aquaculture, livestock, etc. However, in case of marine fishing, the primary asset is the maritime ecosystem and the vessels that harvest the produce. The tools vary across sectors, from simpler hand held implements to industrial scale equipment and high technology systems like sonars, radar, humidity controllers and sensor based equipment.

Labour includes the individual enterprise dedicated to the core farming activities, by the farmer and the farming workers. Human capital in agriculture is involved in controls and decision making and as labour in the activities undertaken. The financial capital cuts across the operations and plays a critical role in the physical capacity to deploy appropriate tools and manpower, as well in the necessary inputs that go into farming. The inputs, such as planting material, water, fertilizer, animal feed, knowledge, etc. are linked to the initial capital available and the capital generated from monetising the output.

The drivers of income growth for farmers are diversification of farm activities towards high-value produce, technology up-gradation and modernisation, knowledge based enterprise development, irrigation (micro-irrigation), each having a multiplier effect in production and productivity. Value chain optimisation at every level in the integrated supply chain, in producing and moving the produce from farm to consumers, optimal price realisation for farmers through competitive markets and improvement in terms of trade are the other factors that ensure that the productivity at field translates into gainful productivity at income level.

The efficiencies achieved from the synergistic exploitation of all of above, is decisive in the productivity achieved at farm level. These efficiencies underpin the final cost of production, the total production achieved, and the reduced stress on man, assets and the ecology. From the farmers' perspective, the cost and volume produced are most critical, as this is the wealth that he/she creates. This wealth is thereafter available to the farmers, to be monetised at prices that are directly linked to demand. The exchange transacted is the final value realised by the farmer, and the productivity impacts on the net income achieved.

0.2 Mandate of Agriculture

At Independence, India's urban population was estimated at 6 crores, and by its 75th anniversary it is expected to be about 48 crores. With such urbanisation, the ratio of urban population in the total population has shifted from 15 per cent to nearly 35 per cent. The dependency load on the agricultural sector for food and other materials has, at a minimum, more than doubled. This has to happen from a fixed land area and depleting resources. Reports also indicate that by 2030 the urban population may touch 50 per cent. This only reflects that agriculture, is increasingly and acutely linked to the sustenance and survival of the urban population. However, this awareness is yet to be fully appreciated by the dependent population.

The globally accepted goal from agriculture, has been to produce more to assure food security. However, food that contains toxins is not food secure, neither is production that is harming the ecology sensible. It is time to go beyond the conventional terms of food security and ensure that food security includes not such quantity but quality of nutrition and quality of production system. Agriculture, in today's world, is not just with purpose to produce to sustain life; it has to produce more from less and in safe manner. In modern day context, the agricultural mandate needs redefining, entailing food and nutritional security, along with sustainability, thereby expanding upon the erstwhile production centric mandate.

i. Agriculture has the moral responsibility of meeting food and nutritional security in consonance with the agro ecological backdrop.
ii. It has to generate gainful employment resulting in income gains to make the farmers more economically secure.
iii. It has to generate raw material that will directly support agro-processing of food and non-food products to support secondary agriculture.
iv. It has to support agro-processing industry to produce primary and intermediate goods, which will feed the manufacturing sector.
v. Agricultural practices need to be on a sustainable basis.

Agriculture has to generate both food and raw material to meet the requirement of modern society for feed, fibre, fuel and other industrial uses, and in a manner that is sustainable.

0.3 Changing Farmers' Income from Seasonal to Perennial

Concentration on few cereal crops has reduced profitability, distracted investment, and dampened growth in the agricultural sector. Agricultural diversification can help to reverse these trends by making the sector more profitable as it becomes flexible in meeting the local and international demands and enables poor people to do something new and remunerative yet within their sphere of competencies and resources.

Diversification is considered a shift of resources from one crop (or livestock) to a larger mix of crops and livestock, keeping in view the varying nature of risks and expected returns from each crop/livestock activity and adjusting it in such a way that it leads to optimum portfolio of income. Diversified farming activities, instead of concentrating on crops alone, can ensure sustainable income. Agricultural diversification can reduce the risk exposure of farm households by optimizing income from a range of activities, more stable employment for farm workers and resources throughout the year.

Agricultural diversification in India is gradually picking momentum in favour of high value crops/livestock/fishery activities to augment incomes rather than a coping strategy to manage risk and uncertainty. In India, today nearly two-thirds of the total agriculture production today is high value (dairy, horticulture, fish, meat, poultry and spices). This has help farmers to shift to less water-intensive crops, reduce dependence on rain, and ensure that their livelihoods are more sustainable. However, this diversification has been largely driven by a few states like Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and West Bengal.

Diversification needs to be more geographically widespread and augmented through further thrust on processing of perishables. This highlights the importance of strong policy support for development of agricultural diversification in India so as to enable farmers to capitalize on the opportunities of diversification. Infrastructural bottlenecks remain a major obstacle for poor farmers to participate in and profit from agricultural diversification due to limited ability to get their produce to markets, limited ability to add value to their produce and also due to lack of market knowledge. Policies are needed to help theses growers by strengthening their marketing skills, providing market access, both on local and national levels and improving market and transport infrastructure.

Also the lack of resources in terms of credit, training and exposure are major constraints for farmers wanting to venture into new lines of production. Restructuring of existing extension systems toward more participatory methods and provision of small term loans in terms of micro-finance options has been found to be an effective means of strengthening the linkages between farmers and the research community. Also, cooperation with local NGOs and producer group with regards to extension work has proved very beneficial so as to fulfil the needs of women, small and marginal farmers.

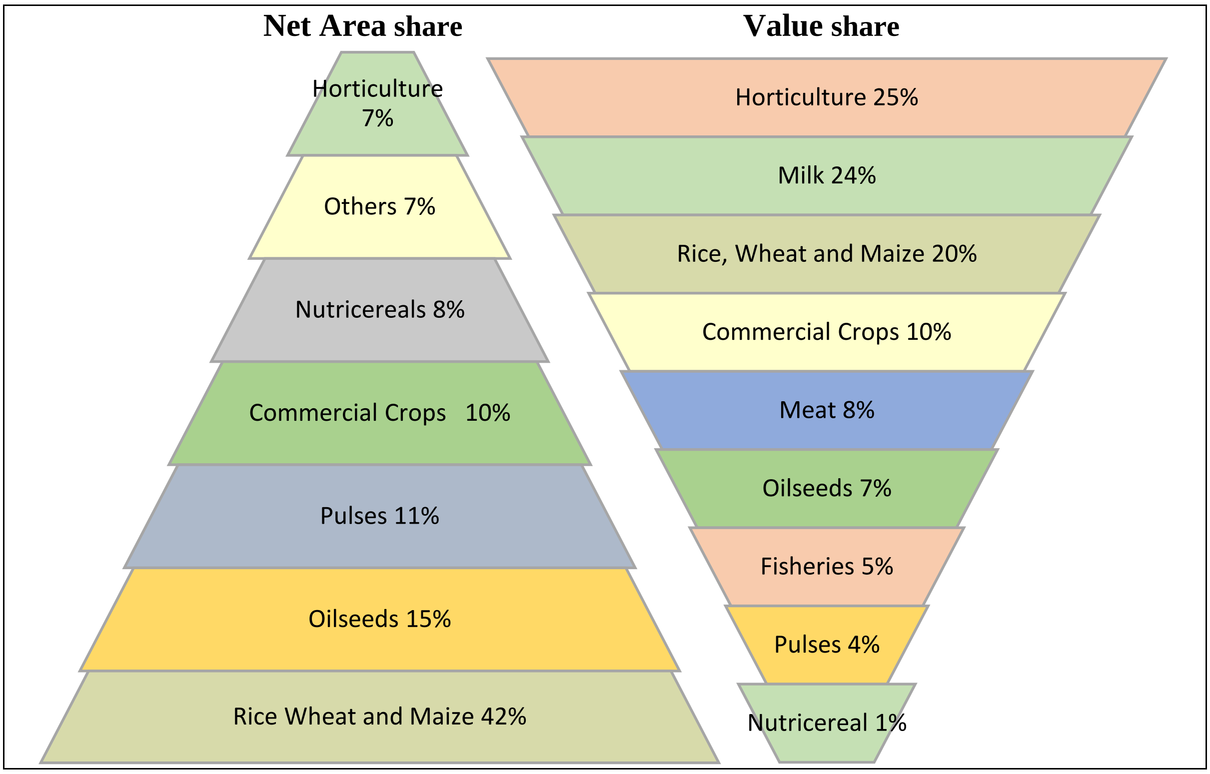
Regional and international networking and contractual research are considered important to quickly resolve a wide variety of constraints in diversification that differs from region to region. The training of farmers in new technologies and processes involved in diversification will improve their technical ability to engage in diversification. There is the need for enabling the establishment of fruitful corporations between native entrepreneurs and foreign businesses and by serving local businesses to upgrade their standards so as to conform to international quality requirements. But for all this to be successful farmers need assistance in acquiring the technical knowledge of these arrangements and assistance in accessing related markets.

0.4 Area and value pyramid

Farmers' income security is as important as nation's food and nutritional security. Agriculture has met the goal of food security with surplus foodgrain production; however, there is a need to assure the nutritional security, along with the gains in farmers' income. Value is important for generating high income of farmers, but as seen in DFI Volume I, no direct correlation among area and value is observed.

The value of any agricultural produce depends on a number of factors. In some cases, the factors include demand linked to administered and allocated values, and in some cases the terms of trade many not be so favourable, despite untapped demand, such as in case of nutri-cereals. It would be worthwhile to evaluate the relationship between acreage and value and use this to plan future actions, to make the most of agricultural assets, outputs and markets. Certainly, there is need to change the crop cafeteria to suit the ecology and the consumers' preference, hence ensuring that value is captured across all areas of concern.

Figure 0.1 Area and Value Pyramid



Source: DFI Committee

In case of field crops, it is observed that 42 per cent of the area is under major cereal crops (rice, wheat and maize) contributing only 20 per cent in the value of output, and just 7 per cent area is under horticultural crops but contributes 25 per cent to the value (Figure 0.1). Thus, a shift in area under cereals to other high value and nutritional commodities like horticulture, pulses, nutri-cereals as per the agro-climatic condition of the regions can may lead to demand fulfilment and income enhancement can also be achieved.

The DFI Committee felt the need for States to undertake comprehensive district level planning, to bring about a shift in area under cereals to other high value and nutritional commodities like horticulture, pulses, nutri-cereals as per the agro-climatic condition of regions, so that along with demand fulfilment, income enhancement can also be achieved.

Unless the concerns on profitability of crops are addressed immediately, it may be difficult to liberate agriculture from its current growth trends. The country has the ability to to meet the food and nutritional demands of its population. However, before initiating a shift in the crop geometry, there will be need to ensure that food security is not disrupted. This can happen through special focus on productivity enhancement.

Except wheat, productivity of other crops in the country is below world average and much lower than agriculturally advanced countries (Chand, 2017). Technology adoption, minimizing yield gaps, better and sustainable irrigation practices etc. are few areas that need attention for enhancing the productivity growth in crops.

0.5 Commodity matrix and Supply Demand balance

Owing to increasing population over the years, demand for food will naturally show an associated increase. Further, socio-economic changes will also influence the trends on overall demand for food. NCAP Vision 2050 and a study by Kumar et al 2016, showed that the demand for fruits and vegetables will surpass the demand for cereals in the years to come.

Table 0.1 Projected Demand for major food commodities in India

Commodity	Current Production (~mill tons)	Projected Demand (mill tons)		Growth in Demand between 2030 to 2050
		2030*	2050**	
Cereals	**250**	284	359	**26.4%**
Pulses	**22**	26.6	46	**72.9%**
Edible Oils	**8**	21.3	39	**83.1%**
Vegetables	**175**	192	342	**78.1%**
Fruits	**93**	103	305	**196.1%**
Milk	**160**	170.4	401	**135.3%**
Sugar	**20**	39.2	58	**48.0%**
Meat	**7**	9.2	14	**52.2%**
Egg	**4**	5.8	10	**72.4%**
Fish	**11**	11.1	22	**98.2%**

Source : **Kumar et al. (2016) for projected demand in 2030*
***NCAP Vision 2050 for projected demand in 2050*

To meet this variation in demand, there will be need to **diversify and shift existing areas into crops where demand is expected to grow at a higher pace**. Looking at the food grain production scenario, country is self-sufficient or rather surplus in food grain requirement thus; we need to assess whether India needs this much of foodgrains? There is a possibility to shift some area to other crops which are high in both nutrition and in value. This will necessitate undertaking important changes in the current agriculture scenario and offers high potential in achieving doubling of farmers' income.

Farmers' income is directly related to both production and the marketing of the produce. There is need to grasp the gains in form of income enhancement along with maintaining the production balance in commodity status. Moreover, moving to sync with changes in the consumer preference for specific commodities and for better quality will also foster trade across the nation, which will further increase the share from farming income and allied activities.
Following table provides an insight from productivity gains from major food commodities and resultant production in 2022-23.

Table 0.2 Current and Projected Output of Agriculture Sector

Crop/ Livestock category	Production, 2015-16 (million tonnes)	Projected Production, 2022-23 (million tonnes)		
		Business as Usual Based on output growth between 2000-15 (% growth)	Accelerated growth scenario	Assumptions
Cereals	235.2	275.7 (2.29)	295.8	No area change, based on productivity growth of 3.1%
Pulses	16.3	20.8 (3.50)	21.9	No area change, based on productivity growth of 3.1%
Oilseeds	25.3	32.9 (3.88)	35.1	No area change, based on productivity growth of 3.1%
Horticulture	286.2	425.3 (5.80)	451.5	Area growth of 2.8%, productivity growth of 3.1%
Milk	151.0	204.0 (5.36)	205.6	Based on output growth of 4.5%
Meat	7.0	14.6 (11.02)	14.6	Based on output growth of 11%

Source: DFI Committee Estimates

It can be clearly noticed that despite no change in acreage under crops, an enhancement in productivity by 3.1 per cent will not only realise desired gains to the farmers in 2022-23 but also increase the nutritional availability. The country faces a deficit in pulses & oilseeds.

It is to note that current outputs can easily outpace the requirements in some sectors. One can naturally expect that the rising food demand will be accompanied by increasing demand for its safety and quality owing to rising health consciousness. Thus, the main challenge will be to develop technologies, practices, varieties and breeds that are high yielding as well as safe to human health. This will need to be accompanied with safe and secure post-harvest management and delivery systems. Together, this will make India's agricultural sectors future ready.

It has also assessed that irrigation management can be a game changer in productivity enhancement by bringing substantial growth in output. It has been established that micro-irrigation can bring substantial increase in productivity and result in water saving (Government of India, 2009). The average productivity of fruits and vegetables has increased about 42.3 and 52.8 per cent, respectively mainly because of judicious use of water. This was met with equal consumer demand and the overall benefits from the micro irrigation system are reflected in the income enhancement of these farmers. In addition to productivity increase and resource conservation, a major advantage of micro-irrigation in the rain-fed areas is to help reduce fluctuations in output under deficit rainfall conditions and hence reduce vulnerability.

Apart from above mentioned indicators for diversifying and to take a productivity approach, major requirement will be to evaluate and sync with the agro-climatic conditions. The crop matrix should be developed in agro-ecological consonance. An overall shift from being production centric to productivity centric approach is the need of the hour to overcome both nutritional requirement and value gains.

0.6 Yield gaps

India is largest producer of pulses in the world whereas the second largest producer of paddy, wheat and sugarcane. India is also an important producer of commercial crops like cotton, sugarcane and tobacco. But in most of the cases the productivity of various crops in India are lower than those in the US, Europe and China, because in most of these countries crops are largely grown in high input management conditions with considerably long growing periods. A measure of the degree of crop yield potential, the attainable yield and the corresponding yield gap (the difference between attainable yield and actual yields) is crucial so as to suggest appropriate policy measures.

There always exists a gap between what is projected as the potential yield of any crop variety at a research station, and what is produced by the farmers themselves. Several factors are responsible for theses yield gaps such as physical, biological, socio-economic and institutional constraints which can be effectively improved through participatory research and government attention. Thus, it is important to revisit yield gaps in various production systems in India to estimate existing yield potential across various agro-climatic zones in India.

The clear objective is to ensure that the maximum potential of any crop variety is harvested at the farmers' field. Significant yield gaps exist across various crops through different states as well as within states. Bridging these yield gaps will not only increase crop production but also helps to improve the efficiency of land and labour use, reduce production cost and add to food security. The current yield gaps show a lack of transfer of technology, adoption and knowhow to farmers.

Improving farm yields is important as it can also release land for other productive uses, such as diversifying into added high value commodities and allow farmers to scale up integrated farming practices. If a farmer can generate the current output, of say wheat, from lesser share of his land, some of the same land can be used to take up horticulture or add mushroom, sericulture, beekeeping or other secondary agricultural activities.

Productivity enhancement requires yield gap minimization between district to state, state to state and state to nation. These variations in crop yields are related to market accessibility, purchasing power/income, agricultural work force, and terrain factors, besides water and fertilizer management. However, closing yield gaps will enhance food self-sufficiency and enable food security at local, regional, and global scales.

There is immense yield potential at every level which needs to be assessed to minimise these yield leakages through better technology adoption, increased participation in FLD (front line demonstration), better irrigation practices, soil health card and other schemes.

Table 0.3 presents the yield gaps across major states producing cereals crops in India. Yield for rice ranges from a maximum of 3.8 tonnes per hectare in Punjab to lowest of 2.0 in case of Odisha, indicating a yield gap of more than 47 percent. The information highlights that crop yields vary across regions, even within the same climatic zones.

Table 0.3 Cereals- Inter-state and Intra-state Yield Gap (2014-15)

Interstate Yield Gap			**Intrastate Yield Gap**				
State	Yield of Major States (ton/Ha)	Percentage Yield Gap with Maximum Yield State	Best Yield District (ton/Ha)	Lowest Yield District (ton/Ha)	Yield range within State (ton/Ha)	Gap in max yield district and Min yield district (%)	Gap in State Avg Yield and Min Yield district (%)
Rice	Best Yield Punjab 3.8						
West Bengal	2.7	28.9	Maldah (3.5)	Darjeeling (2.1)	1.4	40.0	22.2
Uttar Pradesh	2.1	44.7	Auraiya (3.2)	Lalitpur (0.8)	2.4	75.0	61.9
Punjab	3.8	0.0	Sangrur (4.7)	Pathankot (2.5)	2.2	46.8	34.2
Odisha	2.0	47.4	Sonepur (3.4)	Jharsuguda (1.4)	2.0	57.9	29.0
Andhra Pradesh	3.0	21.1	SPSR Nellore (4.0)	Visakhapatanam (1.7)	2.3	57.5	43.3
All India	***2.4***	***36.8***					
Wheat	Best Yield Punjab 4.3						
Uttar Pradesh	2.3	46.5	Baghpat (3.4)	Banda (0.9)	2.5	73.5	60.9
Madhya Pradesh	2.9	32.6	Hoshangabad (4.8)	Dindori (1.3)	3.5	72.9	55.2
Punjab	4.3	0.0	Faridkot (4.8)	Pathankot (2.7)	2.1	43.8	37.2
Haryana	4.0	7.0	*				
Rajasthan	3.0	30.2	Jhunjhunu (4)	Jaisalmer (1)	3.1	75	66.7
All India	***2.8***	***34.9***					
Maize	Best Yield Tamil Nadu 6.4						
Karnataka	3.2	50.0	Kodagu (5.1)	Bidar (1.8)	3.3	64.7	43.8
Madhya Pradesh	1.9	70.3	Seoni (3.6)	Sidhi (1.3)	2.3	63.9	31.6
Bihar	3.3	48.4	Katihar (6.5)	Kaimur (Bhabua) (1.2)	5.3	81.5	63.6
Tamil Nadu	6.4	0.0	Perambalur (11.0)	Tuticorin (5.2)	5.8	52.7	18.8
Telangana	3.3	48.4	Karimnagar (5.0)	Medak (1.8)	3.2	64.0	45.5
All India	***2.6***	***59.4***					

Source: DFI Committee Estimates based on data compiled from DACNET

*District -wise data not available for the year 2014-15

In case of wheat, the yield varies from a high of 4.3 tonnes per hectare in Punjab to a low of 2.3 in Uttar Pradesh. The yield gap in case of major cereals is maximum in case of maize where more than 70 percent difference is seen between the states having the lowest and the highest yield. The table also highlighted large yield gap among the districts in specific states, thus there is considerable yield gap within states, indicating the scope to increase the yield in future, in the districts having comparatively lower yields.

Considerable yield gap also exist between major states producing coarse cereals like Jowar and Bajra where it is more than 64 per cent and as much as 68 per cent respectively.

Table 0.4 Coarse Cereals: inter-state and intra-state Yield Gap (2014-15)

Interstate Yield Gap			**Intrastate Yield Gap**					
State	Yield of Major States (ton/Ha)	Percentage Yield Gap with Maximum Yield State	Best Yield District (ton/Ha)	Lowest Yield District (ton/Ha)	Yield Range within State (ton/Ha)	Gap in Max yield district and Min yield district (%)	Gap in Max District Yield and Avg State Yield (%)	Gap in State Avg Yield and Min Yield district (%)
Jowar	**Jowar: Best Yield Madhya Pradesh 1.7**							
Maharashtra	0.6	64.7	*					
Karnataka	1.1	35.3	Davangere (2.1)	Chamarajanagar (0.4)	1.7	81.0	47.6	63.6
Tamil Nadu	1.5	11.8	Tirunelveli (4.7)	Tiruppur (0.3)	4.4	93.6	68.1	80.0
Rajasthan	0.8	52.9	Rajsamand (2.1)	Jaisalmer (0.1)	2.0	95.2	61.9	87.5
Madhya Pradesh	1.7	0.0	Barwani (3.3)	Rewa (0.9)	2.4	72.7	48.5	47.1
All India	***0.9***	***47.1***						
Bajra	**Best Yield Uttar Pradesh 1.9**							
Rajasthan	1.1	42.1	Dholpur (2.1)	Jaisalmer (0.1)	2.0	95.2	47.6	90.9
Uttar Pradesh	1.9	0.0	Kasganj (3.3)	Allahabad (0.7)	2.6	78.8	42.4	63.2
Gujarat	1.7	10.5	*					
Haryana	1.7	10.5	*					
Maharashtra	0.6	68.4	Jalgaon (1.2)	Parbhani (0.1)	1.1	91.8	50.8	83.3
All India	***1.3***	***31.6***						

Source: DFI Committee Estimates based on data compiled from DACNET

*District -wise data not available for the year 2014-15

District wise yield gap in maximum in Rajasthan both in case of Jowar and Bajra where it is around 88 percent in case of Jowar and more than 90 percent in Bajra. Thus there are serious gaps both at the state level and at the district level which highlights the importance of increasing yield potential, which if addressed properly could help in achieving the target of increasing farmers income.

There exists significant yield gap in case of pulse also, for example in case of Tur (Arhar) the yield ranges from a high of 1.1 (tonnes/hectare) to a low of 0.6 in case of Maharashtra. Same is the case with Gram and Lentil (Masur) where the yield gap is considerable with more than 36 percent in case of Gram and around 50 percent in case of Lentil (Masur).

Table 0.5 Pulses- Inter-state and Intra-state Yield Gap (2014-15)

Interstate Yield Gap			Intrastate Yield Gap					
State	Yield of Major States (ton/ Ha)	Percentage Yield Gap with Maximum Yield State	Best Yield District (ton/Ha)	Lowest Yield District (ton/Ha)	Yield Range within State (ton/ Ha)	Gap in Max yield district and Min yield district (%)	Gap in Max District Yield and Avg State Yield (%)	Gap in State Avg Yield and Min Yield district (%)
Tur (Arhar)	**Best Yield Gujarat 1.1**							
Maharashtra	0.6	45.5	Jalgaon (0.5)	Beed (0.2)	0.3	60.0	40.0	33.3
Madhya Pradesh	1.0	0.0	Damoh (1.5)	Khargone (0.5)	1.0	66.7	33.3	50.0
Karnataka	0.7	0.0	Hassan (1.5)	Tumkur (0.2)	1.3	86.7	53.3	71.4
Gujarat	1.1	0.0	*					
Jharkhand	1.0	0.0	*					
All-India	***0.7***	***0.0***						
Gram	**Best Yield Uttar Pradesh 1.1**							
Madhya Pradesh	1.0	9.1	Shajapur (1.8)	tikamgarh (0.4)	1.4	77.8	44.4	60.0
Maharashtra	0.8	27.3	Hingoli (2.9)	Jalna (0.3)	2.6	89.7	72.4	62.5
Rajasthan	0.7	36.4	Sawaimadhopur (1.4)	Churu (0.3)	1.1	78.6	50.0	57.1
Karnataka	0.7	36.4	Hassan (1.0)	Haveri (0.5)	0.5	50.0	30.0	28.6
Andhra Pradesh	1.1	0.0	Guntur (2.3)	Anantapur (0.1)	0.6	95.7	52.2	90.9
All-India	***0.9***	***18.2***						
Lentil (Masur)	**Best Yield West Bihar1.0**							
Madhya Pradesh	0.7	30.0	Ratlam (1.0)	Shivpuri (0.3)	0.7	70.0	30.0	57.1
Uttar Pradesh	0.5	50.0	Budaun (1.1)	Banda (0.1)	1.0	90.9	54.5	80.0
Bihar	1.0	0.0	Kaimur (Bhabua) (2.6)	Sitamarhi (0.2)	2.5	93.6	62.0	83.1
West Bengal	1.0	0.0	Medinipur west (1.8)	Coochbehar (0.5)	0.5	70.6	44.9	46.6
Rajasthan	1.0	0.0	Pratapgarh (1.2)	Bhilwara (0.6)	0.6	50.0	16.7	40.0
All-India	***0.71***	***29.5***						

Source: DFI Committee Estimates based on data compiled from DACNET

*District -wise data not available for the year 2014-15

Even at district level across different states, there exists huge yield gap mainly due to different cropping systems, biophysical situations and other attributes of farming systems. This highlights the need for taking up adaptive research based technology generation and dissemination in case of major pulses producing states.

In last few years India has emerged as the major importer of food oil and pulses in the world. So by increasing the yield of oilseeds we can restrict the additional burden on state exchequer. In case of oilseeds yield gap across major states is maximum (78.6 percent) in case of Groundnut while it is minimum in case of Rapeseed & Mustard. Significant intrastate yield gaps exist. Thus, there is considerable scope for increasing yield for oilseeds in the country.

Table 0.6 Oilseeds - Inter-state and Intra-state Yield Gap (2014-15)

Interstate Yield Gap			**Intrastate Yield Gap**					
	Yield of Major States (ton/Ha)	Percentage Yield Gap with Maximum Yield State	Best Yield District (ton/Ha)	Lowest Yield District (ton/Ha)	Yield Range within State (ton/ Ha)	Gap in Max yield district and Min yield district (%)	Gap in Max District Yield and Avg State Yield (%)	Gap in State Avg Yield and Min Yield district (%)
Rapeseed & Mustard		**Best Yield Haryana 1.4**						
Rajasthan	1.2	14.3	Hanumangarh (1.5)	Jaisalmer (0.6)	0.9	60.0	20.0	50.0
Madhya Pradesh	1.0	28.6	Mandsaur (2.1)	Umaria (0.4)	1.7	81.0	52.4	60.0
Haryana	1.4	0.0	*					
Uttar Pradesh	0.9	35.7	Mainpuri (1.8)	Banda (0.1)	1.7	95.4	48.6	91.1
West Bengal	1.1	21.4	Paraganas north (1.3)	Darjeeling (0.3)	1.0	77.5	19.7	72.0
All-India	***1.1***	***21.4***						
Groundnut	**Best Yield Tamil Nadu 2.8**							
Gujarat*	2.2	21.4	*					
Rajasthan	2.0	28.6	Bikaner (2.4)	Rajsamand (0.8)	1.6	66.7	16.7	60.0
Tamil Nadu	2.8	0.0	Thiruvarur (4.9)	Nilgiris (1.0)	3.9	79.6	44.9	63.0
Karnataka	0.8	71.4	Udupi (2.0)	Bidar (0.3)	1.8	87.2	62.0	66.2
Andhra Pradesh	0.6	78.6	Guntur (4.5)	Anantapur (0.3)	4.2	93.2	87.6	45.6
All-India	***1.6***	***42.9***						
Soyabean	**Best Yield Madhya Pradesh 1.1**							
Madhya Pradesh	1.1	0.0	Betul (2.1)	Burhanpur (0.6)	1.5	71.4	47.6	45.5
Maharashtra	0.7	36.4	Kolhapur (2.2)	Hingoli (0.3)	1.9	86.4	68.2	57.1
Rajasthan	1.0	9.1	Sawai Madhopur (1.4)	Banswara (0.8)	0.6	42.9	28.6	20.0
Karnataka	0.7	36.4	Dharwad (1.0)	Bidar (0.6)	0.5	44.4	27.9	22.8
All-India	***1.0***	***9.1***						

Source: DFI Committee Estimates based on data compiled from DACNET

*District -wise data not available for the year 2014-15

Table 0.7 presents the yield gap across major commercial crops in India. As can be seen from the table, there exists huge yield gap both across different states and within the same state as well. Several spatial and temporal factors are responsible for such variation in productivity across major states. A thorough understanding and quantification of these factors is needed to estimate the scope to increase productivity in various states.

Table 0.7 Commercial Crops - Inter-state and Intra-state Yield Gap (2014-15)

Interstate Yield Gap			**Intrastate Yield Gap**					
	Yield of Major States (ton/Ha)	Percentage Yield Gap with Max Yield State	Best Yield District (ton/Ha)	Lowest Yield District (ton/Ha)	Yield Range within State (ton/Ha)	Gap in Max yield district and Min yield district (%)	Gap in Max District Yield and Avg State Yield (%)	Gap in State Avg Yield and Min Yield district (%)
Cotton	**Best Yield Gujrat 0.6**							
Gujrat	0.6	0.0	Solapur (0.3)	Beed (0.1)	0.2	66.7	51.6	31.1
Maharashtra	0.3	50.0	Khammam (0.5)	Nizamabad (0.2)	0.3	60.0	20.0	50.0
Telangana	0.4	33.3	Guntur (0.9)	Anantapur (0.2)	0.7	77.4	32.3	66.7
Andhra	0.6	0.0	Gulbarga (0.7)	Chamarajanagar (0.2)	0.5	71.4	42.9	50.0
Karnataka	0.5	16.7						
All-India	***0.5***	***16.7***						
Sugarcane	**Best Yield Tamil Nadu 106.8**							
Uttar Pradesh	62.2	41.8	Shamli (78.8)	Lalitpur (40.4)	38.4	48.7	21.1	35.0
Maharashtra	82.2	23.0	Sangli (108.8)	Washim (29.0)	79.8	73.3	24.4	64.7
Karnataka	91.2	14.6	Davangere (128.3)	Ramanagara (65.6)	62.7	48.9	28.9	28.1
Tamil Nadu	106.8	0.0	Namakkal (126.1)	Tirunelveli (78.0)	48.1	38.1	15.3	27.0
Gujarat	68.9	35.5	*					
All-India	***71.5***	***33.1***						
Tobacco	**Best Yield Uttar Pradesh 4.3**							
Andhra	2.6	39.5	Krishna (6.2)	Anantapur (1.9)	4.3	69.4	58.1	26.9
Gujarat	1.4	67.4	*					
Karnataka	0.7	83.7	Belgaum (1.3)	Mysore (0.6)	0.7	53.8	46.2	14.3
Uttar Pradesh	4.3	0.0	Etah (4.7)	Hardoi (2.5)	2.2	46.8	8.5	41.9
Bihar	1.8	58.1	Khagaria (2.0)	Siwan (1.8)	0.2	10.0	10.0	0.0
All-India	***1.6***	***62.8***						

Source: DFI Committee Estimates based on data compiled from DACNET

*District -wise data not available for the year 2014-15

India is the largest milk producer in the world, milk and other dairy products account for around two thirds of the value of the Indian livestock sector and support the livelihoods of nearly half of India's rural households. Table 0.8 shows the yield gap in milk production. Application for yield gap analyses in dairy sector is significant in context of fact that livestock farming is an important component of smallholder farming systems.

Punjab tops the list for yield across the most categories in the dairy sector owing to various socio-economic reasons. Considerable yield gaps are seen, both across different states and within the states as well.

Table 0.8 Interstate Yield Gap across Major Milk Production States (T.E 2014-15)

Major States	Average daily Productivity (Kg/ Day)	Yield Gap with Maximum Yield State (%)	Major States	Average daily Productivity (Kg/ Day)	Yield Gap with Maximum Yield State (%)
Crossbred	**Best yield Punjab (11.1)**		**Indigenous**	**Best yield Punjab (6.6)**	
Punjab	11.1	0.0	Punjab	6.6	0.0
Chandigarh	9.0	18.4	Haryana	5.2	21.4
Meghalaya	9.0	19.2	Gujarat	4.1	38.7
Gujarat	8.9	19.3	Delhi	4.0	40.2
Kerala	8.8	21.0	Rajasthan	3.7	44.2
All India	***7.0***	***37.0***	***All India***	***2.5***	***62.9***
Buffaloes	**Best yield Punjab (8.7)**		**Goats**	**Best yield Punjab (8.7)**	
Punjab	8.7	0.0	Daman & Diu	1.7	0.0
Haryana	7.6	13.0	Punjab	1.4	18.0
Chandigarh	6.1	29.3	Haryana	0.9	48.9
Jharkhand	5.8	33.2	Uttar Pradesh	0.8	56.2
Delhi	5.8	33.4	Kerala	0.7	62.0
All India	***5.0***	***43.0***	***All India***	***0.4***	***74.3***

Source: Basic Animal Husbandry & Fisheries Statistics 2015, Ministry of Agriculture & Farmers Welfare Department

The dairy sector is only one reflection of India's livestock sector, one of the largest in the world. The socio-economic development and changing lifestyle has resulted in a change in the dietary patterns in India. There has been increased consumption of meat, including poultry and animal-based products.

Also over the last few years, a steep rise in export of bovine meat (carabeef) and this industry has emerged to be significant for providing income and employment in the agricultural sector.

The major states with buffalo meat production centres are Uttar Pradesh, Andhra Pradesh, Maharashtra and Punjab. A significant component of the rural labour force is employed in rearing the livestock and related occupations. There has been sharp rise in the production of animal meat across various states in India but there exists significant yield gap across major meat producing states in India. Table 0.9 provides the yield gap across major meat producing states.

Table 0.9 Interstate Yield Gap across major Meat producing States (2015-16)

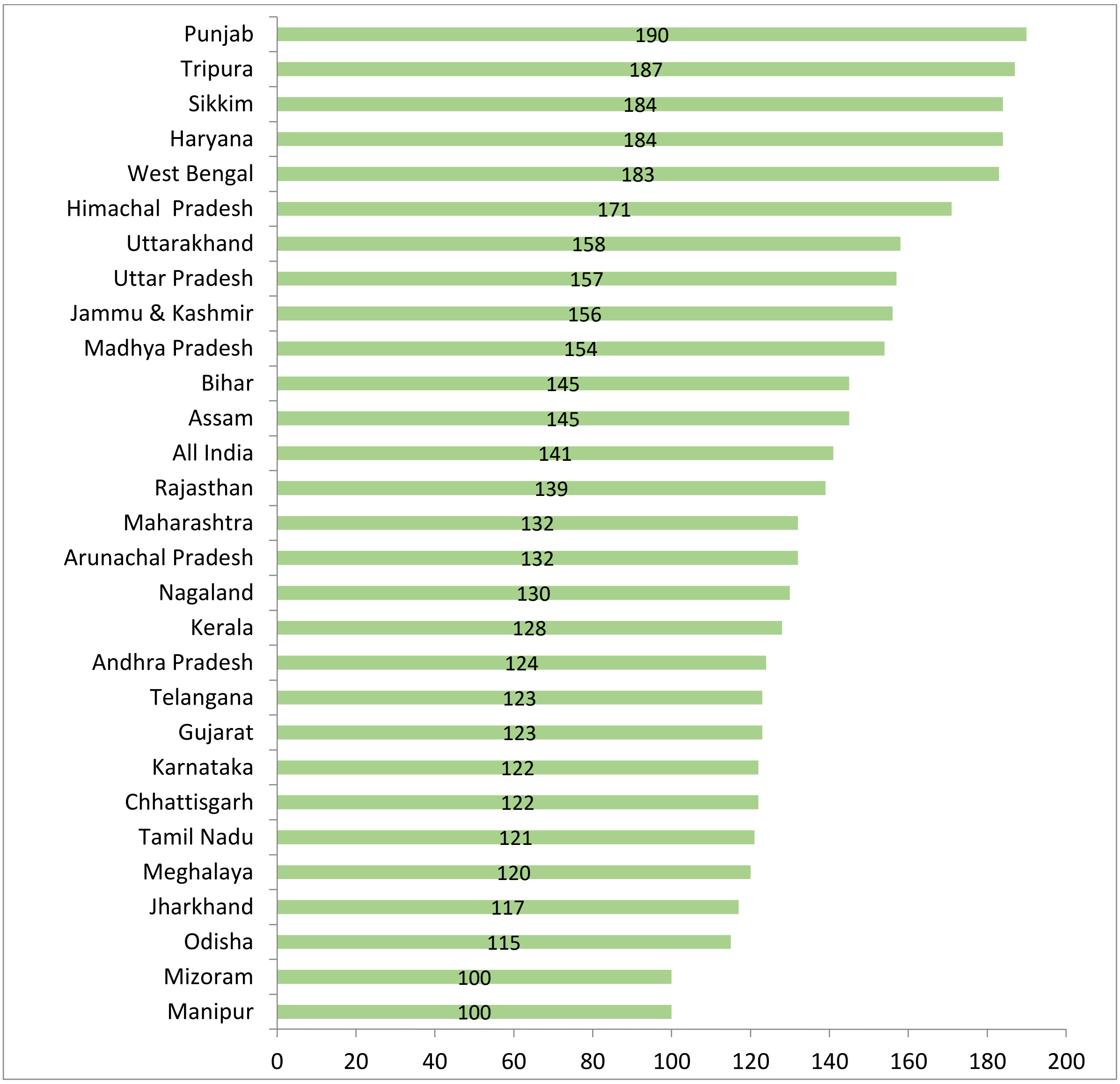
States	Productivity (Kg/animal)	Yield Gap with Maximum Yield State (%)	States	Productivity (Kg/animal)	Yield Gap with Maximum Yield State (%)
Cattle-Adult: Best yield A&N Islands (214.3)			**Cattle-Young: Best yield Kerala (90.1)**		
A&N Islands	214.3	0.0	Kerala	90.1	0.0
Tamil Nadu	147.3	31.3	Tamil Nadu	72.1	19.9
West Bengal	130.8	39.0	Arunachal Pradesh	70.1	22.2
Maharashtra	130.5	39.1	Assam	57.3	36.4
Sikkim	128.4	40.1	Manipur	43.1	52.1
Total	**110.6**	**48.4**	**Total**	**51.0**	**43.3**
Buffalo-Adult: Best yield A&N Islands (240.0)			**Buffalo-Young: Best yield Nagaland (104.7)**		
A&N Islands	240.0	0.0	Nagaland	104.7	0.0
Nagaland	187.4	21.9	Kerala	92.0	12.1
Maharashtra	186.7	22.2	Madhya Pradesh	82.7	21.0
Jammu & Kashmir	168.4	29.8	Maharashtra	81.4	22.2
Delhi	159.9	33.4	Andhra Pradesh	74.4	28.9
Total	**133.9**	**44.2**	**Total**	**63.5**	**39.3**
Sheep-Adult: Best yield Haryana (20.0)			**Sheep-young: Best yield Andhra Pr. (10.7)**		
Haryana	20.0	0.0	Andhra Pradesh	10.7	0.0
Himachal Pradesh	19.3	3.8	Jammu & Kashmir	10.6	1.1
Jammu & Kashmir	16.9	15.7	Rajasthan	10.4	3.2
Karnataka	16.6	17.3	Madhya Pradesh	10.1	5.9
Rajasthan	15.5	22.5	Haryana	9.3	13.6
Total	**13.8**	**31.1**	**Total**	**9.9**	**7.2**
Goat-Adult: Best yield Himachal Pr. (20.2)			**Goat-Young :Best yield Madhya Pr. (12.1)**		
Himachal Pradesh	20.2	0.0	Madhya Pradesh	12.1	0.0
Haryana	19.4	4.0	Jammu & Kashmir	10.7	12.1
Jammu & Kashmir	16.7	17.2	Andhra Pradesh	10.5	13.2
Uttar Pradesh	16.6	17.7	Rajasthan	10.2	16.2
Madhya Pradesh	16.6	18.0	Kerala	9.0	26.2
Total	**11.2**	**44.4**	**Total**	**8.9**	**26.3**
Pig-Adult: Best yield Mizoram (86.9)			**Poultry: Best yield Lakshadweep (3.2)**		
Mizoram	86.9	0.0	Lakshadweep	3.2	0.0
Nagaland	79.4	8.6	Sikkim	2.5	21.1
Kerala	75.0	13.6	West Bengal	2.0	36.7
Rajasthan	60.4	30.5	Manipur	2.0	37.0
Arunachal Pradesh	60.0	30.9	Mizoram	1.9	40.5
Total	**38.0**	**56.3**	**Total**	**1.4**	**57.4**

Source: Basic Animal Husbandry & Fisheries Statistics 2015, Ministry of Agriculture & Farmers Welfare.

0.7 Cropping Intensity

According to the latest available data triennium 2014-15, the index of intensity of cropping for the country as a whole is 141 per cent. It shows great spatial variations with 'higher levels in northern plains and lower levels are found in dry, rain-fed regions of Rajasthan, Gujarat, Maharashtra and Karnataka. Punjab has the highest cropping intensity of 190 per cent, followed by north eastern states of Tripura and Sikkim and Haryana (184 per cent).

Figure 0.2 State-wise cropping intensity (T.E. 2014-15)



Source: DFI Committee - estimates based on data compiled from DACNET.

To fulfil the increasing food demand, intensifying cropping over the existing area is the only viable option we had today. Higher cropping intensity implies higher productivity per unit of arable land during one agricultural year.

The level of cropping intensity is determined by several factors. The most important factor is the availability of water from natural or man-made sources for irrigation purpose. However, the scope for year round cropping activities in most states of India is severely constrained by the seasonal distribution of rainfall.

So long as this natural constraint is mitigated, by developing irrigation facilities, the level of multiple cropping cannot be improved. Volume I of the DFI reports provides insight on how micro irrigation can benefit famers' income growth.

0.8 The Crop Geometry

Shifting little area from staple to high value in the suitable region (basis agro-climatic condition and availability) can lead to a sizable increase in the returns for farmers. This can be clubbed with crop planning matrix to understand the potential location for area and crop shifting. Diversification towards high value crop needs current attention (NITI Aayog Policy Paper and Volume I and Volume II of DFI Committee Report). High value crops offer comparatively better growth in terms of value of output contribution as compared to the staple crops. Birthal, *et al.* (2013) has also noted that diversification into production of fruits and vegetables, in general, and vegetables, in particular, is likely to benefit the small and marginal farmers more than the medium and large farmers.

Table 0.10 provides the existing crop geometry and shows that in the majority of states, maximum area is occupied under foodgrains, followed by oilseeds. Area under nutri-cereals and horticultural crops is lower despite its potential to generate higher returns.

Table 0.10 Existing crop geometry across states (area share to GCA %)

States	**GCA (000 ha)**	Rice	Wheat	Maize	Nutri cereals	Total Pulses	Total Oilseed	Total Food-grain	Hortic ultural Crops
Andhra Pr	**7909**	29.7	0.1	4.0	3.1	14.7	17.5	51.6	13.7
Arunachal Pr	**293**	43.8	1.1	16.2	8.1	3.5	11.4	72.7	9.3
Assam	**4086**	60.6	0.7	0.6	0.1	3.6	7.5	65.7	12.8
Bihar	**7725**	41.8	27.5	9.2	0.3	6.9	1.6	85.7	6.0
Chhattisgarh	**5705**	66.6	1.8	2.0	2.4	15.6	5.1	88.4	2.6
Gujarat	**12620**	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.8
Haryana	**6461**	19.2	39.2	0.1	7.7	2.1	8.5	68.3	1.1
Himachal Pr	**941**	7.9	8.0	8.1	3.1	8.2	8.4	8.5	14.2
J & K	**1162**	23.2	25.9	26.1	3.5	2.2	5.4	80.9	8.8
Jharkhand	**1628**	65.0	4.2	6.0	0.9	10.2	4.1	88.0	7.4
Karnataka	**12087**	10.9	1.7	11.1	17.5	19.5	11.6	60.7	8.8
Madhya Pr	**23662**	8.4	23.5	4.0	3.1	22.8	31.5	61.9	3.1
Maharashtra	**22915**	6.9	4.3	4.2	17.9	15.5	17.7	48.7	5.5
Manipur	**356**	53.3	0.6	6.7	0.0	8.5	11.0	69.2	14.9
Meghalaya	**342**	32.1	0.1	5.2	0.0	1.4	3.7	39.6	47.5
Mizoram	**125**	24.1		4.7	0.0	3.0	1.7	31.8	65.4
Nagaland	**496**	38.2	0.6	13.9	2.1	7.7	13.1	62.5	20.1
Odisha	**5136**	79.5	0.0	1.7	0.6	14.6	3.7	95.8	0.1

States	GCA (000 ha)	Rice	Wheat	Maize	Nutri cereals	Total Pulses	Total Oilseed	Total Food-grain	Horticultural Crops
Punjab	**7858**	36.4	44.7	1.6	0.2	0.7	0.6	83.6	2.3
Rajasthan	**24769**	0.6	12.4	3.8	20.8	14.5	19.7	52.0	4.0
Sikkim	**142**	8.0	0.3	28.1	5.7	4.4	5.7	40.8	48.5
Tamil Nadu	**5677**	29.4		5.6	8.4	13.0	7.1	56.4	12.2
Telangana	**5801**	27.3	0.0	11.6	2.0	9.1	8.0	50.0	4.5
Tripura	**477**	53.5	0.1	0.9	0.0	2.3	1.4	56.7	26.7
Uttarakhand	**1107**	23.4	31.7	2.3	18.6	5.8	2.9	81.9	5.4
Uttar Pradesh	**25955**	22.8	37.8	2.9	4.9	9.0	4.3	77.3	4.6
West Bengal	**9589**	56.8	3.4	1.3	0.2	2.6	7.9	64.3	18.0
All India	**197852**	**22.1**	**15.5**	**4.5**	**8.1**	**12.1**	**13.5**	**62.4**	**6.6**

Source: DFI Committee Estimates based on data compiled from DACNET.

With appropriate infrastructural and logistic support, a chunk of area can be shifted to high value commodities for generating higher returns to farmers.

The change in this existing crop geometry will require investing in tandem to develop strong structural support for these highly perishable produce types. Both central and state assistant is required to build the necessary infrastructural facilities. The current e-NAM scheme can also prove beneficial by providing a trading platform for these commodities.

0.8.1 Changing Crop Geometry

Tables 0.11 provide us a glimpse about future requirement for wheat in India (projected demand based on actual consumption in NSS Family Budget Survey plus average export of wheat for last ten years) based on two scenarios i.e. business as usual and accelerated growth scenario; thus, approximately 2.5 million hectares can be released from wheat cultivation and can be shifted to more required and remunerative crops.

Table 0.11 Estimated land which can be released from Wheat Crop

		Output (Million Tonnes)	Projected Demand (Million Tonnes)	Surplus (Million Tonnes)	Productivity (Tonnes/ Hectare)	*Land to be released (Million Hectare)
2016-17	Existing Status	98.4	91.0	7.4	3.0	2.5
2021-22	#Business as usual	105.0	100.6	4.4	3.5	1.3
2021-23	@Accelerated growth scenario	112.0	100.6	11.4	3.7	3.1

Source: DFI Committee Estimates

Output projected using the productivity growth of 1.9 % per year (last 10 year growth) with area constant at 30.2 Million ha at 2015-16 level.
@Output projected using the productivity growth of 3.1 % per year as given in NITI Policy Paper with area constant at 30.2 Million ha at 2015-16 level.
*Calculated by dividing surplus production divided by the wheat productivity

Many parts of northern India, especially Punjab is facing severe water crisis because of a complicated mix of economic, geographic, and political factors. In global comparison, India also uses almost twice the amount of water to grow crops as compared to China and United States (Table 0.12). In the past half century, majority of the growth to net irrigated area has come through the assurance of continuous supply of ground water. The primary cause of over-exploitation of ground water has been the rising demand from agricultural sector. In most of the cases, decisions such as cropping pattern and cropping intensity are primarily driven by continuous supply of ground water without caring about negative environmental impact.

Table 0.12 Water use for crop production in different countries (in cubic metres/tonne)

Crops and Crop Products	Average Amount of Water Needed to Grow Crops in			
	Brazil	**India**	**China**	**United States**
Rice	3,082	2,800	1,321	1,275
Sugarcane	155	159	117	103
Wheat	1,616	1,654	690	849
Cotton	2,777	8,264	1,419	2,535

Source: R. Suhag, Overview of Groundwater in India, Tech. Rep. 2016.

Policy measures like power subsidies for agriculture have played a major role in the decline of water levels especially in the northern part of India. Also, even though Minimum Support Prices (MSPs) are currently announced for number of crops, growers of sugarcane, wheat and rice are largely benefitted from this policy. These issues have created highly skewed incentive structures in favor of water intensive crops. Water-intensive crops like sugarcane and paddy are mostly grown in the naturally water-starved areas of the country for instance paddy in Punjab and Sugarcane in Maharashtra with Maharashtra being the second largest grower of sugarcane in India and Punjab being the third largest grower of rice (Agricultural Statistics at a glance 2016). Central Ground Water Board (CGWB, Ministry of Water Resources) used to measure ground water resources in the country at different scales at different time interval at state level and within districts, such as blocks/mandals/talukas/watersheds. Ground water development is a ratio of the annual ground water extraction to the net annual ground water availability. It specifies the quantity of ground water available for use. Table 1.13 illustrates the level of ground water development in the country over the past two decades.

Table 0.13 Ground Water Situation in India (Past 20 Years)

Level of ground water development	Explanation	% of districts in 1995	% of districts in 2004	% of districts in 2009	% of districts in 2011
0-70% (Safe)	Areas which have ground water potential for development	92	73	72	71
70-90% (Semicritical)	Areas where cautious ground water development is recommended	4	9	10	10
90-100% (Critical)	Areas which need intensive monitoring and evaluation for ground water development	1	4	4	4
>100% (Overexploited)	Areas where future ground water development is linked with water conservation measures	3	14	14	15

Source: R. Suhag, Overview of Groundwater in India, Tech. Rep. 2016.

0.8.2 Different scenarios of staple foodgrains production

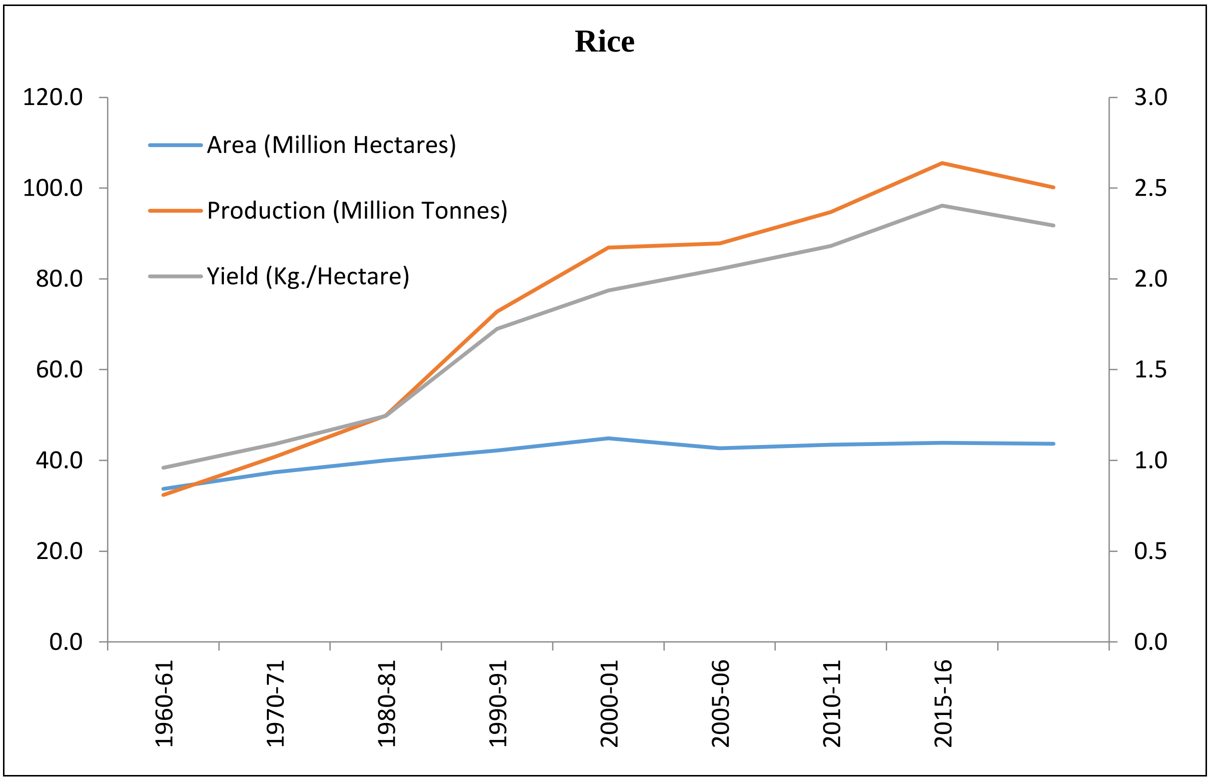
From 1960-61 to 2015-16, rice production increased from around 34 million tonnes to around 44 million tonnes and wheat production increased from 10.4 million tonnes to around 92.0 million tonnes. The yield improved from around 1.0 tonnes per hectare to around 2.4 tonnes per hectare in case of rice and fourfold in case of wheat, from 0.8 to 3.0 tonnes per hectare. Nonetheless, the area under rice cultivation has increased only marginally; it was around 40 million ha in 1980-81 and 44 million ha in the year 2015-16.

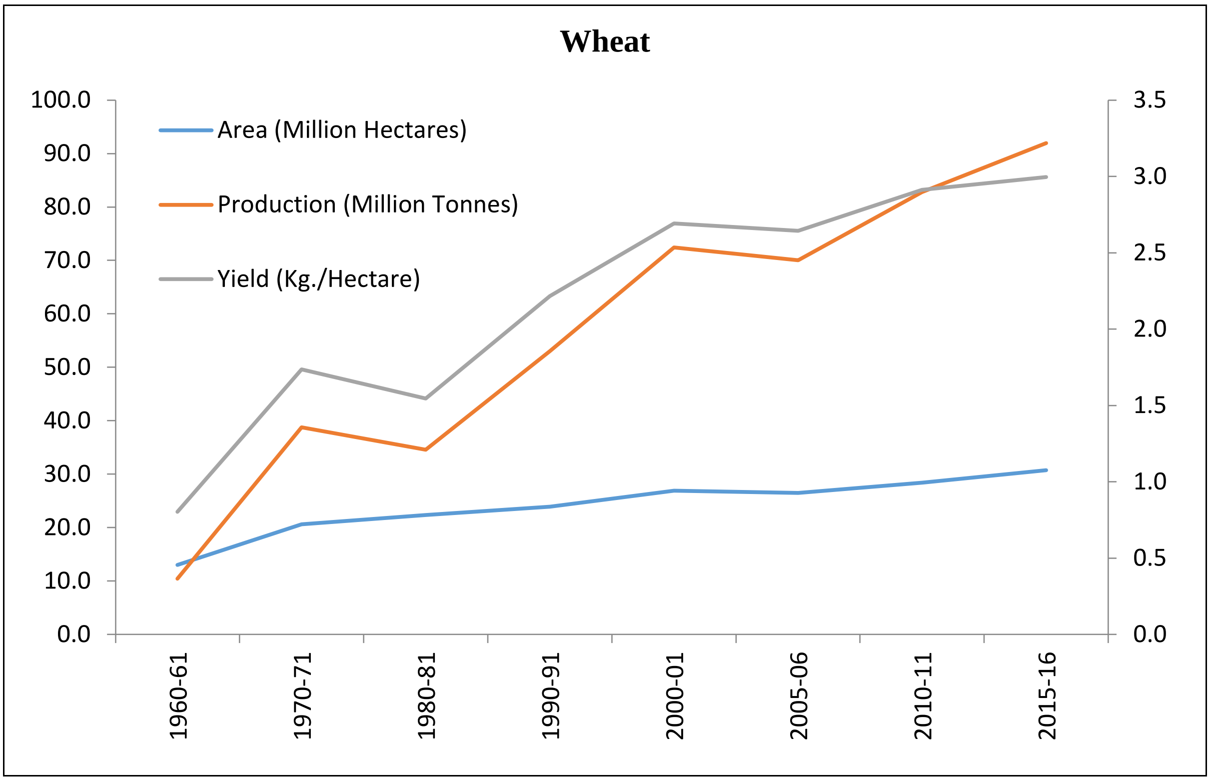
Table 0.14 Rice and Wheat (Area, Production and Yield)

	Rice			**Wheat**		
Year	Area (mill Hectares)	Production (mill tonnes)	Yield (ton/Ha)	Area (mill Hectares)	Production (mill tonnes)	Yield (ton/Ha)
T.E. 1960-61	33.7	32.4	1.0	13.0	10.4	0.8
T.E. 1970-71	37.4	40.8	1.1	20.6	38.8	1.7
T.E. 1980-81	40.0	49.9	1.2	22.4	34.6	1.5
T.E. 1990-91	42.2	72.8	1.7	23.9	53.0	2.2
T.E. 2000-01	44.9	86.9	1.9	26.9	72.4	2.7
T.E. 2005-06	42.7	87.8	2.1	26.5	70.1	2.6
T.E 2010-11	43.4	94.8	2.2	28.4	82.8	2.9
T.E.2015-16	43.9	105.5	2.4	30.7	92.0	3.0

Source: DFI Committee Estimates based on data available in Agricultural Statistics at a Glance

Figure 0.3 Trends in Area, Production and Yield of Rice and Wheat in India





The trends show that future production of rice may face some stagnation. Various agencies had suggested different growth rate for production of various commodities in India as shown in Table 0.15.

Table 0.15 Average Annual Growth Rate of Production of Selected Food Commodities in India as suggested by different agencies

	Actual Growth Rate	FAO/ OECD	USDA	FAPRI	IGC	NCAER	
						India stand-alone Cosimo Model	Econom-etric Model
	2004-14	**2013-23**	**2013-23**	**2013-21**	**2013-19**	**2015-24**	**2015-23**
Wheat	3.6	1.5	0.8	1.1	1.0	1.2	1.6
Rice	2.0	1.5	0.8	NA	1.9	1.5	2.5
Coarse grains	2.1	1.8	2.3	1.9	1.8	1.5	2.6
Pulses	3.8						1.3
Total oilseeds	1.0	2.6	2.1	0.6	1.3	1.5	4.9

***Source:** State of Indian Agriculture 2015-16*

Scenario A: Business as Usual

In the last five years since 2011-12 to 2015-16, in case of rice, the area is almost stagnant at 44 million hectare whereas the production is increasing at a slow rate. Average growth rate for the area between the last ten years (2006-07 to 2015-16) is -0.01 per cent and average growth rate for production comes out as 1.42 per cent.

Table 0.16 Projected Area, Yield and Production for rice and wheat

	Rice*	Wheat#	Demand Supply Projections[1]				
Year	Production- (million tonnes)	Production- (million tonnes)	Commodities	Year	Supply Projection	Demand Projection	Demand supply gap
2016-17	106	96	Rice	2020	108.1	111.8	-3.7
2017-18	107	100		2030	122.1	122.4	-0.3
2018-19	109	103	Wheat	2020	104.2	98.3	5.9
2019-20	110	106		2030	128.8	114.6	14.2
2020-21	112	109					
2021-22	113	113					
2022-23	115	116					

Source: DFI Committee Estimates based on data available in Agricultural Statistics at a Glance

* (Area constant at 43.4 hectares at 2015-16 level and annual production grows at rate of 1.4 percent per year)
# (Area constant at 30.23 hectares at 2015-16 level and annual production grows at rate of 3.2 percent per year)

Using area constant at 43.4 million hectares at 2015-16 level and average annual production growth rate of 1.4, the rice production is projected at 115 million tonnes in 2022-23. In case of wheat average growth rate for the area between the last ten years (2006-07 to 2015-16) is 1.36 whereas average growth rate for production is 3.19. Using the area constant for wheat at 30.23 hectares at 2015-16 level and average production growth rate of 3.19 per cent, wheat production is projected at 116 million tonnes for the year 2022-23.

Scenario B: Optimistic Approach

In this scenario, keeping area under rice constant at 43.4 million hectares, a higher annual growth rate of production at 2.5 per cent is used.

Table 0.17 Optimistic scenario for rice and wheat production

Year	Rice Area (mill Hectares)	Rice Production (mill tonnes)	Wheat Area (mill Hectares)	Wheat Production (mill tonnes)
2015-16	43.4	104.3	30.2	93.5
2016-17	43.4	106.9	30.2	96.8
2017-18	43.4	109.6	30.2	100.2
2018-19	43.4	112.3	30.2	103.7
2019-20	43.4	115.1	30.2	107.3
2020-21	43.4	118.0	30.2	111.0
2021-22	43.4	121.0	30.2	114.9
2022-23	43.4	124.0	30.2	119.0

Source: DFI Committee Estimates based on data available in Agricultural Statistics at a Glance

[1] Adapted from Kumar P. et al (2016)

In this case, with higher yield from same area, total supply of rice will be 124 million tonnes in 2022-23. Using the same criteria for wheat with area fixed at 30.23 hectares at 2015-16 level, and a higher annual growth rate of 3.5 per cent, the wheat production will be 119.0 million tonnes in 2022-23.

0.8.3 Specific Case of Punjab

Over 97% of the cultivated area in Punjab is irrigated, the highest in the country though only 25% of the area benefits from canal irrigation the remaining 75% is irrigated using groundwater. Average annual decline in groundwater table in the central Punjab was about 17 cm during the 1980s and about 25 cm during the 1990s, it was alarmingly high at 91 cm per annum during 2000–2005.

Table 0.18 District-Wise Ground Water Assessment for Punjab (as on 31.03.2011)

Area	Total Irrigated Area (Hectares)	Wheat (Hectares)	Percentage of Total Irrigated Area	Level of Exploitation of Groundwater	Yield (Tonnes/ Hectare)
Amritsar	414392	188233	45.42	Over exploited	3.91
Barnala	248570	113785	45.78	Over exploited	4.62
Bathinda	556800	253581	45.54	Semi-Critical	4.80
Faridkot	247996	115607	46.62	Over exploited	4.81
Fatehgarh Sahib	191061	84411	44.18	Over exploited	4.05
Fazilka	475007	206201	43.41	Critical	4.43
Firozepur	415567	188220	45.29	Over exploited	4.66
Gurdaspur	413016	183010	44.31	Critical	3.35
Hoshiarpur	322489	142345	44.14	Semi-Critical	3.60
Jalandhar	412947	167475	40.56	Over exploited	4.10
Kapurthala	267159	110234	41.26	Over exploited	3.90
Ludhiana	592502	252702	42.65	Over exploited	4.46
Mansa	357668	165382	46.24	Over exploited	4.47
Moga	381307	175067	45.91	Over exploited	4.54
Muktsar	446362	208148	46.63	Safe	4.36
Nawanshahr	179612	75234	41.89	Semi-Critical	3.71
Pathankot	55440	22909	41.32	Safe	2.74
Patiala	510722	233229	45.67	Over exploited	4.39
Rupnagar/ Ropar	134508	65673	48.82	Safe	4.03
S.A.S Nagar/ Mohali	104214	50022	48.00	Safe	3.96
Sangrur	635311	284263	44.74	Over exploited	4.81
Tarn Taran	394413	188215	47.72	Over exploited	4.13
Total	7757063	3473946	44.78		4.29

Source: Dynamic Ground Water Resources of Punjab State, Central Ground Water Board, 2013 and Agricultural Statistics at a Glance 2016.

In 22 districts of Punjab water table is declining in 110 blocks due to over-extraction of water than recharge. By 2023, the water table depth in central Punjab is projected to fall below 70 feet in 66% area, below 100 feet in 34% area and below 130 feet in 7% area (Central Ground Water Board 2014-15).

There are districts like Amritsar, Fatehgarh Sahib, Jalandhar, Kapurthala and Tarn Taran, all these districts fall under the over exploited category also their productivity level is low as compared to other districts. Because of the depletion of the groundwater, irrigation cost for wheat crop has increased significantly in these areas; this has resulted in more adverse effect relatively on the small and marginal farmers who lack necessary resources to finance such investments.

This has further contributed to increasing incidence of farmers' indebtedness as a result of increasing cost of well deepening and pump replacement. Thus, these districts may be targeted to release the area from wheat and some other crops may be grown there which are more remunerative.

Similarly, there are several other districts in different states, which have low water table and are struggling with irrigation issues, but traditionally are growing water intensive crops like paddy and sugarcane. These should be marked and specific tailor made policies/programmes should be designed for these districts so as to encourage them to grow crops, which are less water intensive at the same providing higher returns.

The need of the hour is to shift from water guzzling crops of rice, wheat and sugarcane towards less water consuming crops like pulses, coarse cereals, vegetables and fruits. But, it needs several policy measures for encouraging the farmers to make a shift from wheat-rice cycle to other cereals and pulses. Since wheat and rice coupled with other crops are backed by minimum support prices (MSP) and input subsidy (whether water, fertilizer or power) regime, there is a huge enticement for the farmers in some parts of the country to grow these crops.

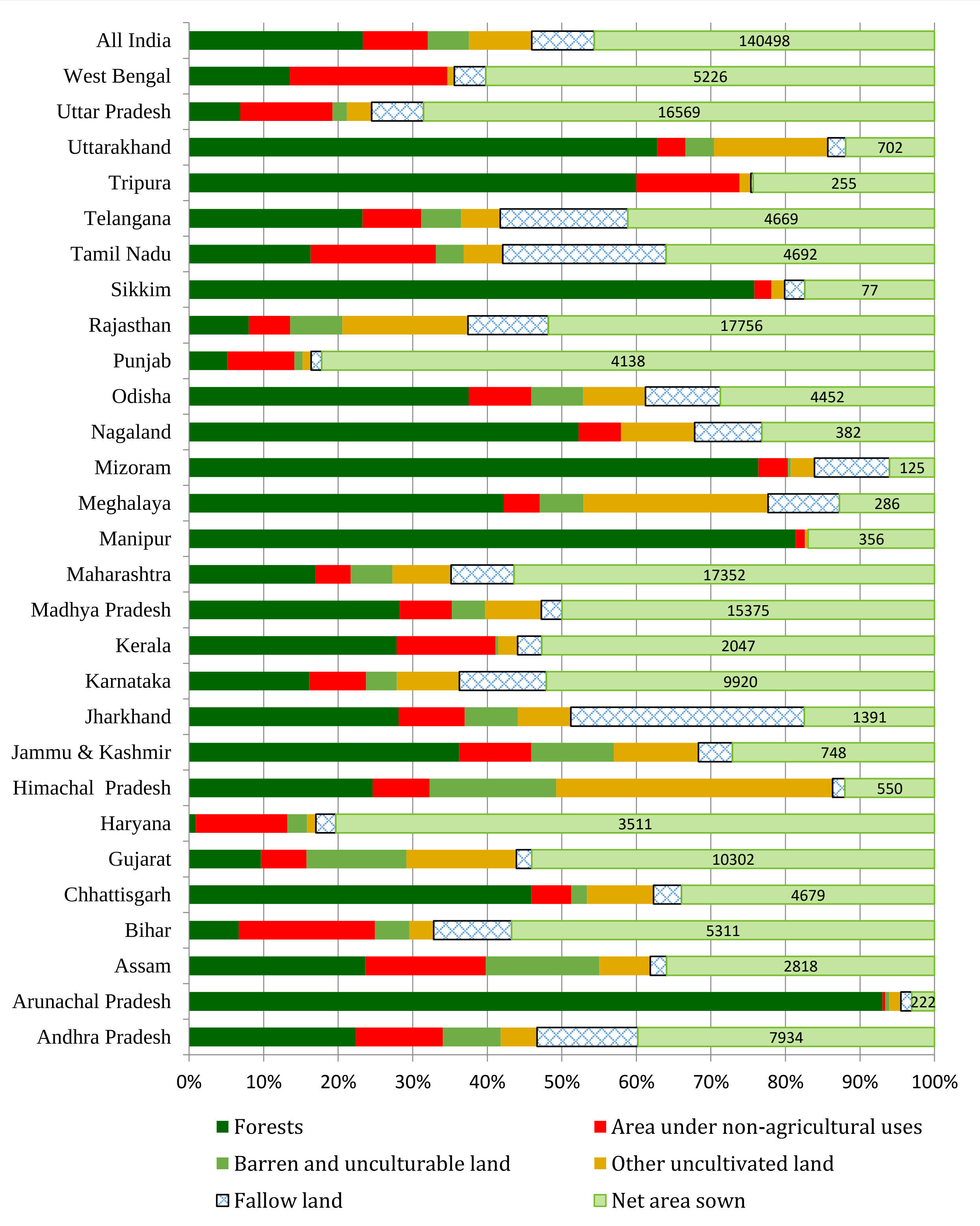
Most of the time major policy response to is problem has always been to disincentivise farmers from growing these crops by making meagre enhancements in the MSP. However, this alone is not sufficient, we need a complete package of agricultural practices that will help the farmers in growing alternative crops for that we required huge investment in public infrastructure. For instance, due to the rice milling industry in Haryana and Punjab, there is now a proper established market in place for different varieties of rice.

Until such a marketplace is available for other crops, farmers are unlikely to make a shift to other crops like pulses. In such a scenario, KVKs can play a key role in sensitizing the farmers towards environmental issues emerging because of consistent growing of crops which are consuming enormous amount of water and benefit of growing alternative crops like pulses, coarse cereals, vegetables and fruits.

0.9 State-wise land use pattern

India's land-use pattern shows total geographical area of 3.28 million square km. As per the land use statistics only 94 per cent of the total geographical area is available for utilisation.

Figure 0.4 State wise land use pattern in India ('000 Hectares, T.E 2014-15)



Source: DFI Committee Estimates based on data compiled from DACNET

Out of this, 45.5 per cent is net sown area, forest cover is 23 per cent, and 5 per cent is current fallow land (Table 0.15). This land-use pattern varies across states.

Every state in the country has significant area under culturable waste, and barren and unculturable land, which comprises 10 per cent as a whole for India. This area can be judiciously brought under cultivation following intense land management practices.

There is scope to bring culturable waste land under agriculture or by altering the area currently not fit for cultivation. The latter comprises of area under non-agricultural use, barren and unculturable land. This land area is unfit for cultivation due to problematic soil conditions like acidic soil, large treks and mainly is rainfed. Such land can be upgraded to support optimal crop production. There is need to follow proper land management practises.

In view of mounting pressure on land for numerous purposes, it is necessary to plan appropriate use of all the available land. This may be done by taking fitting measures to control soil erosion, desertification, improvements made on irrigation and water and soil conservation. Likewise, with the help of up-to-date and scientific methods of farming, productivity of land can also be amplified. All endeavours should be made to strike a balance amongst diverse use of land.

Nutri-cereals are typical to the dry land ecosystem, and play an important role in agricultural value system, the same as rice and wheat in irrigated areas. In the dry land parts of the country, nutri-cereals can play a significant role in doubling the farmers' income while also addressing concerns on nutrition.

Though income generation through enhancement in the productivity gains during green revolution has great significance, however, the dry land crops were not able to reap the same benefit as two staple cereals (rice and wheat).

In case of nutri-cereals productivity enhancement measures must be implemented along with demand enhancement through value addition so as to achieve objectives. Different policy measures are needed in order to enhance the productivity potential of millets in India. Developing innovative supply chain models as market linked value systems, will add to farmers' share in consumers' rupee and increase their income. Creation of farmgate level primary processing clusters for millets will increase the consumption of millets in the production zones. Creation of awareness about the health and environmental benefits associated with consumption of millets will aid demand creation for millets in the country.

Along with doubling farmers' income in various agro-ecological commodities and cropping systems the aspect of imparting nutritional security should also has to be considered.

Table 0.19 State wise land use pattern in India (thousand Hectares, T.E 2014-15)

State/ Union Territory/ Year	Geogra-phical Area	Reporting area for land utilisation statistics	Forests	Not available for cultivation		Other uncultivated land excluding Fallow Land			Fallow Lands		Net area Sown	Gross Cropped Area	Agri. Land (Culti-vable / Cultur-able /Arable)	Cultivated land	Un-cultivable land	Un-cultivated land
				Non-agricultural uses	Barren &unculturable land	Permanent pastures & other grazing lands	Land under misc. tree crops	Culturable waste land	Fallow other than current fallows	Current fallows						
Andhra Pradesh	19934	19934	4461	2324	1550	313	199	457	1087	1609	7934	9823	11285	9542	8649	10391
Arunachal Pradesh	8374	7241	6735	26	38	18	35	63	66	37	222	293	424	259	6817	6982
Assam	7844	7844	1854	1269	1193	170	223	144	86	87	2818	4086	3359	2906	4485	4938
Bihar	9416	9360	622	1711	432	15	247	45	121	856	5311	7677	6580	6167	2780	3192
Chhattisgarh	13519	13790	6333	738	289	877	1	353	259	261	4679	5705	5553	4941	8237	8849
Gujarat	19602	19069	1834	1171	2552	851	4	1960	16	379	10302	12620	12661	10681	6408	8388
Haryana	4421	4371	39	538	115	25	7	20	20	97	3511	6461	3655	3607	717	764
Himachal Pradesh	5567	4576	1126	350	777	1510	64	122	22	54	550	941	812	604	3764	3971
Jammu & Kashmir	22224	9339	1000	267	306	114	63	136	15	111	748	1162	1072	859	2955	3168
Jharkhand	7972	7970	2239	707	569	114	100	352	1074	1424	1391	1628	4341	2815	3630	5155
Karnataka	19179	19051	3073	1447	787	906	280	411	529	1698	9920	12087	12838	11618	6213	7433
Kerala	3886	3886	1082	515	14	0	3	98	56	71	2047	2611	2275	2118	1611	1768
Madhya Pradesh	30825	30756	8693	2146	1363	1293	20	1014	481	371	15375	23662	17261	15746	13495	15010
Maharashtra	30771	30758	5205	1466	1724	1245	250	917	1194	1406	17352	22915	21118	18758	9640	12000
Manipur	2233	2100		26	1	1	6	1	0	0	356	356	363	356	1737	1744
Meghalaya	2243	2242	946	109	131		165	390	155	60	286	342	1056	346	1186	1896

State/ Union Territory/ Year	Geogra-phical Area	Reporting area for land utilisation statistics	Forests	Not available for cultivation		Other uncultivated land excluding Fallow Land			Fallow Lands		Net area Sown	Gross Cropped Area	Agri. Land (Culti-vable / Cultur-able /Arable)	Cultivated land	Un-cultivable land	Un-cultivated land
				Non-agricultural uses	Barren &unculturable land	Permanent pastures & other grazing lands	Land under misc. tree crops	Culturable waste land	Fallow other than current fallows	Current fallows						
Mizoram	2108	2075	1585	82	8	7	52	7	161	48	125	125	393	173	1682	1902
Nagaland	1658	1652	863	93	2		93	69	99	50	382	496	694	432	958	1220
Odisha	15571	15495	5814	1301	1078	528	208	559	641	915	4452	5136	6775	5366	8721	10129
Punjab	5036	5033	259	453	53	5	8	46	6	65	4138	7858	4263	4203	769	829
Rajasthan	34224	34267	2749	1898	2400	1687	25	4064	1980	1709	17756	24769	25534	19465	8734	14802
Sikkim	710	443	336	10			4	4	5	7	77	142	97	84	346	358
Tamil Nadu	13006	13033	2125	2191	489	109	243	327	1716	1141	4692	5677	8119	5833	4914	7200
Telangana	11359	11346	2641	890	611	300	113	180	761	1180	4669	5801	6903	5849	4443	5497
Tripura	1049	1049	629	145		1	12	3	2	1	255	477	273	257	776	793
Uttarakhand	5348	5886	3695	222	228	192	389	316	86	55	702	1107	1548	757	4337	5129
Uttar Pradesh	24093	24170	1658	2988	468	65	327	413	528	1153	16569	25955	18990	17722	5180	6449
West Bengal	8875	8684	1173	1833	12	2	49	20	13	356	5226	9589	5664	5581	3020	3102
All India	328726	307702	71732	26767	17006	10257	3158	12500	10941	14844	140498	197852	181940	155342	125761	152360

Source: DFI Committee Estimates based on data compiled from DACNET

The measures to consider for increasing the production of millets would include bringing more fallow and waste lands under millet cultivation, bridging existing yield gaps and increasing the resource use efficiency. These steps will help in increasing the nationwide availability of nutri-cereals and supplement marginal dry land farmers' income. Development of value added products will help in growing the demand for millets in the country.

Volume VIII-A

Cereals: Staple Crops
Rice, Wheat and Maize
Nutri-Cereals, including Millets
Pulses & Oilseeds

Volume VIII-B

Commercial Crops: Cotton, Sugarcane

Chapter 1
Cotton- White Gold

Cotton, often quoted as white gold, is an integral part of commerce and symbol of economic prosperity to millions of farmers. However, this primary fibre cash crop faces challenges of sustainability of production, overcoming biotic and abiotic stresses, imminent climate change, meeting requisite fibre quality standards and maintaining economic cost of cultivation. A large number of farmers cultivate cotton and special interventions are required, to improve their returns from white gold.

1.1 Introduction

Indian agriculture has achieved remarkable growth in production and productivity of many crops post-Independence. The increased volume of crop output was the outcome of intensification of agriculture-driven by green revolution during the mid-sixties. This helped in enhanced area under cultivation, production and generate more employment opportunities in the rural areas, particularly for the landless labourers (Narayanamoorthy *et. al.,* 2003 and Pingali (2012). Cotton has been cultivated and used to make fabrics for at least 7,000 years. It may have existed in Egypt as early as 12,000 B.C. Pieces of cotton fabrics have been found by archeologists in Mexico (from 3500 B.C.), in India (3000 B.C.), in Peru (2500 B.C.), and in the southwestern United States (500 B.C.).Cotton is an important crop of commerce of India, with recent global realignment in position as leader in area and production, ahead of China, and offering livelihood security for the country's farming community and allied industries. It is grown in the country on variable land holdings, on different planting dates, under diverse conditions of soil and water availability and largely under rainfed situations. Sustainability of production, overcoming biotic and abiotic stresses, meeting requisite quality standards and maintaining economic cost of cultivation, even under climate change impact are some of the challenges that need continued attention of the scientists, development officials, field functionaries and cotton growers. India ranks first in area (11.8 m ha; about 34.0% of world cotton area) and production (33.8 million bales), followed by China in global scenario in 2015-16. In the domestic scenario, it contributes around 65 per cent of the raw material to the textile industry and provides employment to 60 million people.

India is the only country where all four cultivated species of cotton are grown on commercial scale and the area hovers about 10-12 million hectares (Table 1.1, 1.2, 1.3 & 1.4). Qualitative and quantitative transformation took place in cotton production in India since 1970.

Table 1.1 Area, production and productivity of cotton in India from 1947-48 to 2016-17

Year	Area in lakh hectares	Production in lakh bales of 170 kgs	Yield kgs per hectare
1947-48	44.24	33.36	132
1950-51	58.82	34.3	99
1960-61	76.1	60.12	134
1970-71	76.05	56.64	127
1980-81	78.23	78	169
1990-91	74.39	117	267

Year	Area in lakh hectares	Production in lakh bales of 170 kgs	Yield kgs per hectare
2000-01	85.76	140	278
2001-02	87.3	158	308
2002-03	76.67	136	302
2003-04	76.3	179	399
2004-05	87.86	243	470
2005-06	86.77	241	472
2006-07	91.44	280	521
2007-08	94.14	307	554
2008-09	94.06	290	524
2009-10	103.1	305	503
2010-11	112.35	339	517
2011-12	121.78	367	512
2012-13	119.78	370	525
2013-14	119.6	398	566
2014-15	128.19	386	511
2015-16*	118.77	338	484
2016-17*	105.00	351.00	568

Source: Cotton Advisory Board (CAB)

The production increased from a meagre 3.33 million bales (170 kg lint/bale) in 1947-48 to an all-time record high of 39.8 million bales (m bales) during 2013-14. During the past seven years, the production has been around 30-35 m bales, indicating sustainability of the production system, and also pointing to the need for generation of newer technologies and innovative approaches for meeting increased requirements (both domestic and global). It is very gratifying to note that India has registered highest growth as regards cotton production with a share of 27 per cent (2015-16) in global cotton production, nearly more than double its share of 12 per cent in 2001-02. The spectacular increase in production and productivity is mainly due to the intensive research programmes that have been carried out under the aegis of AICRP (All India Coordinated Research Project) on Cotton by the Central Institute of Cotton Research (CICR), Nagpur and appropriate policy initiatives of the Ministry of Agriculture and Famers' Welfare, besides positive role played by private sector in introducing transgenic cotton and untiring efforts of cotton farmers.

Table 1.2 State wise cotton area (in lakh ha) from 2007-08 to 2016-17

State	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16p	2016-17p
Punjab	6.04	5.27	5.11	5.30	5.60	4.80	4.46	4.20	3.39	2.56
Haryana	4.83	4.56	5.07	4.92	6.41	6.14	5.36	6.48	6.03	4.98
Rajasthan	3.69	3.02	4.44	3.35	4.70	4.50	3.93	4.87	4.48	4.42
NORTH ZONE	14.56	12.85	14.62	13.57	16.71	15.44	13.75	15.55	13.90	11.96
Gujarat	24.22	23.54	26.25	26.33	29.62	24.97	25.19	27.73	27.19	24.00
Maharashtra	31.95	31.42	35.03	39.42	41.25	41.46	41.92	41.90	38.27	38.06
Madhya Pradesh	6.30	6.25	6.11	6.50	7.06	6.08	5.14	5.47	5.47	5.99
CENTRAL ZONE	62.47	61.21	67.39	72.25	77.93	72.51	72.25	75.10	70.93	68.05
Telangana								17.13	17.78	12.50

State	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16p	2016-17p
Andhra Pradesh	11.33	13.99	14.75	18.79	18.79	24.00	23.89	8.21	6.66	4.49
Karnataka	4.03	4.08	4.55	5.45	5.54	4.85	6.62	8.75	6.33	4.64
Tamil Nadu	0.99	1.09	1.04	1.22	1.33	1.28	1.52	1.87	1.42	1.50
SOUTH ZONE	16.35	19.16	20.34	25.46	25.66	30.13	32.03	35.96	32.19	23.13
Odisa	0.50	0.58	0.54	0.74	1.02	1.19	1.24	1.27	1.25	1.36
Others	0.26	0.26	0.21	0.33	0.46	0.51	0.33	0.31	0.50	0.50
TOTAL	94.14	94.06	103.10	112.35	121.78	119.78	119.60	128.19	118.77	105.00

Source: Cotton Advisory Board as on 24:10:2016

Table 1.3 State wise cotton production (in lakh bales of 170 kg) from 2007-08 to 2016-17

State	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16p	2016-17p
Punjab	20.00	17.50	13.00	16.00	17.50	18.50	18.50	10.50	5.00	6.50
Haryana	15.00	14.00	15.25	14.00	23.00	23.00	21.00	20.00	12.00	17.00
Rajasthan	9.00	7.50	12.00	9.00	16.90	15.90	12.90	15.90	13.90	16.90
NORTH ZONE	44.00	39.00	40.25	39.00	57.40	57.40	52.40	46.40	30.90	40.40
Gujarat	110.0	90.00	98.00	103.0	118.8	89.80	120.8	108.8	90.80	91.80
Maharashtra	62.00	62.00	65.75	82.00	70.25	75.25	78.25	74.25	69.25	83.25
Madhya Pradesh	20.00	18.00	15.25	17.00	17.30	18.30	18.30	18.30	17.30	20.30
CENTRAL	192.0	170.0	179.0	202.0	206.3	183.3	217.3	201.3	177.3	195.3
Telangana								49.90	58.90	47.40
Andhra Pradesh	46.00	53.00	54.50	53.00	53.50	77.50	71.50	20.60	18.10	13.10
Karnataka	8.00	9.00	12.25	10.00	13.90	15.90	21.90	32.90	18.90	19.90
Tamilnadu	4.00	5.00	5.00	5.00	4.30	3.80	2.80	3.80	2.80	3.80
SOUTH ZONE	58.00	67.00	71.75	68.00	71.70	97.20	96.20	107.2	98.70	84.20
Odisa		1.50	1.00	2.00	3.45	3.95	3.95	2.95	2.95	2.95
Others	1.00	0.50	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
TOTAL	295.0	278.0	293.0	313.0	340.9	343.9	371.9	359.9	311.9	324.9
Loose cotton	12.00	12.00	12.00	26.10	26.10	26.10	26.10	26.10	26.10	26.10
GRAND	307.0	290.0	305.0	339.1	367.0	370.0	398.0	386.0	338.0	351.0

Note: Production calculated based on pressed bales for the respective states; p – Provisional,

Table 1.4 State wise cotton Productivity (kg/ha) from 2007-08 to 2016-17

State	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16p	2016-17p
Punjab	563	565	432	593	607	744	800	526	376	598
Haryana	528	522	511	587	690	719	761	603	423	683
Rajasthan	415	422	459	513	651	642	605	593	569	692
NORTH ZONE	514	516	468	571	651	704	729	579	459	668
Gujarat	772	650	635	686	700	633	837	687	588	673
Maharashtra	330	335	319	378	313	332	341	324	333	398
Madhya Pradesh	540	490	424	463	433	531	628	563	559	596
CENTRAL	522	472	452	498	471	452	534	476	448	512
Telangana								501	569	653
Andhra Pradesh	690	644	628	538	543	595	555	549	613	719
Karnataka	337	375	458	346	460	596	590	661	537	769
Tamilnadu	687	780	817	1003	831	797	559	545	599	680
SOUTH ZONE	603	594	600	519	540	604	561	553	573	691
Odisa		440	315	471	583	571	548	401	408	375
India	554	524	503	513	512	525	565	511	484	568

Note: Productivity calculated including pressed cotton and loose cotton of the respective states; p – Provisional,

Source: Cotton Advisory Board as on 24:10:2016

With the adoption of Bt cotton hybrids, favourable government policies and vigorous promotion of technological adoption in certain regions, average cotton productivity has increased from 302kg/ha in 2003 to around 570 kg/ha in 2017 (AICRP, 2017). However, the productivity has reached a plateau in the last five years, the productivity is not showing any positive change and has been in the range of 503 to 570 kg/ha (*kilogram lint per hectare*). Prevailing low productivity trend means lower profitability of cotton farming and a threat to the livelihood security of cotton farmers. To double cotton farmers' income, cotton productivity needs to be raised by 40 per cent to realize 700 kg/ha, while ensuring that there is only a marginal increase in the operational costs (Kranthi, 2017a).

Commercially, cotton is grown in 77 countries. However, 123 countries are involved in cotton related activities. Thirty eight countries (38) are the major producers and also the consuming countries, while 30 countries are major raw cotton exporters, 25 countries exclusively import cotton (Table 1.5). The world cotton production is estimated at 105.72 million bales of 480 lb in 2016-17 (USDA, March 2017), around 9.3 per cent more than the previous year. It is also indicated that area under cotton declined by of 1.28 million ha (4.18%) as compared to 2015-16. The estimate of USDA indicates that, India continued to be the leading producer of raw cotton followed by China and the United States.

Table 1.5 World cotton situation in major cotton producing countries: 2016-17

Country	Area Harvested	Productio n	Import	Export	Domestic Consumptio	Ending Stocks	Yield
Australia	550	4,500	0	4,100	-115	2,448	1,781
Brazil	930	6,500	200	2,800	3,050	7,009	1,522
Burkina	700	1,300	0	1,150	15	435	404
China	2,850	22,500	4,500	50	36,250	48,898	1,719
Egypt	55	175	525	120	590	169	693
India	10,500	27,000	2,200	4,500	23,750	11,894	560
Mali	670	1,200	0	1,075	25	486	390
Pakistan	2,400	7,700	2,600	150	10,225	2,540	699
Turkmenistan	545	1,325	0	800	650	704	529
United States	3,853	17,230	10	13,200	3,340	4,500	974
Uzbekistan	1,180	3,550	0	1,700	1,550	1,248	655
World	29,223	1,05,719	35,957	35,949	1,12,336	90,482	788

*Note: Due to loss in domestic consumption, Australia domestic consumption figure in negative; area in 1000 ha; yields in kg/ha and quantity in million bales of 480 lb.*Source: United States Department of Agriculture as on 18thMarch 2016.

Besides, maintaining the largest area under cotton in the world and being second largest exporter of cotton next to the United States. India also sustained the position of being the second largest consumer of cotton and is expected to consume 23.75 million bales. A significant increase in area under cotton in the United States and Australia was observed, whereas the area under cotton in India declined by 11.76 per cent (14 lakh ha) compared to last year. The cotton productivity in Brazil, Pakistan, China, United States and India is expected to increase as against reduction of over 200 kg lint/ha in Australia. Brazil productivity is likely to increase from 1345 to 1522 kg/ha; Pakistan from 544 to 699 kg/ha; China from 1570 to 1719 kg/ha; United states from 859 to 974 kg/ha; and in India from 483 to 560 kg/ha.

Area under Bt Cotton

The surge in Bt cotton area has benefited the farmers more than in case of conventional hybrid and local varieties. The cotton area under the high-yielding and the pest-resistant genetically modified *Bacillus thuringiensis* (Bt) cotton resistant to pink bollworm has seen marvellous expansion ever since its introduction. By the year 2013-14, of the total area under cotton, share of Bt cotton peaked at 95 per cent. It however declined to less than 90 per cent in 2016-17. The decline was on account of yield stagnation in the latest Bollgard variety and pest attack on Bt cotton seeds.

In the year 2016-17, the coverage under Bt cotton was 8.77 million hectares (m.ha) as against the total cotton area of 10.82 m. ha., accounting for 81 per cent. In 2017-18, while the total area under cotton was 12.44 m. ha, that under Bt cotton went up to 11.07 m. ha. The estimated output of cotton for the year 2017-18, as per Cotton Advisory Board is 37 million bales. The yield was seen to be affected in the year, due to pink bollworm attack on the crop in the states of Maharashtra, Telangana and Andhra Pradesh. However, this estimated production is higher than the 2016-17 output of 34.5 million tonnes.

1.2 Constraints and Yield Gap in cotton

1.2.1 Yield gap

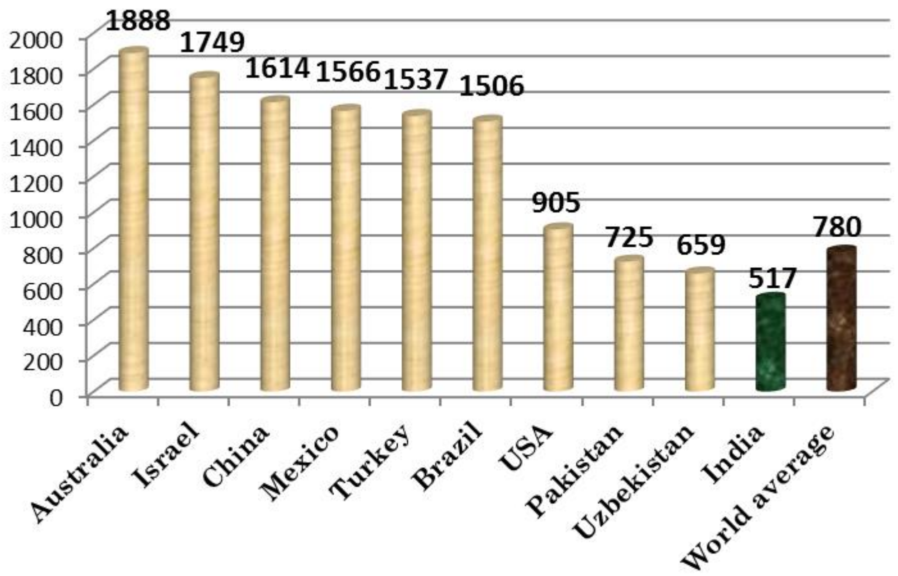
The current yields in cotton in India are significantly lower compared to world average and other major cotton growing countries like Australia, Brazil, USA, China etc. Like in case of most other crops grown in India, cotton production is also associated with low productivity compared to world average. The average cotton lint yield in India is only 520 kg/ha compared to a world average of 780 kg/ha.

Various reasons are attributed to low yields of cotton in India (Fig.1.1). The actual yield achieved depends on a wide range of external factors that vary from farm to farm. Achievable yield is defined as the highest yield achieved in that locality during the recent past. Yield gap is defined as the difference between this achievable yield and the actual yield achieved by the farmer during period of reference.

Yield gap was found to be higher in Central Zone when compared with Northern and Southern Zones. Yield gap ranged from 6.66 q/ha in Tamil Nadu to 18.40 q/ha in Gujarat. Highest yield gap was found in Gujarat (18.40 q/ha), followed by Madhya Pradesh and Maharashtra. In North Zone, the yield gap was comparatively high in Rajasthan. In Punjab and Haryana the yield gap was about 7.5 q/ha, while it was 9.86 q/ha in Rajasthan. In South Zone, highest yield gap was seen in Andhra Pradesh (11.0 q/ha) followed by Karnataka (9.72 q/ha) and Tamil Nadu (6.66 q/ha). Highest achievable yield was also found in Gujarat (53.13 q/ha), followed by Madhya Pradesh (46.60 q/ha).

Hence, there is much scope to increase average yield by addressing the constraints which are limiting the yield in these two states. In nutshell, the yield gap in cotton was highest in the States of Gujarat, Madhya Pradesh and Maharashtra, modest in Andhra Pradesh and relatively low in Tamil Nadu.

Figure 1.1 Global lint yield of cotton (Kg/ha)-2015-16



Source: www.cotton.org › Economics › Crop Information

Table 1.6 Zone wise yield gap (%) in nine cotton growing states in India

Zones	States	Highest achieved yield (q/ha)	Actual Average yield (q/ha)	Yield gap	
				(q/ha)	(%)
North Zone	**Punjab**	29.38	22.13	7.35	24.68
	Haryana	28.90	21.31	7.61	26.33
	Rajasthan	29.29	19.43	9.86	33.66
Central Zone	**Gujarat**	53.13	35.73	18.40	34.63
	Maharashtra	30.13	18.52	11.61	38.53
	Madhya Pradesh	46.66	30.83	15.83	33.93
South Zone	**Andhra Pradesh**	34.42	23.42	11.00	31.96
	Karnataka	32.56	22.84	9.72	29.85
	Tamil Nadu	29.98	23.32	6.66	22.20

1.2.2 Yield gaps in select districts of cotton growing states of India

From a study under Technology Mission on Cotton (TMC 2015), it could be inferred that among the selected districts of North Zone, in Bathinda district of Punjab, the highest achieved cotton yield among the sample was 30.0q/ ha, whereas average yield was 23.0q/ha. Yield gap was estimated at 7.0 q/ha (Table 1.7). In Mansa district, the highest achieved cotton yield among the sample farmer was 28.75 q/ha, whereas average yield was 21.25 q/ha.

Yield gap was estimated at 7.50 q/ha. In case of Haryana, average reduction in yield due to identified constraints ranged from 19 to 23 q/ha in both the selected districts of Sirsa and Hissar with a yield gap of 7 to 8q/ha. In case of Sriganganagar district in Rajasthan, the maximum observed yield of seed cotton among the sample farmers was 22.63 q /ha, whereas the average yield of this district came out to 17.03 q/ha resulting into a yield gap of 5.60 q/ha. In case of Hanumangarh district of Rajasthan, the average yield of seed cotton was estimated at 15.83 q/ha., while the highest being 25.95q/ha. The yield gap which is the difference between average yield and maximum yield showed upto 10.12 q/ha.

In case of select districts of Central Zone, the districts of Surat, Bharuch, Vadodara, Surendranagar and Ahmadabad in Gujarat were selected randomly based on the area under cotton in these districts.

In Surat district, the highest achieved cotton yield among the sample was 60.0 q/ha, whereas average yield was 40.0 q/ha. Yield gap was estimated to be 20.0 q/ha.

In Bharuch district, the highest achieved cotton yield among the sample was 62.50 q/ha, whereas average yield was 37.50 q/ha. Yield gap was estimated to be 25.0 q/ha.

Table 1.7 Select district wise yield gap in the cotton growing states of India (q/ha)

States	Districts	Highest achieved yield	Average yield	Yield gap
North Zone				
Punjab	**Bathinda**	30	23	7
	Mansa	28.75	21.25	7.5
Haryana	**Sirsa**	27.17	19.02	8.15
	Hissar	30.86	23.79	7.07
Rajasthan	**Sriganganagar**	22.63	17.03	5.6
	Hanumangarh	25.95	15.83	10.12
Central Zone				
Gujarat	**Surat**	60	40	20
	Baruch	62.5	37.5	25
	Vadodara	48	40	8
	Surendranagar	42	29	13
	Ahmedabad	40	32	8

States	Districts	Highest achieved yield	Average yield	Yield gap
Maharashtra	**Yavatmal**	27.5	17.3	10.2
	Jalgaon	32.75	19.73	13.02
Madhya Pradesh	**Khandwa**	45	32.5	12.5
	Khargone	45	30	15
	Barwani	50	30	20
South Zone				
Andhra Pradesh	**Guntur**	34.42	23.42	11
Karnataka	**Dharwad**	31.43	22.19	9.24
	Haveri	33.68	23.48	10.2
Tamil Nadu	**Coimbatore**	29.52	21.36	7.16
	Perambalur	31.44	25.27	6.17

In Vadodara district, the highest achieved cotton yield among the sample was 48.0 q/ha, whereas average yield was 40.0 q/ha. Yield gap was estimated to be 8.0 q/ha; In Surendranagar district, the highest achieved cotton yield among the sample was 42.0 q/ha, whereas average yield was 29.0 q/ha. Yield gap was estimated to be 13.0 q/ha.

In Ahmedabad district, the highest achieved cotton yield among the sample was 40.0 q/ha, whereas average yield was 32.0 q/ha. Yield gap was estimated to be 8.0 q/ha. In all the districts of Gujarat, incidence of sucking pests, weed infestation, leaf reddening, pink boll worm, shortage of fertilizer and mealy bug are common major constraints which are affecting cotton production. Besides these, delayed sowing, wilt, non-availability of seeds, labour shortage and electricity problem caused considerable yield loss.

In Maharashtra, Yavatmal and Jalgaon were the selected districts for the study wherein the yield gap hovered around 10 to 13 q/ha with highest achieved yield of 27 to 32 q/ha and average yield of 17 to 19 q/ha.

In Madhya Pradseh, Khandwa, Khargone and Barwani districts were selected randomly based on the area under cotton in these districts. In Khandwa district, the highest achieved cotton yield among the sample was 45.0 q/ha whereas average yield was 32.5 q/ha. Yield gap was estimated to be 12.5 q/ha. In Khargone district, the highest achieved cotton yield among the sample was 45.0 q/ha, whereas average yield was 30.0 q/ha. Yield gap was estimated to be 15.0 q/ha. In Barwani district, the highest achieved cotton yield among the sample was 50.0 q/ha whereas average yield was 30.0 q/ha. Yield gap was estimated to be 20.0 q/ha.

Amongst the selected districts of South Zone, Guntur district of Andhra Pradesh was selected based on the area under cotton, wherein the highest achieved cotton yield among the sample was 34.42 q/ha, whereas average yield was 23.42 q/ha. Yield gap was estimated to be 11.0 q/ha in Guntur.

In Dharwad district of Karnataka, the highest achieved cotton yield among the sample was 31.43q/ha whereas average yield was 22.19 q/ha. Yield gap was estimated to be 9.24 q/ha. In Haveri district, the highest achieved cotton yield among the sample was 33.68 q/ha, whereas average yield was 23.48 q/ha. Yield gap was estimated to be 10.2 q/ha.

Non availability of labour affected entire cotton area in Dharwad district. Average loss due to this problem was estimated to be 2.24 q/ha making the total loss in the district as 11.51 lakh quintals of seed cotton. Weed infestation ranked fourth with an estimated loss of 1.3 q/ha. Nearly 15 per cent of cotton growers are facing this constraint. Sub optimal use of inputs is another important constraint with a yield loss of 1.1q/ha. Nearly 15 per cent of cotton area is affected due to this problem.

Coimbatore and Perambalur districts were selected from Tamil Nadu, in which the yield gap of 6 to 7q/ha was registered during the period of study with the highest average cotton yield of 29 to 31q/ha and average yield of 21 to 25q/ha.

The yield gaps and constraints are becoming a major problem in the entire cotton growing areas which need to be taken care of. There is scope to improve cotton productivity if the constraints limiting the production are addressed properly. There is need to devise policies to supply good quality inputs at right time. Sucking pests are becoming a major problem across the entire cotton growing areas which need urgent attention. Similarly, weed management is one of the biggest issues that has to be tackled. These problems are associated with the shortage of human labour and continuous rains during initial crop growth periods

The shortage of labour during the picking stage is one of the emerging constraints in North Zone, though it has not figured in the top five prioritised constraints needing prior attention. It is now necessary to bring together multiple stakeholders (including farmers, extension staff, researchers, input suppliers, government policy makers) to discuss issues on management strategies and research needs and test these in participatory on-farm research mode. It is also necessary to promote the most promising interventions and strategies including revisiting Minimum Support Price. With Union Budget 2018 announcement to provide a minimum profit margin of 50 per cent over cost of cultivation, cotton growers will stand to benefit

1.3 State-wise Constraints and Reasons for Low Productivity

The realization of the production potential at the farm level with the given technologies is determined by their adoption or otherwise, as well as the constraints associated with the adoption and of the production system *per se*. Therefore, the constraints associated with adoption of available technologies or the present method of cotton cultivation should be addressed at research, extension and institutional levels for furthering the productivity. As many as 40 constraints have been identified and categorized under abiotic, biotic and socio-economic constraints.

In North Zone, higher degree of use of inferior quality seed, incidence of sucking pests, incidence of leaf curl virus, dry spell during flowering and boll development stage, Lack of knowledge about recommended practices, Widespread use of spurious plant protection chemicals are the major constraints contributing to yield loss of 0.4 to 2.15 q/ha in Punjab; around 0.44 to 1.42 q/ha in Haryana; and 0.7 to 2.05 q/ha in Rajasthan (Table 1.8).

Table 1.8 State wise identified constraints prioritized based on the yield loss in select cotton growing districts

States/ Districts)	Constraints – reasons for low productivity	Yield loss (Q/Ha)
Punjab (Mansa, Bathinda)	➢ Higher degree of use of inferior quality seed ➢ Incidence of sucking pests ➢ Incidence of leaf curl virus ➢ Dry spell during flowering and boll development stage ➢ Lack of knowledge about recommended practices	1.17 to 1.42 1.0 1.0 0.56 to 0.81 0.44
Haryana (Hissar, Sirsa)	➢ Higher degree of use of inferior quality seed ➢ Incidence of sucking pests ➢ Lack of knowledge about recommended practices ➢ Dry spell during flowering and boll development stage ➢ Lack of availability of genuine plant protection chemicals	1.82 to 2.15 1.34 to 1.61 1.10 to 1.32 1.15 to 1.31 0.40
Rajasthan (Hanumangarh, Sriganganagar)	➢ Incidence of sucking pests ➢ Delayed sowing due to non availability of canal water ➢ Higher degree of use of uncertified seed ➢ Dry spells during flowering and boll development stage	1.11 to 2.05 0.7 to 1.73 0.44 to 0.90 0.89 to 1.79
Gujarat (Vadodara, Surendranagar)	➢ Incidence of sucking pests ➢ High price and non-availability of quality seeds ➢ Scarcity of human labour ➢ Weed infestation	8.0 to 9.0 8.5 to 12.0 5.0 to 6.0 4.5 to 6.0
Maharashtra (Yavatmal, Jalgaon)	➢ Incidence of sucking pests ➢ Weed infestation and dry spells during flowering and boll development stage ➢ Leaf reddening and parawilt ➢ Delayed sowing due to late onset of monsoon ➢ Water logging	1.9 to 3.4 2.2 to 2.55 2.1 to 3.0 2.3 to 2.8 3.9
Madhya Pradesh (Khandwa, Khargone)	➢ Incidence of sucking pests ➢ Weed infestation ➢ Pink bollworm infestation ➢ Leaf reddening ➢ Non availability of genuine fertilizers and its high cost	8 3.67 to 4.17 3.5 to 8.0 4.67 to 6.33 7.00 to 9.00
Andhra Pradesh	➢ Non availability of human labour	6.23

States/ Districts)	Constraints – reasons for low productivity	Yield loss (Q/Ha)
(Guntur)	➢ Dry spells during flowering/boll development stage ➢ Incidence of sucking pests ➢ Lack of credit facilities	5.78 4.18 3.65
Karnataka (Dharwad, Haveri)	➢ Non availability of human labour ➢ Weed infestation ➢ Use of inferior quality seed ➢ Untimely interculture ➢ Under utilization of fertilisers	2.24 to 3.67 1.3 to 1.84 2.18 1.9 1.11
Tamil Nadu (Coimbatore, Perambalur)	➢ Weed infestation ➢ Shortage of human labour ➢ Untimely interculture ➢ Delayed monsoon ➢ Inadequate irrigation facilities	3.4 to 3.6 3.8 1.19 to 2.1 2.9 2.8 to 3.1

In case of Central Zone, incidence of sucking pests; the major constraints leading to yield loss of 1.9 to 12 q/ha. included, high price and non-availability of quality seeds, scarcity of human labour, weed infestation and dry spells during flowering and boll development stage; leaf reddening and parawilt; delayed sowing due to late onset of monsoon, water logging, pink bollworm infestation; and non-availability of genuine fertilizers and their high cost. Major yield loss due to these constraints was recorded in Gujarat at 4.5 to12 q/ha, followed by 3.5 to 9q/ha yield loss in Madhya Pradesh, and 1.9 to 3.4 q/ha in Maharashtra (Table 1.8).

The scenario of South Zone is such that yield loss to the tune of 1.11 to 6.23q/ha was recorded due to non-availability of human labour; dry spells during flowering/boll development stage; incidence of sucking pests, lack of credit facilities; weed infestation; use of inferior quality seed; untimely interculture; underutilization of fertilizers; delayed monsoon; and inadequate irrigation facilities.

The yield loss was highest in Andhra Pradesh at hovering around 3.65 to 6.23 q/ha; whereas in Karnataka and Tamil Nadu, it was less at around 1.11 to 3.67 q/ha (Table 1.8).

In all, scarcity of human labour, weed infestation, inferior quality seeds, delayed monsoon and incidence of sucking pests were the major constraints in cotton production. These were invariably predominant in all the three cotton Zones of India.

1.4 Total Factor Productivity of Cotton

Sustainability of agricultural system in economic terms is assessed on the basis of: (i) productivity (measured in terms of yield or net income), (ii) stability of yield or net income, (iii) low vulnerability of yield or net income, and (iv) equitability in terms of income distribution. Productivity analysis provides an answer to the question on the extent to which change in input is responsible for the changes in output.

Total Factor Productivity (TFP), sometimes referred to as multi-factor productivity, is a true measure of economic efficiency. It can be interpreted as a measure of change in cost of producing a unit of product, holding all factor prices constant. Alternatively, it can be interpreted as a measure of the change in output relative to a weighted combination of all inputs, where the weights are factor shares. TFP is also defined as the ratio of aggregate output to aggregate input. It provides a measure of the increase in total output that is not accounted for by increases in the quantity of inputs. It is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth in total output less the total increase in inputs. Total output and total input are measured in an index form.

The recent advances in bio-technology and agronomical practices like precision farming are part of the renewed scientific effort to break the yield barrier and increase productivity in agriculture. Most studies on agricultural productivity during the last decade have focused on agriculture as a whole or total crop production. The total factor productivity index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth rate in total output less the growth rate in total inputs. Tornqvist-Theil TFP indices are used to compute TFP of cotton. The Tornqvist-Theil index is a superlative index that accounts for changes in quality of inputs. Since current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates.

Total Input Index (TII), Total Output Index (TOI) and Total Factor Productivity (TFP) are estimated for cotton for Punjab, Haryana and Rajasthan of North zone, Gujarat, Maharashtra and Madhya Pradesh of Central zone; Andhra Pradesh, Karnataka and Tamil Nadu of South Zone in India for the period 1981-82 to 2008-09. For analysing the growth rates of TII, TOI and TFP, the whole period under study was divided into following sub periods:

- Period I (1981-1990),
- Period II (1991-2000),
- Period III (2001-2009)
- Overall period (1981-2009)

Table 1.9 State wise Total Factor Productivity Growth Rate of Cotton (1981-2009)

States	**TFP Growth Rate**											
	1981-1990			1991-2000			2001-2009			1981-2009		
	TII	**TOI**	**TFP**	**TII**	**TOI**	**TFP**	**TII**	**TOI**	**TFP**	**TII**	**TOI**	**TFP**
North Zone												
Punjab	1.02	10.58	9.45	0.99	-10.91	-11.79	-4.65	11.75	17.20	0.71	0.81	0.10
Haryana	-0.24	1.67	1.91	-0.11	-6.25	-6.14	1.85	12.49	10.45	0.54	0.42	-0.12
Rajasthan	-	-	-	1.67	-2.18	-3.78	1.97	4.11	2.10	0.97	1.65	0.68
Central Zone												
Gujarat	-1.81	-0.76	1.05	-1.71	6.43	8.14	1.41	12.20	10.79	-0.27	5.44	5.71
Maharashtra	4.56	4.41	-0.14	-4.66	6.49	11.69	0.63	13.37	12.65	0.25	5.00	4.74

States	TFP Growth Rate											
	1981-1990			1991-2000			2001-2009			1981-2009		
	TII	**TOI**	**TFP**	**TII**	**TOI**	**TFP**	**TII**	**TOI**	**TFP**	**TII**	**TOI**	**TFP**
Madhya Pradesh	9.30	5.59	5.64	1.43	8.20	6.68	7.27	0.89	-5.95	4.39	8.20	3.65
South Zone												
Andhra Pradesh	-2.97	-4.90	-1.99	-0.17	3.07	3.25	-0.74	6.67	7.46	-0.17	4.10	4.28
Karnataka	-3.64	5.22	9.19	-1.53	0.95	2.51	-1.81	7.28	9.25	-1.53	4.24	5.86
Tamil Nadu	0.60	5.07	4.45	-2.25	2.13	4.48	-2.44	6.63	9.29	-1.07	4.29	5.41

(TII – Total Input Index; TOI – Total Output Index; TFP – Total Factor Productivity)

In North Zone, Punjab had the best TFP performance during 2001 to 2009. The growth rate was 17.20 per cent mainly on account of larger growth in TOI due to introduction of Bt cotton in this period and decline in TII due to lesser use of plant protection chemicals. For the overall period, TFP growth was dismal. In Haryana, it was 10.45 per cent due to high growth of TOI at 12.49 per cent. In case of Rajasthan, during 1995-2000, TFP registered worst performance, the growth rate being negative (-3.78) due to failure of crop during this period, the growth rate of TOI was -2.18 per cent. The presentation of TFP was better (2.10) during 2001-2009, because of higher productivity of crop, growth rate of TOI was 4.11 per cent (Table 1.9).

In the Central Zone, TFP index showed a positive growth rate of 4.74 per cent during the period 1981-2009 in case of Maharashtra. This indicates the sustainability of cotton output growth in the State which registered a positive output growth of 5 per cent. Total input index increased at the rate of 0.25 per cent during the period of analysis which was statistically not significant. This indicates the presence of bottlenecks in enhancing the input use in cotton production.

Total output growth during this period was 5 per cent. This growth was due to the growth in TFP whereas in case of Gujarat, the growth of TFP was positive and significant during the period of analysis, and increased at the rate of 5.7 per cent. Total output index showed a significant growth of 5.44 per cent. This analysis indicates that the output growth of cotton in this State is sustainable as it is driven by the positive TFP growth. It also indicates that the growth of output can be strengthened further by improving input growth. In case of Madhya Pradesh, TFP index showed a positive growth rate of 5.64 per cent during the period 1981-1990. The growth in the total input index was 9.30 per cent. Output index showed a positive growth of 5.59 per cent. As the growth in output is backed by the growth in TFP, the output growth is sustainable. TFP growth was negative during period III. During this period TFP registered a negative growth of -5.95 per cent (Table1.9).

In case of South Zone, the Total Factor Productivity Index was greater than one (1) from 1991 onwards which indicates the higher returns of cotton cultivation in Andhra Pradesh. It was highest during 2001-2009 to the tune of 7.46 per cent due to higher TOI (6.67) indicating higher returns with judicious use of inputs. Total Input Index (TII) of cotton in Karnataka is higher than one (1.0) during the year 1991-2000 implying that the cost of the inputs was higher but increased yields have led to positive TFP growth during this period. In Tamil Nadu, Total Input Index (TII) of cotton has been stagnating around one (1) over the years. Total Output

Index (TOI) in Tamil Nadu was not increasing appreciably because of lower productivity (Table 1.9). The TFP growth was almost same during all the decades hovering around 4 to 5 per cent.

India's agriculture has made substantial gains in productivity, as measured by indices of TFP. These gains have varied by period. The rate of change in TFP has been high. Growth in TFP has contributed 1.1 to 1.3 per cent per year to cotton production growth in India. Conventional inputs have also contributed to the growth since 2000. The changes in productivity of cotton could not be generalised throughout the country. There is a need for greater research emphasis in the States for further harnessing the potential.

1.5 Reasons for Low Profitability to Cotton Growers

Cotton cultivation in India signifies total diversity in vastness, spread, agro-climate conditions, farming methods, cropping systems, planting and marketing seasons, varieties, duration, yield, quality and costs and returns. In general, constraints are unique to the regions and systems of cultivation. Northern region zone, being more consistent in terrain, weather, resource endowment, varietal discipline, agro-techniques differs from central and southern zone as cotton cultivation vary widely in terms of agro-climate, species diversity, farm endowment, varietal proliferation, cropping system, crop rotations, input use, factor and product market, state policies, etc. (Ramasundaram *et. al*., 2001 and Wangarwar, 2017).

1.5.1 Low productivity

Cotton productivity in India is far behind of that in Australia (1888 kg/ha), Brazil (1506 kg / ha), China (1614 kg/ha) and in comparison to world average (780 kg/ha). However, comparison of India's productivity with other countries may not be appropriate since availability of natural resources, technologies, government policies and support programmes vary from country to country. Even in comparison to Pakistan, India's productivity is less since cotton is cultivated as irrigated crop in Pakistan, while in India more than 60 per cent of the area is rainfed. Cotton requires deep soil, but the crop is cultivated in major areas in shallow soil in Maharashtra. In western countries, well-identified crop belt system is followed. On the contrary, crop selection in India is voluntary in nature and the selected is based on remunerative returns which may not always be in sync with soil and climate. With adoption of *Bt* cotton hybrids, and the impact of Technology Mission on Cotton, the average productivity has increased from 302kg/ha in 2003 to 566kg/ha in 2014. However, quantum jump in cotton productivity was not observed during the last five years, indicating the need for breakthrough technologies, which can break the stagnation of productivity.

1.5.2 Major areas under rainfed condition

More than 60 per cent of cotton area is under rainfed condition. A survey was conducted in Parbhani district to study economics of rainfed and irrigated cotton production (Pawar *et. al*., 2006). It is worth noting that net profit on the rainfed cotton farm was Rs.5,969/ha, which was three times less than that on the irrigated cotton farm (Rs. 18,786/ha). The output-input ratio was 1.4 and 1.8 on the rainfed and the irrigated cotton farms, respectively. Narayanamoorthy *et. al.*,2014 compared the rainfed *vs* irrigated cotton cultivation and found that irrigated cotton crop was profitable at all the time points.

Although the cost of cultivation has almost doubled from Rs.5,801/ha in 1983-84 to Rs.9,040/ha in 2010-11, the profit over cost of cultivation has increased substantially, because of increased value of output in the irrigated situation. The rainfed cotton does not provide a respectful profit most of the time. With cost of cultivation rising abnormally, the cotton farmers of Maharashtra have been struggling to get a steady profit which generally fluctuates every alternate year. Besides reaping better profit, the farmers of the irrigated state of Gujarat have reaped profit more number of times as compared to their counterparts in Maharashtra. The better irrigated cotton farmers reaped profits in 25 out of 29 years (86.20 %), while rainfed cotton farmers of Maharashtra acquired profits only in 16 out of 24 years (66.70 %). The analysis suggests that the irrigated cotton-growers are relatively well placed over the rainfed cotton-growers in terms of reaping profit.

1.5.3 Adoption of hybrids in non-suitable region

Hybrid cotton is more intensive one, more than 80 per centof water and nutrients are required by the plants during flowering and fruiting phase, with the extended reproductive window demanding intensive irrigation and fertilizer management for high yields. Hybrid vigor leads to more vegetative bio-mass comprising of leaves and stems, thereby resulting in low harvest index. Since they are bushy, the hybrid plants need space and light. Thus, plant population for hybrid cotton was optimized at a low density of 6,000 to 16,000 plants per hectare depending on irrigation and soil type. To accommodate the bushy plants with hybrid vigor, a wide spacing upto 150 x 120 cm was adopted in irrigated regions mainly in Gujarat and 90 x 60 cm in rainfed Maharashtra. Multiple pickings associated with hybrids resulted in variable quality, generally with inferior quality in late picked cotton due to poor availability of soil moisture and nutrients at the terminal stages of the crop (Kranthi, 2017b). Seeds harvested from a hybrid crop cannot be used subsequently for sowing, whereas varietal seeds can be saved and sown recurrently for several seasons. Farmers are required to procure freshly produced hybrid seeds every year from the market. Over 30 years of intensive efforts, about 30 new intra-*hirsutum* hybrids have been released for commercial cultivation and the area under cotton hybrids reached 38 to 40 per centby the year 2000. With the introduction of Bt-cotton only in hybrids, the area under hybrid cotton reached 95 per cent by 2011. Hybrids are suitable for irrigated regions of central and south India and should be promoted in such regions only (Kranthi, 2013)

1.5.4 Higher cost of agro inputs

Recently introduced pesticides/fungicides/weedicides are costlier. Most of the new chemistries are safer molecules which could undergo photo-degradation, microbial degradation as well as chemical degradation, leaving very less amount of residues in the environment. Conventional pesticide formulations like WP, EC etc are endangering human health and polluting environment. Newly developed modern formulations like water emulsifiable gel, floating granules, drift-less dust, macro and micro encapsulated suspension, hollow fibers, monolithic matrix, laminated structures etc can overcome these problems. The prime motto for these developments is to give protection to the crops along with safety to the natural enemies of different pests and a holistic safe approach to environment (Bhattacharya *et. al*., 2009). High investment requirement in R&D for new molecule development and long gestation period of 3-5 years for registration of new chemicals are the major reasons for enhanced cost of new molecules. The utility of these novel chemistry molecules is understandable, but net profit is rather lessened.

Establishment of input-use-efficient sustainable cereal-legume based cropping systems integrating INM, IWM and IPM technologies for self-sustaining sturdy and ecology based agriculture is good and holds potential to reduce urea application in cotton at least by 50 per cent. Multiple abiotic/ biotic resistant varieties and IPM approach can reduce pesticide use immensely. Science based eco-friendly IPM and Insecticide Resistance Management (IRM) have the potential to reduce chemical pesticides at least by 50% (20,000 metric tons) worth Rs.3,000 crore (Kranthi, 2015)

1.5.5 Poor adoption of technology

In India, only 15-20 per cent of technologies generated by the scientific institutions are adopted by the farmers. There are several socio-economic factors that are responsible for slow or non-adoption of technology besides the merit of the technology (Govindaraj *et. al*., 2000 and Singh et al 2016).The technology is one important key factor that can undo the decelerating agricultural growth. The appropriate technology generation based on the need of different stakeholders and adopting it are the two most vital factors in boosting agricultural growth. The study on cotton cultivation made in western Maharashtra has revealed, that per hectare use of all the inputs for cotton were below the recommendations. The proportionate gap between the recommended and use levels was maximum for manures (78%), followed by potash (72%), nitrogen (48%) and phosphorus (39%). The return from each rupee spent on cotton production was 1.15 (Hileet *et. al*., 2014).

1.5.6 Impact of climate change in cotton

The earth temperature has increased by 0.74°C during the last century (1906 to 2005) due to increase in greenhouse gases through anthropogenic emissions as reported by IPCC. The increase in temperature is likely to be 1.8 - 4.0°C by the turn of 21st century resulting in anticipated greater instability in food, feed and fibre production. Increase in temperature can reduce crop duration, change pest populations, hasten mineralization in soils and increase evapo-transpiration. It is reported that 40 and 50 per cent less biomass is anticipated in cotton at 20/10°C and 40/30°C, respectively, with optimum temperature of 30/20°C. However, increase in atmospheric CO_2 increases the quantum of yield produced photosynthetically, net photosynthesis, biomass production and ultimate output in C3 plant.

Besides higher output, increasing inputs-use efficiency in cultivated crops is also realized and the same at much greater pace in C3 plants (cotton). Study showed that increase in seed cotton yield up to 43 per cent was realized at elevated CO_2 of 550 ppm throughout the crop-growing period. Severe sucking pest problem and dominance of weeds are expected in cotton. Thus, in total, elevated CO_2 favours cotton growth and yield but higher temperature influences these negatively. The effect of climate change on national cotton production system interpreted that increasing CO_2 concentration could help to increase cotton production in all the three zones. However, increasing precipitation with decreasing temperature may prolong the vegetative growth and extend the crop duration, which pose difficulties in timely sowing of succeeding rabi crops in north zone. The expected increasing of temperature, decreasing rainfall with erratic distribution in central and south zone leads to frequent wet and dry spell with high evapo-transpiration demands. Prolonged dry spell during critical crop growth periods may affect yield (Sankaranarayanan *et al* 2010). Appropriate varietal planning and strategic policy initiative for overcoming climate change induced aberrations are much desired.

1.6 Broad Strategies for Increasing Production in Cotton

With increasing population density and arable land being constant or rather declining, increasing per hectare yield is the only way to solve the ever growing demand for agricultural produce in India. Indian cotton production has undergone a metaphoric changes from 2002-03, after transgenic Bt cotton hybrids were introduced in the country, as seen from significant increase in area, production and productivity (Table 1.1-1.4). With growing demand for cotton garments in the world, there are ample opportunities for the country to play a leading role in the cotton production and export. Following steps will help in increasing the income of cotton producers in the country.

1.6.1 Potential cotton genotypes

ICAR-All India Coordinate Research Project (AICRP) on Cotton and ICAR-Central Institute for Cotton Research (CICR), Nagpur have developed and released improved genotypes including twelve varieties of *Gossypium hirsutum* (MCU 5 VT, LRA 5166, Supriya, Kanchana, Anjali, CNH36, Arogya, Surabhi, Sumangala, CNH 120 MB, Suraj and CNHO 12), three varieties of *G. arboreum* (CISA 310, CISA 614 and CNA 1003 (Roja)), one variety of *G. barbadense* (Suvin) , nine intra-hirsutum hybrids (Savitha, Suguna, Surya, Kirthi, Omshankar, CSHH 198, CSHH 238, CSHH 243 and CSHG 1862), two interspecific (*G. hirsutum* x *G. barbadense*) hybrids and one intra-arboreum hybrid (CISA 2). The CICR varieties, LRA 5166, LRK 516, Surabhi, Suraj and many others possess excellent adaptability characteristics and are being commonly utilized in majority of the highly adaptive commercial private hybrids that are grown across the country.

The world's best extra-long staple variety 'Suvin' was developed by CICR. Research efforts, since the formation of AICRP on cotton in 1967, have led to the release of more than 300 Cotton varieties and hybrids for the different cotton growing tracts of the country and development of economical and eco-friendly package of practices for realizing enhanced productivity. These well adapted cotton cultivars need to be suitably redeployed in plant breeding programme to evolve ideally suited plant types for niche areas in short span of time for wide and sustainable use in enhancing productivity matching to international levels.

1.6.2 Large gene bank resource

India has one of the world's largest gene banks with an array of 11,345 accessions of all the four cultivated species of cotton. India is the only country in the world that cultivates all the four species are under commercial cultivation viz., *Gossypium hirsutum*, *G. barbadense*, G. *arboreum* and G. *herbaceum*. The gene bank is an invaluable treasure of a wide range of economically important quality traits, that can be sourced and pyramided into cultivars with resistance to identified biotic and abiotic stresses and are suitable for specific agro-eco zones in the country. The gene bank provides a powerful opportunity to combat the challenges posed by climate change uncertainties.

1.6.3 Conservation agriculture

Conservation Agriculture (CA) provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora, in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the bio-diversity in an agricultural production system on a micro as well as macro level. Conservation agriculture includes reduced tillage, mulching, cropping system approach and irrigation management.

Wherever possible, zero-tillage and strip tillage should be practiced to facilitate timely planting rather than waiting for optimum soil conditions for conventional tillage. In zero-till or strip till systems, winter cover crops protect the emerging cotton seedlings. Plant legume crops such as soybean, cowpea, groundnut, sesbania and sunnhemp or melon and pumpkin are sown in alternate rows of cotton as cover crops. Results indicate that mean seed cotton yield under zero tilled permanent broad-bed sowing with residue retention (PBB + R) was about 24 and 51% higher compared with zero tilled narrow-bed sowing without residue retention (PNB) and conventional tillage (CT) plots, respectively. The plots under zero tilled permanent broad-bed (PNB) sowing with residue retention (PBB + R) also had the highest net returns (based on mean values of last two years) that was 36 and 13% higher compared with CT and PNB plots. Therefore, growing cotton–wheat system under permanent beds with residue retention is recommended under irrigated conditions in north zone due to its potential of increased productivity, profitability and resource conservation (Das *et. al*., 2014)

1.6.4 Soil moisture conservation

Soil and water are precious for agriculture. Every drop of water and every soil particle have to be protected and conserved and excess runoff water is to be disposed off safely, for enhancing water and soil conservation. Systems involving graded, narrow or broad ridges or beds separated by furrows for drainage reduce run off and soil erosion and increase infiltration of rainfall. The experiments showed the superiority of broad ridges or beds of 1.50 m wide over narrow (0.75m wide) ridges for water infiltration, erosion control and flexibility for intercropping. Forming beds (120-180cm wide) and furrows on a grade for *insitu* water harvesting is found to be efficient in deep black soils with a rainfall of 700-850 mm.

Broad bed and furrow permits relatively small run-off and soil losses from this practice appear to be within the acceptable range. The broad bed furrows system recorded higher yield (1204 kg/ha) followed by compartmental bunding (1189 kg/ha) and CCC spray (1158 kg/ha) as against 1034 kg/ha obtained with control (interculturing and hand weeding). Opening of furrow after every rows of cotton between 30 to 45 days after sowing and spreads of crop residue mulch were found to be promising. On Vertisols, reduced tillage system has been reported to yield equal to or higher than conventional system (Blaise *et. al*., 2005)

1.6.5 Integrated weed management

Weed infestation in cotton has been reported to offer severe competition and causing yield reduction to the extent of 85 per cent (Sankaranarayanan*et. al*., 2012b). Being a rainfed and long-duration crop, weeds flourish in many flushes and compete with the crop of cotton for nutrients, moisture, light, space *etc.* and also harbour insects pests and diseases. Labour is not only costly, but its timely availability is also a problem. Application of pre-emergence chemicals under rainfed condition has many limitations. Thus, effective, broad spectrum and cheaper post-emergence chemicals for weeding in cotton are needed. Recently available selective post-emergence weedicides for cotton are costly and cost of weeding is almost equal to manual weeding. RRF technology is not available yet due to various reasons.

Glyphosate is non selective but cheaper, broad spectrum and systemic weedicide (Riaz*et. al*., 2007). Selectivity of glyphosate by non-transgenic methods is attempted at ICAR-CICR, Coimbatore. The selectivity of the chemical was attempted by covering crop plants using PVC pipes cut through length wise. Cotton seedling was covered without any physical damage by PVC pipes with 6 inch diameter and 20 feet length which was cut half in length wise which could cover a single row and the chemical was applied. At later stages (40 DAS), the chemical was sprayed with protected shield attached to the nozzle of delivery system to avoid direct chemical contact with crop plants. Application of Glyphosate @ 5.0ml/l at 20 & 40 DAS with protective mechanism registered significantly highest net return (Rs.61,875/ha) and benefit cost ratio (2.56)

1.6.6 Integrated pest management

The current scenario in cotton revolves around increased cost of cultivation, enhanced use of pesticides, change in pest status as a result of transgenic cotton introduction, pest resurgence following frequent use of chemicals for sap sucking pests, application of new molecules and deterioration of quality of ecosystem. The best pest management is done through host plant resistance that can be supplemented by naturally occurring biological control. Varieties that are resistant to sap sucking pests provide a robust foundation for integrated pest management. Coupled with appropriate seed treatment, these varieties can tolerate sap-sucking pests and diseases, so that there would not be any need for pesticide applications early in the season at least for 2-3 months after sowing.

1.6.7 Intensification through space and time dimensions

Cotton is a crop of relatively longer duration; its slow initial growth offers a vast scope for cultivation of suitable intercrops. Multi-tier cotton based vegetable inter-cropping system was developed at CICR, Coimbatore (Sankaranarayanan *et. al*., 2012a). The significantly highest gross return (Rs1, 50,279/ha), net return (Rs 99,232/ha), per day profitability (Rs 662/day) and seed cotton equivalent yield (73.1 q/ha) had been arrived with multitier system consisting of cotton with radish, cluster bean and beet root (Table 1.10). Intensification of crop on time and space dimension in the system by selecting short duration, non-competitive crops and method of planting adopted had not suppressed growth of base crop (cotton) and produced statistically as much as equal seed cotton yield (25.5 q/ha). In addition, production of 6773 kg of radish, 4566 kg of cluster bean and 5645 kg of bee root, which favoured higher economic return**.** Cotton based farming system is one of the major farming system in Vidharbha and Marathwada region of Maharashtra (Singh *et. al.*, 2014). Improved low cost farm practices, and reliable prices of their farm produce is needed for improvement in productivity and profitability of crops and livestock in the area. This will enable farmers to bear the high cost of health and education in the era of commercialization.

Table 1.10 Seed cotton yield (kg/ha) and economics of multi-tier system

Cropping system	Seed cotton Yield (q/ha)	Gross Return (Rs/ha)	CC (Rs/ha)	Net return (Rs/ha)	B/C Ratio	SCEY (q/ha)
Multi tiersystems (.Cotton +radish+ cluster bean+ beet root)	25.5	150279	51047	99232	2.94	73.7
Sole Cotton	26.2	53320	29038	24282	1.8	26.1

Source: Sankaranarayananet al, 2012a
SCEY- Seed Cotton Equivalent yield

1.6.8 Sub-soiling to break hard-pan

Hard-pan is a major problem in many regions in the country that results in poor root penetration and low yields. Land preparation must be done by sub-soiling at a depth of 40-45 cm to break the hard-pan and sub-soil layer to improve water through root penetration. It helps avoid compaction due to tillage machinery to retain porosity and soil structure for internal drainage which is a limiting factor in heavy clay soil. Chisel the soils having hard pan formation at shallow depths with chisel plough at 0.5 M interval, first in one direction and then in the direction perpendicular to the previous one, once in three years. Apply 12.5 t farm yard manure or composted coir pith/ha besides chiselling to get increased yield. Cross sub soiling at 1.0m x 1.0 m distance gave significantly higher seed cotton yield at Faridkot (3829 kg/ha) and Bhatinda (2733 kg/ha), which was 33.6 and 33.7 per cent higher than control, respectively (AICRP on Cotton, 2017)

1.7 Technological Interventions

The cotton cultivation in India is spread over 17 agro-climatic zones in 11 states. Hence, the production technologies are also varying and cannot be generalised. After concerted efforts by all the stake holders the following modules have been shortlisted which will be instrumental in meeting the objective of doubling of farm income

1.7.1 High density planting system

Many cotton producing countries like Brazil, China, Australia, Uzbekistan, Argentina and Greece tested, proved and adopted narrow row planting system of cotton as tool to achieve higher productivity (Kranthi, 2013). Increased plant density would be beneficial to enhance cotton yield in the lower fertility field. High density planting system has been suggested as an alternative strategy instead of conventional one to increase yield. Prevailing manual picking cost constitute about 30-40 per cent of total cost of cultivation, which necessitate machine picking, thus ultimately warranting high density planting system with compact genotypes for its suitability. Packages for high density planting System (HDPS) including genotypes, spacing, nutrient requirement, mechanical sowing, land shaping, canopy management and weed control were developed.

Table 1.11 Seed cotton yield (q/ha) and returns (Rs/ha) as influenced by HDPS cotton

Treatments	Seed Cotton Yield (q/ha)			Gross Return (Rs/ha)			Net Return (Rs/ha)		
	Irrigated	Rainfed (PI)	Mean	Irrigated	Rainfed (PI)	Mean	Irrigated	Rainfed (PI)	Mean
HDPS (60 X 10 cm)	32.4	29.0	30.7	111262	99891	105576	53495	47108	50301
Conventional Planting (75X 45 cm)	20.2	17.6	18.9	69665	60848	65257	26695	22438	24567

Source: TMC 2015
PI-Protective irrigation (one provided)

At Hisar, compact culture, H1465 exhibited superior performance; however, in Sriganganagar, the highest seed cotton yield was recorded with RS2718. Amongst spacing tested, 67.5 x 20 cm and 67.5 x 15cm produced high yield at Hisar and Sriganganagar, respectively. High density planting of 60 cm between rows and 10 cm between plants recorded significantly higher seed cotton yield for the both locations of Rahuri and Surat. Nutrient response was significant at Surat but not at Rahuri (AICRP on Cotton, 2017). High density planting system, in the Indian context, provided 25–30 per cent higher yield over recommended spacing on shallow to medium deep soils under rainfed conditions (Venugopalan *et al*, 2013). The HDPS trials conducted at Coimbatore in 2014-15 revealed that conventional planting registered mean of seed cotton yield of 18.9 q/ha and mean net return of Rs 24567/ha (Table 1.11). However planting under HDPS registered mean seed cotton yield of 30.7q/ha and mean net return of Rs 50301/ha which were 62.4 and 104.8 per cent higher than conventional planting, respectively (TMC, 2015).

1.7.2 Short duration Bt cotton varieties

Most prominent change in cotton cultivation was the introduction of Bt-cotton hybrids in 2002. The study conducted in Punjab revealed that productivity is found to be substantially higher in Bt cotton than that of non-Bt cotton. Although the results of the study clearly suggested that the profit from Bt cotton cultivation is substantially higher than the non-Bt-cotton, the Bt hybrids are not completely free from pest problems, especially in the recent years (Priyabratabhoi and Singh,2015). Now, the adoption of Bt hybrids has reached a saturation point. Further improvement of productivity and profitability may not be possible in Bt hybrids.

Similarly, Bt cotton hybrids are long in duration (of 180-200-day duration) and are not suited for rainfed conditions because of narrow length of growing periods. Bt hybrids suffer from severe moisture stress during the critical period of peak boll formation, by withdrawal of late seasonal rainfall. More over Bt cotton hybrid seeds are costly. However, Bt varieties are suitable in rainfed/ low length of growing region. Recently Bt technology has been made available in varieties also. Recently ICAR has released two Bt cotton varieties (PAU1 Bt and RS2013 Bt) for north zone and some more varieties are under consideration for release in other zones.It is perceived that high yields can be obtained from these Bt cotton varieties at low production cost and even under rainfed farming by adopting high density planting system.

1.7.3 Plastic mulching

The use of plastic mulches is negligible in India. In China, plastic mulches are used extensively to cover almost all cotton fields across the country in 30 to 40 lakh hectares, especially in the arid and semi-arid regions of northern China and coastal saline-alkali areas. Polythene mulch could control evaporation completely. Water saving of 40 per cent with conventional irrigation and upto 85 per cent of water saving when combined with drip irrigation was worked out, which could prevent weed growth and no additional weed management is required. Faster mineralization and higher nutrient mobilization was noticed.

The poly mulch + Drip at 0.4 ET_c recorded the highest seed cotton yield of 5494 kg/ha and this treatment combination recorded the lesser water requirement of 44.5 ha cm and the highest water use efficiency of 123.5 kg/ha cm (Table1.12). Poly mulching alone without drip is found significantly superior to drip alone either at 0.4 or at 0.8 Etc in terms of yield attributes and seed cotton yield. The conventionally irrigated cotton recorded the highest water requirement of 95.8 ha cm with the lowest water use efficiency of 36.0kg/ha cm (Nalayini *et.al.*, 2011 and Feng *et al*, 2017). Silver colour mulch recorded lesser pest incidence also. Polyethylene mulching was made as biodegradable by adding patented additive at the time of manufacturing the poly film.

Table 1.12 Water saving, growth, yield and quality of ELS cotton under poly mulching, drip and drip + poly mulching

Treatments	**SCY(kg/ha)**	**WR(ha cm)**	**WUE**
Control	3450	95.8	36.0
Poly mulch	4982	55.8	89.0
Drip 0.4 ET_c	4009	44.5	90.08
Poly mulch + Drip 0.4 ET_c	5494	44.5	123.5
Drip 0.8 ET_c	4551	53.3	85.4
Poly mulch + Drip 0.8 ET_c	5486	53.3	102.9
CD (p=0.05)	**497**		

Source: Nalayini et al, 2011

1.7.4 Drip fertigation

Further improvement of cotton productivity is possible through efficient & optimal use of precious farm inputs i.e, water and nutrients that shall ensure higher profitability to farmers. Management of water and nutrients play a key role in breaking the undesired tempo in productivity plateau reached after major emphasis on Bt cotton. Cotton is one of the identified crops for promotion of drip irrigation. In absence of newer irrigation projects, bringing more area under irrigation would mostly depend on the efficient use of water.

In this context, micro irrigation could play a key role in higher productivity and increased water use efficiency (WUE) besides fulfilling sustainability mandates with economy in use and higher crop productivity. Adoption of this technology might help in raising the irrigated area, productivity of crops and WUE. Drip-fertigation, where fertilizer is applied through an efficient irrigation system (drip method), may effect nutrient use efficiency of as high as 90 per cent compared to 40-60 per cent in conventional methods.

Table 1.13 Seed cotton yield and comparative economics in low cost drip systems (Rs/ha)

Items	Existing Drip system	Low cost -Polytube drip system (150)
Total system cost	**74080**	**31252**
Per annum irrigation cost	12594	7273
Saving in total cost of the system (%)	-	57.8
Saving in per annum irrigation cost (%)	-	42.3
Cost of cultivation Excluding irrigation cost	20271	19917
Total cost of cultivation	32865	27190
Seed cotton yield (q/ha)	27.1	26.2
Gross Return	67625	65500
Net Return	34760	38310
BCR	2.06	2.41

Source: Sankaranarayanan et et.al. (2010)

High initial cost is one of the major constraints hindering its rapid adoption in annual crops including cotton. Adoption of drip system per hectare land of cotton is estimated at Rs 65,000 to Rs 75,000 and the initial investment is high. Hence, low cost drip systems poly-tube based drip (57.8%) was developed through rigorous testing procedures for optimum efficiency at CICR, Coimbatore (Sankaranarayanan *et.al*, 2010a and Feng *et al*, 2017). Moderately higher yield (26.2 q/ha) with all the positive effects (of drip) along with lower cultivation cost (Rs 27,190/ha) were incurred in poly tube drip system that further led to higher net return (Rs 38,310/ha) and BCR (2.41) (Table 1.13). Thus, the technology focused on the suitability and viability of the use of low cost polytube drip for an efficient on farm irrigation scheduling in cotton.

1.7.5 Labour saving techniques & mechanical picking

Farm mechanization can be helpful in bringing out significant improvement in cotton productivity and profitability by reducing the cost of cultivation and the factors justifying the requirement of farm mechanization in cotton crop are numerous. Being a labour intensive crop, cotton requires on an average 240 man days per hectare from planting to picking that makes the crop a fit case for rapid farm mechanization. In addition, net return per labour is least for cotton. Moreover, labour is becoming increasingly costlier resulting in poor crop husbandry, rising cost of cultivation and poor income to the farmers.

More than the cost involved, the availability of labour and the age (old & aged human labour) of available agricultural labour are of greater concern. Moreover, farm operations like hoeing, irrigation, harvesting, and marketing need to be performed early at appropriate time in order to maximize both yield and profit margin. Cotton is one crop whose cultivation has not been mechanized to the extent of other crops like wheat, maize, sunflower and rice.

Cotton requires special machines to handle certain operations in its cultivation; therefore, the general purpose implements and machines developed for other crops could not be adapted to cotton. However, implements and machineries have been developed and are available for seed bed preparation, sowing, weeding, inter-culture and plant protection. Popularization of proven technology enhances the adoption and reduces the labour dependency in cotton cultivation. Urgent need for cotton picker is felt by farmers throughout the country, because of labour intensiveness associated with picking. ICAR-CICR is about to release suitable picker for mechanical picking in cotton shortly.

1.8 Policy Interventions

Having left behind the 'Trade Quota Regime' by December 2004, the textile industry across various segments has seen expansion and modernization. This has happened both in India, as also in other major exporting countries, leading to increased demand for cotton. India, which already enjoys a trade surplus in respect of cotton needs to sustain this, and one of the primary requirements is ensuring quality of cotton fibre, besides steadiness of output, and cost efficiency in production. Some important policy issues area discussed below.

1.8.1 Improving the quality lint

The quality of lint and yarn in India has been seriously affected by poor fibre attributes, rapid deterioration of fibre quality of hybrids with successive pickings, high percentage of trash (4-7 per cent) and contaminants. Another important aspect relates to multiplicity of varieties (around 300), which have introduced variable fibre length and quality. This situation only compromises the uniform quality of yarn along the value chain – from field to ginning factory to pressing unit. This does not suit the modern textile industry, which demands uniform fibre length, higher strength and superior micronaire to withstand the high RPM. In order to cater to the industrial demand from within and outside the country, meeting high standards of quality becomes relevant.

1.8.2 Market intelligence and research

One of the basic principles, that is emphasized by the DFI Committee is demand-led production, whereby the farmers produce what can be sold in the market, and that which fetches optimal financial returns. Hence, the critical role of market research and intelligence. The Cotton Corporation of India (CCI), should undertake this responsibility, and in association with the proposed 'Institutional Mechanism' for price and demand forecast to be rolled out by the Department of Agriculture, Cooperation and Farmers' Welfare (DACFW). Further, in partnership with APEDA (Ministry of Commerce) and DMI (in the DACFW) should be able to identify specific requirements of quantity and quality of demand in domestic and export markets and advise the farmers on informed production decisions. The technology transfer relating to production will of course be the responsibility of the Ministry of Agriculture.

1.8.3 Contract farming

In the context of liberalized global trade regime, among different possible avenues that could safeguard the interests of the small and marginal farmers, Contract Farming is the most convenient and safer option, in terms of guaranteed income and low capital investment. There are examples of contract farming in cotton. Super Spinning Mills of Tamil Nadu have entered into contract farming in cotton in Tamil Nadu since 2003 in the districts of Salem, Coimbatore, Vellore, Namakkal, Madurai and Theni. Super Spinning Mills followed centralised model of contract farming which involves a centralised processor and/or packer buying from a large number of small farmers, vertically coordinated with quota allocation and tight quality control and control of most production aspects. The total cost of cultivation was higher in case of non-contract farming when compared to contract farming by a difference of Rs.2,000/- which was due to higher labour use in the former case.

The B:C (Benefit:Cost) ratio over total cost and cost of production per quintal was remunerative under contract farming (1.64; Rs.1581.60/q) compared to non-contract farming (1.08;Rs.1911.19/q) in cotton. The farmers' net price under non contract farming in case of channel I (Cotton growers-Wholesalers-Retailers-Farmers) was 75.77 per cent and in channel II (Cotton Growers-Processors-Wholesalers-Retailers - Farmers) it was 73.60 per cent. The total marketing cost (transport, handling, processing, physical loss, taxes, storage) worked out to 7.04 per cent in channel I and 9.98 percent in II.

Likewise the intermediaries' margin was 3.32 per cent in case of channel II (Processor), 6.29 per cent in channel I and 4.50 per cent for wholesaler and 10.90 and 8.60 per cent, respectively in case of retailers. Under contract farming, the farmers' net price is 100 per cent as the produce is directly sold to the sponsors. The contract farmers avail the advantage of increase in yield to the tune of 700 to 800kgs as against 400 to 500 kgs in case of non-contract farmers. Likewise cost minimization upto Rs.1,500 per acre could be obtained under contract farming. The sponsor could get the *kapas* as per their mill requirements with low trash content, less contamination and increased yarn realization by weight under contract farming. A set of contract farmers, in spite of enjoying higher price were not satisfied with the stipulated contract price by the sponsor. To conclude, it could be seen that the contract farmers benefited more than the non-contract farmers.

Cotton contract farming studies made in Parbhani and Beed districts of Maharashtra found that gross return was Rs. 49,719 and Rs. 35,312 under contract and non-contract farming. In which contract farming main produce was Rs. 47,616 and by produce was Rs. 2103, in case of non-contract farming main produce was Rs. 34,050 and by produce was Rs. 1,262 per hectare. In case of cost of cultivation, total cost was Rs. 37,441 and Rs. 33,471 in contract and non-contract farming. The net profit was Rs. 12,278 and Rs. 1,842 regarding contract and non-contract farming. Then the benefit: cost ratio over total cost was 1.33 and 1.05 in case of contract and non-contract farming (Maske and Chavan, 2015). In case of cotton also, there is a considerable amount of economic impact compared to pre-contract farming (65583) to post-contract farming (878983)(Sahana *et. al*., 2017).

Cotton farming will help in supporting the farmers in production of high quality of cotton fibre, as the arrangement facilitates transfer of suitable technology and extension support. It also is helpful in linking the production with the textile industry. With the roll out of the Model Contract Farming and Services Act by the Union Government, the state governments should be able to offer this opportunity to their cotton farmers.

1.8.4 Minimum Support Price (MSP) for Cotton

Minimum Support Price (MSP) is the price that is notified by the Government that takes into consideration the cost of production and a certain percentage of profit thereon. This is also the price at which government agencies purchase crops/farm produce from the farmers in case the market prices fall below MSP. The minimum support prices are announced by the Government of India at the beginning of the sowing season on the basis of the recommendations of the Commission for Agricultural Costs and Prices (CACP).

The Union Budget, 2018 has made a commitment to offer a minimum of 50 per cent as the margin of profit over the cost of production. This will result in substantial increase in MSP for cotton and incentivize farmers to focus on realizing higher productivity. Simultaneously, the assurance to put in place robust procurement system will help cotton growers. Currently cotton procurement is undertaken by Cotton Corporation of India (CCI), but a very small percentage of the total output is procured.

If the new procurement policy can target to procure upto 40 per cent of the MSR (marketable surplus ratio) will certainly help in creating market buoyancy by sucking out the surplus and correcting, the supply-demand position. This will help in safeguarding the farmers from price falls below MSP.

Procurements linked to MSP become important in agriculture sector, since agriculture markets can never always be efficient, and therefore prices may dip below MSP, calling for government support.

1.8.5 Value addition in cotton

The cotton crop is much more than just a fiber source. While the fiber is woven into apparel and textiles, the seeds are used as a high-quality feed for milch animals. Cotton farmers do not get benefit commensurate with the high cost of cotton cultivation required to raise this commercial crop. Also, the by-products such as seed and cotton stalks are not properly used by farmers for capturing value in the form of linters, cotton seed oil, meal, etc.

Cotton stalk can be used for preparation of particle boards, binderless boards, growing oyster mushrooms, production of pulp and paper materials, preparation of cellulose powder, preparation of compost and vermi-compost. Nearly 2-5 tonnes of cotton stalks are obtained from each hectare and can provide an additional income of about 5-10 per cent per hectare to the farmers.

Cotton seeds obtained after ginning are used currently to expel oil by subjecting the whole seeds for crushing. By this process, industrial raw materials like linters (5%) and hulls (30%) are wasted. About 8 million tonnes of ginned seeds are produced in the country today, scientific processing of which could provide linters (raw material for absorbent cotton; high grade pulp, etc.) and hulls (cattle feed) that find use in several applications. Bio-enriching hulls to make it useful as component in an enriched cattle feed can be used as a component in the feed ration. Cotton milk is also one of the value additions, which is obtained from extraction of cotton seed, having rich cooling effect and also helps in easy digestion. The improved value chain could make cotton production, processing, marketing system more sustainable and highly profitable one, especially when all the stakeholders including farmers are taken on board and the advantages of such a mechanism are ensured to all including cotton farmers.

In China, cotton processing and value chain industry stood to gain because of high value addition from the phenomenal textile exports worth US $ 237 billion in 2017 compared to the Indian textile exports worth US $ 42 billion. With immense resource advantages at hand, India should seriously consider strengthening the textile and trade industry and emulate China's success story of producing huge value added goods and earn tremendous foreign exchange. A suitable mechanism has to be devised to dovetail the gains expected out of improved cotton value chain to flow into farmers hands so that the profitability of cotton farming is sustained.

1.8.6 Transporting cotton

The movement of cotton within the country is unfortunately is costly. As per reports, the cost of transporting cotton from Gujarat to Tamil Nadu, which accounts for 47 per cent of spinning mills is more than double of the cost of transporting it from West Africa to Tamil Nadu. Government of India, realizing this, has relaxed cabbotage rule for cotton transport. (Economic Times, 24th May, 2018). This is a significant step. However, other measures to reduce the cost of transportation should be worked out so that cotton farmers gain from reduced logistics cost.

India has gained from its cotton exports and exports pave way for evacuation of surplus stock thereby benefiting the farmers. Realizing the importance of cotton exports, Government of India has relaxed the rules applicable to cotton and cotton yarn export. The relaxations include Government of India dispensing with the requirement of registration at the Directorate General of Foreign Trade (DGFT) for exports of cotton and cotton yarn which was earlier mandatory for the traders along with notification of their targeted export volume for the year. This has ensured the ease of doing business.

Though India imports cotton, the balance of trade is in favour of the country. During 2016, India was the second largest exporter of cotton in the world. Vietnam was the largest importing country in the world followed by China and Turkey. India's major export destinations in 2016-17 were Bangladesh, China and Pakistan. Countries such as Bangladesh, Vietnam, Pakistan and Taiwan are scaling up their cotton imports from India to meet the requirements of their export-focused garment industries.

It is essential, that India maintains its competitiveness in the global market. This calls for increasing productivity and reducing cost of cultivation besides producing the right staple length in demand in world market. The following table presents the data on India's raw cotton import-export.

Table 1.14 Status of India's export-import for cotton raw including waste:

(Qty in lakh MT & Value in Rs Crore)

Year	2012-13		2013-14		2014-15		2015-16		2016-17		2017-18	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Export	**20.57**	**20277**	**19.48**	**22338**	**11.43**	**11643**	**13.47**	**12821**	**9.96**	**10907**	**10.97**	**12156**
Import	2.33	2467	1.81	2376	2.89	3102	2.33	2566	5.00	6339	4.69	6307
Trade Balance	**18.24**	**17810**	**17.67**	**19962**	**8.53**	**8541**	**11.14**	**10255**	**4.96**	**4568**	**6.28**	**5849**

Source: DGCIS, DoC

1.8.7 Prioritising research needs

In the light of the emphasis brought to aspects of fibre quality & demands of modernised textile industry (high speed of spindles) it is reiterated that R&D in cotton should priortise various parameters like fibre length, fibre strength, high maturity, high extensibility, superior micronaire, uniformity etc.

In contrast to Bt Cotton hybrids (with long duration of 180-200 days) which are not appropriate for rainfed and low length of growth regions, **Bt cotton varieties** are a good substitute. Hence, Bt cotton varieties deserve priority, keeping in mind the interests of the farmers living in such areas. Develop broad-based Bt cotton hybrids, particularly to negotiate growing intensity of abiotic stresses, in the context of climate change.

1.9 Annotation

Theoretical yield of cotton from potential growth or photosynthesis and respiration rates by growth analysis, from radiation use efficiency or by simulation modelling indicate that it could be about 5,000 kg lint/ha (Constable and Bange.,2015). The theoretical yield is nearly about ten-fold the present productivity in the country. It can be concluded here that the cotton crop is a highly potential crop and improving the productivity and doubling the net profit to cotton farmers is a realistic one.

While deep soils in assured rainfall areas (or areas with supplemental irrigation) can still support cotton hybrids, in the drier areas, hybrids due to their longer duration and bushy growth habit fail whenever there is a terminal drought, more so in shallow soils. Planting short duration, compact varieties of American cotton or desi cotton, immediately after the first monsoon showers under high density planting can help avoid terminal water stress, escape pink bollworm and enable the farmer realise economic yields. Plant breeding efforts should be directed to develop specific varieties suited for the marginal soils and monsoons of Vidarbha area of Maharashtra. The ideal variety should have short duration (140-160 days), compact architecture, high harvest index, resistance to sap-sucking pests and high ginning out-turn (>40%) (Venugopalan, 2017).

It is necessary to ensure climate resilient production modules tailor made to emerging situations and increasing demand. Incorporating components like quality seed, bio-fertiliser, INM, IRM and IPM will enhance production coupled with greatly reduced cost of cultivation leading to increase in farmers' income, be it irrigated or rainfed situation in the country.

The expert panel of International Cotton Advisory Committee (ICAC) on Social, Environmental and Economic Performance (SEEP) of Cotton Production enlisted 68 core, measurable indicators (along with uniform units) for evaluation, monitoring and comparison of sustainability of cotton production. These indicators encompass environmental (pest and pesticide management, water management, soil management, bio-diversity and land use, climate change), economic (viability and poverty reduction, risk management and social (labour, worker health and safety, equity and gender, farmer organisations) dimensions of sustainability of cotton production.

Convergence of cost effective technologies, effective transfer of technologies, hassle-free credit facilities and positive policy initiatives including matching minimum support price for the quality produce shall trigger further transformation in quantity and quality profile of important natural fibre crop and ensure doubling of cotton farmers' net income on a sustainable basis.

- Thrust on diploid cotton deployment which is a natural source for overcoming biotic & abiotic stresses and for marginal lands
- High density planting system (HDPS) with short duration compact genotypes and altered geometry
- Identification of multi-adversity resistant cotton lines for specific eco regions
- Special programme for identification of ELS cotton (*G. barbadense*) and *G. arboreum* cotton genotypes
- Cropping system approach for assured economic returns and long term sustainability.
- Use of modern extension tools to enhance technology adoption rate
- Coordination efforts for fructification of newer transgenic events by Public and Private institutions by following established regulatory procedures
- In order meet the demand for qualitative and contamination – free cotton fibre from both domestic and export markets, as also to cater to the demands of a modern textile industry, R&D and extension services should focus on these aspects at the cultivation/production stage.

Key Extracts

- Cotton is the most important commercial crop of India, contributing around 65 per cent of the raw material to the textile industry and provides employment to around 60 million people.
- India ranks first with around 11.8 million hectare under cotton (~34.0% of total world area under cotton), ranked first in production (34.6 million bales) followed by China in 2015-16.
- In contrast, India lags in terms of yield. Prime reason for this is, that more than 60 per cent of area under cotton cultivation is rainfed (studies suggested that profit on the rainfed cotton farm was around three times less than that on the irrigated cotton farm).
- Indian cotton cultivation has undergone a dynamic change since 2002-03, after the introduction of Bt cotton; however several steps are needed for improving the productivity and congruently increasing the income of farmers.
- Growing cotton–wheat system under permanent beds with residue retention is recommended under irrigated conditions in north zone due to its potential of increased productivity, profitability and resource conservation.
- High density planting system (HDPS) instead of conventional one is suggested as an alternative strategy to enhance cotton yield in the lower fertility fields.
- The adoption of Bt hybrids is at saturation point; Bt cotton hybrids are long duration (180-200-day) and are not suited for rainfed conditions because of low length of growing periods.
- Cotton cultivation has not been mechanised to the level of crops like wheat, maize, sunflower etc. The general purpose machines developed for other crops could not be adapted to cotton
- Cotton farmers do not get commensurate economic benefit because of its high cost of cultivation and not capturing value from by-products such as seed and cotton stalks.
- There is an imperative need for fine-tuning the MSP further in order to ensure that the interests of farmers in both irrigated and rainfed areas are equitably taken care of.
- The agri-logistics for internal movement of raw cotton from different production centres to major consumption centres like spinning mills of Tamil Nadu should be upgraded.
- Production and maintenance of the quality of fibre (length & strength), micronaire, uniformity etc.), as also free from contamination are critical to meet the demands of both domestic and export markets.

Chapter 2
Sugarcane – a sweat to sweet commodity

Sugarcane occupying approximately 3.5 per cent of net cultivated area contributes about 0.69 per cent to national GDP. A long duration, high input and high labour requiring crop with good capability to withstand adverse weather, it serves as mainstay of peasant prosperity and rural industrialization in many parts of the country. Ever increasing demand for sweeteners, electricity cogeneration in sugar mills and targets for fuel-ethanol blending has opened up new vistas of growth for the sector. Diversification is the optimal solution to ensure that farmers receive adequate and timely payments on the cane that they supply to the factories.

2.1 Introduction

India is the second largest producer and the largest consumer of sugar in the world. Next to 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 the last eight decades have been spectacular. Cane area witnessed a fourfold increase from about 1.17 million hectares (m ha) in 1930-31 to 4.93 m ha during 2015-16. During this corresponding 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 sugar production from 0.12 million tonnes in 1930-31 to 25.13 million tonnes during 2015-16. The average sugar recovery also showed an improvement from 8.96 per cent to 10.62 per cent. The number of sugar factories in operation went up from 29 to over 526 during this period.

In India, sugarcane is grown under varied agro-climatic conditions. The crop faces various biotic and abiotic stresses that impact the productivity in a significant way. However, in many states including Maharashtra and Karnataka it is grown in low rainfall area with major dependence on ground water. This is not a sustainable production system. Emphasis is needed on water saving technology in these areas. In the Indo-Gangetic Plains of Uttar Pradesh, the focus needed is on growing varieties with higher sugar recovery percentage. Red rot is the main disease prevalent throughout the country and affecting the crop, which has been largely and effectively managed through the deployment of resistant varieties. Decades of sugarcane research on aspects like varietal improvement, production and protection technology, and mechanization and post–harvest management techniques have provided a strong technological base for its impressive growth. Technological breakthroughs have equally benefitted both, the farmers and the industry.

Increasing cost of cane cultivation is a major factor for decreasing farm income in the recent past. Sugarcane cultivation requires 300 to 350 man days during the crop season to perform operations like planting, inter-culture and harvesting. Decreasing working hours per unit of labour, quality of labour hours and ever increasing wages have resulted in the increased production cost.

There exists great scope for making sugarcane cultivation cost effective, especially by promoting resource conserving crop production technologies, such as precision irrigation methods, site-specific fertilizer application and adoption of soil health sustaining nutrient management practices. Supporting farmers with timely weather forecast, weather and crop advisories, ICT based technology backstopping, institutional credit and site-specific crop insurance cover would help them to negotiate the challenges of sugarcane production system.

2.2 Sugarcane Production Scenario in States

Sugarcane in India is cultivated broadly under two distinct agro-climatic conditions, commonly referred to as tropical and sub-tropical regions. Tropical region comprising the states viz., Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Telangana, Madhya Pradesh, Gujarat, Odisha and Chhattisgarh accounts for 42.9 per cent of the total sugarcane area in India. Sub-tropical region on the other hand consisting of Uttar Pradesh, Bihar, Punjab, Haryana, Uttarakhand, West Bengal and north-eastern states contributes 57.1 per cent of the total crop area. Based on area spread (> 75,000 ha) and magnitude of annual production during the last five years, it emerges that only 11 states account for around 97 per cent of the area and production of sugarcane in the country. Of these, Uttar Pradesh tops the list with 2.2 m ha area (43.7%) followed by Maharashtra (0.98 m ha). Other important states are Karnataka, Tamil Nadu, Gujarat, Andhra Pradesh, Telangana, Bihar, Haryana, Punjab and Uttarakhand.

Of the two agro-climatic regions referred supra, tropical region is more suitable for sugarcane growth and development owing to prevalence of round the year conducive climatic conditions for the crop. However, sugarcane is grown for longer duration with high input application in this region, that leads to low remuneration despite high productivity and recovery linked yield. The region contributes about 48 per cent to the total cane production in the country with an average productivity of 85 t/ha. Sub-tropical states face extremes of temperature during summer and winter months resulting in comparatively shorter conducive growth period from July to November for sugarcane and consequentially low average productivity of 59.3 t/ha. This is lower than the national average by 11t/ha. In table 2.1, the status of sugarcane in different states is analysed.

Table 2.1 Sugarcane area, production, productivity and its growth over the years in different states of India

State	QE year 2015-16 (Area: Th ha Prod: Th tons and Yield: tons/ha)	Per cent share	CAGR (%)			
			1971-72 to 1984-85	85-86 to 94-95	1995-96 to 2005-06	2001-02 to 2014-15
Area						
UP	2191.0	43.72	1.8	0.8	0.35	0.69
Uttarakhand	106.1	2.12	-	-	-	-1.54
Haryana	96.8	1.93	-0.6	-1.0	-0.15	-4.51
Punjab	83.2	1.66	-2.7	0.2	-3.61	-3.81
Bihar	246.1	4.91	-	-	-	7.69
Maharashtra	981.0	19.57	3	3.3	-2.31	6.04
Andhra Pradesh	192.2	3.84	0.9	2.2	0.85	-1.58
Gujarat	189.2	3.78	8	3.1	1.64	0.06

State	QE year 2015-16 (Area: Th ha Prod: Th tons and Yield: tons/ha)	Per cent share	CAGR (%)			
			1971-72 to 1984-85	85-86 to 94-95	1995-96 to 2005-06	2001-02 to 2014-15
Karnataka	429.6	8.57	4.6	5.1	-3.59	2.47
Tamil Nadu	317.1	6.33	1.9	4.6	-1.6	0.99
All India	5011.7	100.00	1.7	1.1	-0.17	1.50
Production						
UP	131.0	37.30	2.6	3.2	0.27	1.20
Uttarakhand	6.3	1.80	-	-	-	-1.43
Haryana	7.1	2.03	-1.4	1.9	1.18	-2.48
Punjab	5.9	1.68	0.6	-0.3	-4.43	-2.33
Bihar	12.8	3.63	-	-	-	10.07
Maharashtra	79.4	22.61	5.8	2	-4.73	6.99
Andhra Pradesh	15.2	4.31	0.3	2.6	0.92	-1.38
Gujarat	13.2	3.75	11	3.8	2.55	-0.08
Karnataka	38.8	11.05	3.9	6.8	-4.88	3.20
Tamil Nadu	32.7	9.32	3.3	6.5	-2.17	1.16
All India	351.2	100.00	2.8	3.2	-1.19	2.14
Productivity						
Uttar Pradesh	59.8		0.9	2.4	-0.62	0.51
Uttarakhand	59.6		-	-	-	0.19
Haryana	73.4		-0.8	2.9	1.33	2.13
Punjab	70.3		3.4	-0.5	-0.85	1.54
Bihar	51.8		-	-	-	2.21
Maharashtra	80.9		2.7	-1.3	-2.47	0.90
Andhra Pradesh	78.7		-0.7	0.5	0.06	0.19
Gujarat	69.7		2.8	0.7	0.88	-0.14
Karnataka	90.3		-0.7	1.6	-1.34	0.71
Tamil Nadu	102.8		1.3	1.8	-0.58	0.17
All India	70.1		1.1	2.0	-1.03	0.64

Source: Sharma and Pathak (2017)

Compound annual growth rates (CAGRs) for area, production and productivity of sugarcane in different states over time have been analysed for the periods 1971-72 to 84-85, 1985-86 to 94-95, 1995-96 to 2005-06 and 2000-01 to 2014-15. As evident, the all India growth rate for area, production and productivity of sugarcane remained positive till mid-nineties, followed by a negative growth during 1995-96 to 2005-06. However, the growth turned positive for the period 2001-02 to 2014-15 at the national level.

2.3 Yield Gap Analysis

Sugarcane productivity varies from region to region. In addition to varying potential of the agro-climatic conditions under which sugarcane is grown, other reasons that explain the variation include difference in input supply, adoption of new & improved varieties, pest and disease management, soil health status issues, change in climate and price policy triggers.

Continued mono-cropping of sugarcane without crop rotation for several decades has depleted soil fertility considerably. It is reported that there is an estimated loss of 4.5 to 7.9 per cent in sugarcane yield due to soil degradation in India. Soil productivity has come down due to degradation of 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. Many of the sugarcane growing regions contain less than 0.5 per cent soil organic carbon against the minimum required limit of 0.65 per cent for effective response from applied inputs in sugarcane crop (Srivastava *et al*., 2016). About 7-8 lakh hectares of area under the crop is affected by soil salinity and related problems limiting the crop yield to a large extent. Though the crop is moderately tolerant to salinity, losses are significant.

Major diseases like smut, wilt and yellow leaf disease (YLD), 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 in managing them through behavioural, chemical and biological methods have only been partially successful.

There exist wide gaps in the productivity of sugarcane within a state/ region in terms of the difference between the highest yield achieved and the average yield, or the gap between Front Line Demonstration (FLD) yield and the average yield (Table 2.2).

Table 2.2 Yield ((ton/ha)) gap analysis in sugarcane

State	Cane yield (t/ha)				Yield gaps		
	PY	FLD	DHY	SAY	FLD-SAY	DHY-SAY	PY-SAY
Maharashtra	182	101.5	102.9	76.9	24.5	25.9	80.5
Gujarat	140	88.4	88.43	72.0	16.4	16.4	51.5
Karnataka	150	96.5	110.5	85.6	10.8	24.8	53.5
Tamil Nadu	194	112.9	131.6	102.6	10.2	28.9	81.0
Andhra Pradesh	169	95.9	99.8	77.8	18.0	21.9	73.0
Uttar Pradesh	173	73.2	76.3	58.9	14.2	17.3	99.7
Bihar	97	66.0	68.5	46.0	20.0	22.5	30.9
Haryana	111	81.9	78.8	67.7	14.2	11.1	29.0
Punjab	83	71.1	74.7	63.6	7.5	11.0	11.8

Source: Sharma and Pathak (2017)

PY-Potential Yield; FLD-Front Line Demonstration, DHY-District Highest Yield, SAY-State Average Yield

The average cane yield in sub-tropical zone at 59.3 t/ha is far below the average cane yield in the tropical zone at 85 t/ha. Considering the gap between FLD and state average yield (SAY), it is obvious that it varies from 7 to 20 t/ha among sub-tropical states against that of 10 to 25 t/ha among tropical states. The difference between highest yield achieved in a cane growing district of the state and the State Average Yield (SAY) indicates, that with adoption of advancements in production technology in tropical states, cane yield can be enhanced to 16 to 29 t/ha. However such improvement is lower and ranges from 11 to 22 t/ha for the states of sub-tropical region.

Climate change has significantly impacted sugarcane production system across the country with frequent droughts, floods and diseases. Approximately 2.97 lakh ha of sugarcane area is prone to drought, affecting the crop growth during its formative phase causing 30-50 per cent reduction in yield. Floods and water logging are serious problems in eastern UP, Bihar, Odisha, Coastal Andhra Pradesh and parts of Maharashtra. Approximately 2.13 lakh ha is prone to flood/water logging in different states. Water logging affects all stages of crop growth and can reduce germination, root establishment, tillering and growth which will causing reduced yield of sugarcane and sugar recovery.

Box 2.1 Reasons for low productivity of sugarcane in different states[1]

Uttar Pradesh	• Lack of proper seed cane production and distribution system in the state. • Continuation of old varieties in sizeable area. • Summer planting of sugarcane after harvest of wheat that covers about 30-40 per cent of sugarcane area in western Uttar Pradesh. This results in crop duration of just 08 months with poor tonnage and sugar yield. • Prevalence of abiotic (water logging and water stress) and biotic stresses (diseases and insect-pests) • Imbalance use of fertilizers: excessive and late use of N fertilizers coupled with less than recommended dose of P and K • Lack of soil testing facilities • Increase in area under poplar plantation particularly in Western UP causing nutrient and water stress to sugarcane crop and facilitating build of white grub. • Low ratoon productivity: Poor productivity of ratoons and yield reduction in successive ratoons are serious problems in UP due to poor management and almost no nutrient application. This is apart from the varietal differences for ratooning potential as well as for sustaining productivity over several ratoons. • Frequent climatic aberrations during crushing period due to Western disturbances is an important reason contributing to low sugar recovery.
Maharashtra	• Lack of adequate participation of the sugar mills in the development of sugarcane. There is no cane development wing in the sugar mills and wherever such wing is existing, it is understaffed, not adequately trained and utilized mainly for harvesting programme. • The existing manpower and infrastructure with sugar mills for cane development and technology transfer is insufficient. • Sugar mills are not implementing season wise and variety wise sugarcane planting and harvesting programme in their operational areas considering their maturity period.

	• There is no adequate availability of quality seed-cane with sugar mills and the seed replacement ratio is not matching the requirement. Adequate attention in application of tissue culture technique for disease free seed multiplication is lacking or absent. • Irrigation water management practices are very inefficient. Excessive use of irrigation water deteriorates soil fertility and productivity. An efficient water management technology of drip irrigation and fertigation is not spreading comprehensively. • Lack of integrated nutrient management approach affects soil fertility, productivity and sustainability. Depletion of soil organic carbon mainly due to total reliance on inorganic fertilizers is a serious issue. There is less awareness in bio-fertilizers and soil test based balanced fertilizers application. • Excess irrigation, poor drainage and mono-cropping of sugarcane in vast area has created soil health problems like salinity and sodicity. • Inadequate attention to development and dissemination of information regarding better farm appliances/equipment for planting, inter-culture, fertilizer applicators, harvesting etc. • Laxity in ratoon crop management, which covers 40 to 45 per cent of total area under sugarcane, therefore less average cane productivity. • Problems in timely and adequate availability of quality inputs including credit • Inadequate attention to use of crop residue from sugarcane and sugar industry by- products such as press mud, sugarcane trash and distillery effluents
Tamil Nadu	• Pre-dominance of only one or two sugarcane varieties all over the state makes the sector vulnerable to stresses. • Lack of proper seed production and distribution system in sugarcane • Improper varietal balance, i.e. pre-dominance of mid-late varieties • High cost of production of sugarcane owing to high labour and input cost. • Non-availability of labour and high cost of harvesting • Insufficient irrigation facilities and frequent power cuts • Sugarcane planted on sandy loam soils which cover maximum area under sugarcane require 40 irrigations. In state major crop rotation is of paddy-groundnut, paddy – pulses & paddy-sugarcane which cause salinity & alkalinity in soil. Wide spread iron deficiency in the state. • Lack of quality seed production or seed farm concept in the state. • Poor ratoon productivity mainly due to improper crop management and prevalence of 2-3 ratoon crops after a plant crop.
Karnataka	• Pre-dominance of old sugarcane varieties in southern Karnataka and slow replacement • Lack of proper seed production and distribution system • High cost of production of sugarcane • Non-availability of labour and high cost of harvesting • Water stress • Sugarcane growing soils in the state are saline, alkaline or acidic in reaction. Soil reclamation is not attempted effectively in sugarcane- paddy growing areas. Iron deficiency is very common. At some places sandy soils are there which needs more irrigation. • Flooding/ water logging of sugarcane fields during rainy season

	• High cost of cultivation, high labour cost, labour scarcity, hampering the adoption of new improved management practices in sugarcane. • High temperature during the end of crushing season causes fast deterioration of harvested cane leading to a sharp decline in sugar recovery. • Ratoon covers 60 per cent of area in state & no proper management practices is followed to improve the yield of ratoon. • Large scale adoption of traditional sugarcane farming and lack of improved practices like wider spacing, deep ploughing and drip irrigation. • Early shoot borer, inter nodal borers, whitefly are the major insect pest in the state.
Bihar	• Many prevalent sugarcane varieties possess high fibre content in cane in association with low cane yield and low sugar recovery. • Slow replacement of old varieties. Lack of proper seed production and distribution system in sugarcane. Less area under early maturing varieties (22% approximately during 2011-12) • Large scale prevalence of early drought and late water logging conditions • Lack of sufficient irrigation facilities especially during pre-monsoon season
Gujarat	• Sugarcane – paddy crop rotation is very common in the state which leads to excessive use of water causing soil salinity. • Sugarcane varietal planning and season of planting needs to be in tandem as many growers plant Co 86032 early, but this variety actually is recommended for mid late planting. • Over irrigation by canals in sugarcane crop causes loss of nutrients from upper layer of soil. Excess moisture creates the water logging problem in soil. • Due to labour shortage farmers are burning cane to make harvesting easy (50% - 70% farmers go for cane burning at harvest) which leads to the loss of recovery from 0.5 -1 per cents. Burnt cane should be crushed within 12 hr. (which is not presently happening) and that leads to bacterial contamination & further reduction in the sugar content. • Continuous monoculture of sugarcane in the same fields leads to soil deterioration, insect-pests and diseases build up. • Less use of organic manures.

[1]Reports of working group on sugarcane productivity and sugar recovery in country. Directorate of Sugar (2013), Department of food and Public Distribution, Ministry of Consumer Affairs, Government of India.

2.4 Total Factor Productivity (TFP) Growth in Sugarcane

Total factor productivity (TFP) is a measure to quantify sustainability of any system. It measures the amount of increase in total output, which is not accounted for, by the increase in total inputs. A sustainable system would have a non-negative trend in TFP over the period of concern. The TFP index is a composite measure of productivity, which relates output to all inputs simultaneously, and the change in TFP index can be used as one measure of technological change. Based on available literature on the subject, the trends in TFP of sugarcane both at national and state levels for different time periods are summarised in the following paragraphs as well as in Fig.2.1.

2.4.1 TFP growth in sugarcane during 1971-2000

Based on analysis of the changes in output, input and TFP using micro-farm level data covering the period 1971-72 to 1999-00, the TFP growth of sugarcane grown in different states/regions of India was worked out by Kumar and Mittal (2006), revealing that both the regions (sub-tropical and tropical) were having positive TFP growth during 1971-86 period (Table 2.3). However, only two states Andhra Pradesh and Karnataka registered > 2 per cent growth in TFP during this period. Bihar, on the other hand recorded decline in TFP growth and all other major cane growing states witnessed no change. For the period 1986-2000, except for eastern states including Bihar, the annual compound growth rates of input index were higher compared to output index, resulting in negative growth rate as well as negative share of TFP in output growth across the country.

Table 2.3 Annual growth rate in input, output, TFP of sugarcane in regions of India, 1971-2000

Region	Period	Input	Output	TFP	Share of TFP in Output
East	1971-86	0	0	0	Negative
	1986-00	2.22	11.9	9.68	81.34
West	1971-86	4.74	4.46	-0.28	Negative
	1986-00	6.47	5.97	-0.5	Negative
North	1971-86	0.9	1.35	0.45	33.1
	1986-00	3.6	3.11	-0.49	Negative
South	1971-86	0.66	3.48	2.82	81.05
	1986-00	6.27	5.84	-0.43	Negative
India	1971-86	1.24	2.02	0.79	38.92
	1986-00	4.36	4.26	-0.1	Negative

Source: DFI Committee Estimates
East: Includes states of Bihar, Odisha, Assam and West Bengal
West: Includes states of Rajasthan, Madhya Pradesh, Maharashtra and Gujarat
North: Includes states of Punjab, Haryana, Uttar Pradesh and Himachal Pradesh
South: Includes states of Andhra Pradesh, Tamil Nadu, Karnataka and Kerala

In case of important cane growing states, except for Bihar, none else experienced growth in TFP during the period. Growth in TFP in Bihar may be attributed to low growth in input use and costs. Uttar Pradesh witnessed decline in TFP growth in sugarcane during the period. All other major cane growing states viz., Maharashtra, Karnataka, TN, AP, Haryana did not observe any change in TFP growth.

Further analysis with respect to the distribution of area according to TFP growth in India during 1986-2000 exhibited that 90.9 per cent of sugarcane area was under stagnant TFP; 5.4 per cent with less than 1 per cent TFP growth; and only 3.7 per cent area had >1 per cent annual TFP growth in the country. The trend indicates that no significant technological gains occurred in sugarcane during 1986-2000 period and the gains occurred during early years of Green Revolution were exhausted by then.

Hence, it may be concluded that sugarcane remained at a disadvantage with respect to TFP growth in comparison to major competing crops like rice, wheat, cotton and groundnut during the period 1986-2000. It also reveals that technological gains have not benefited sugarcane during this period (Table 2.4).

Table 2.4 Trends in Total Factor Productivity (TFP) growth in sugarcane and competing crops in different states (1971-2000)

Change in TFP growth	Period 1971-86			Period 1986-2000		
	Sugarcane	Rice	Wheat	Sugarcane	Rice	Wheat
Less than 1%	-	-	-	-	WB	-
1-2% increase	-	AP, Assam	Punjab, Rajasthan	-	AP, Bihar, TN	Haryana, Punjab
Greater than 2%	AP and Karnataka	Haryana, Punjab, TN, UP	Haryana, UP	Bihar	-	-
No change	Haryana, Maharashtra TN, and UP	Bihar, Karnataka MP, WB	MP, WB	AP, Haryana, Karnataka, Maharashtra, TN	Karnataka , UP,	Bihar, UP
Decrease	Bihar	-	Bihar	U.P.	Haryana, Punjab	

Source: DFI Committee Estimates

In another study, the total factor productivity (TFP) and its share in output growth, and returns to public investments on research in agriculture in India for the period 1975-2005 were estimated (Chand *et al*. 2012).

The estimates of TFP have shown negative TFP growth across different states for sugarcane crop. These wide variations in TFP growth further indicate that technological gains have not been experienced in sugarcane in many states (Table 2.5).

Table 2.5 Annual growth rate (%) in factor productivity, productivity share in output and real cost of production of sugarcane (1975-2005)

Crop	Total factor productivity growth	Productivity share in output growth	Growth in real cost of production	States with negative TFP growth
Sugarcane	-0.41	(-)	-0.36	Bihar, Karnataka, Haryana, Andhra Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh

Source: DFI Committee Estimates

2.4.2 Sugarcane TFP growth in Maharashtra (2000-2009)

A study carried out at VNMKV, Parbhani in Maharashtra measured total factor productivity of sugarcane crop in Marathwada region of Maharashtra for the period 1999-00 to 2008-09 by using farm-level data on yield, level of inputs use and their prices collected from the cost of cultivation scheme (Sanap, 2015). Total factor productivity growth in the state was found negative at -1.62 per cent. The share of TFP growth in total output growth was 69.06 per cent (Table 2.6).

Table 2.6 Output, input and TFP indices growth rates of sugarcane in Marathwada

Time period	Output Index	Input Index	TFP	TFP Share in output (%)
Period 1999-00 to 2008-09	-2.35	-0.73	-1.62	69.06

Source: DFI Committee Estimates

2.4.3 Sugarcane TFP growth in Karnataka (1980-2009)

In Karnataka, input and output indices showed negative growth yet positive TFP growth during 1980s. However, high input growth as compared to output growth resulted in negative TFP growth of 5.27 per cent in 1990-91 to 1999-00. During 2000s growth in output and TFP was 0.97 and 1.51 per cent, respectively. Overall, TFP of sugarcane registered positive growth of only 0.73 per cent indicating that sugarcane production is input based with technology playing some role in it (Table 2.7).

Table 2.7 Annual growth in input, output and TFP indices of sugarcane in Karnataka

Sugarcane	Input	Output	TFP	Share of TFP in Output growth (%)
1980-81 to 1989-90	-7.03	-0.34	6.69	Negative
1990-91 to 1999-00	6.04	0.78	-5.27	Negative
2000-01 to 2007-08	-0.55	0.97	1.51	156.45
1980-81 to 2007-08	-0.27	0.46	0.73	157.93

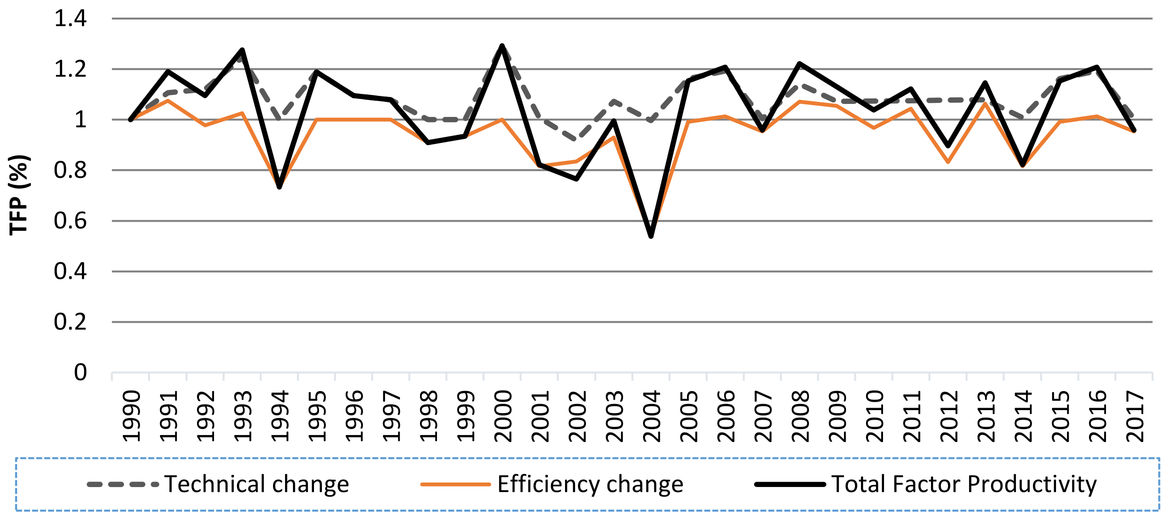
Source: DFI Committee Estimates

2.4.4 Sugarcane TFP growth in India during 1990-91 to 2016-17

The farm level data on sugarcane yield and the use of inputs and their prices from 1990-91 to 2016-17 collected under the "Comprehensive scheme for the study of cost of cultivation of principal crops," Directorate of Economics and Statistics (DES), Government of India (GOI), were used in the analysis of TFP. The output prices were collected from the Co-operative Sugar Journal. The missing year data on inputs and their prices were collected using interpolations based on the trends of the available data. The time-series data on sugarcane area, yield, production, irrigated area and coverage under high-yielding varieties (HYV) was collected from the various published reports of the DES (GOI). Cane production across the country is diverse and input use depends on the physical environment, which includes factors such as soil quality and climate.

Sugarcane productivity is cyclical in India. The post-Green Revolution phase is characterized by high input-use and decelerating total factor productivity growth. Sugarcane productivity attained during the 1980s could not be sustained during the 1990s and early 21st century. However, adoption of improved sugarcane varieties giving high sugar recovery in tropical as well as sub-tropical India and efficient crop management techniques have accelerated the productivity growth since 2005-06 and is still sustaining at the National level. Total factor productivity (TFP) at the all India level recorded steady growth over the time since 1990 with annual variation ranging from 0.5 to 1.3 per cent. Large influence of weather, particularly of rainfall on crop performance is evident from the data with conspicuous dips in TFP growth rates for the years experiencing drought (2002-03, 2003-04 and 2013-14).

Figure 2.1 Total Factor Productivity in sugarcane in India



Source: DFI Committee Estimates

The productivity measures are divided into two sources of growth, namely, input use efficiency change and technological change (varieties and crop management technologies). The results indicate phenomenal growth in the TFP brought about by technological change rather than input use efficiency. In both the periods, productivity was sustained through technological progress brought about by the introduction of new & improved varieties, and better crop management practice like trench planting and wide-spread use of trash as mulch in sugarcane fields. Data reveals that the variation in TFP trend is almost entirely due to the variation in output, as total input use sustained smoothly over time. The rate of growth in TFP during the period of 1990-2017 was 1.03 percent per annum (Table 2.8).

Table 2.8 Total Factor Productivity in sugarcane

	EFFCH	TECH	TFP
1991 – 2000	0.98	1.04	1.01
2001-2010	0.92	1.03	0.97
2010-2017	1.04	1.16	1.10
1991-2017	0.98	1.08	1.03

Source: DFI Committee Estimates

EFFCH- input use efficiency change (seed, fertiliser, labour and etc.); TECH- technical/technological change and (varieties and improved technologies); TFP- Total factor productivity

It is thus clear, that from a growth accounting perspective, sugarcane production in India in the post-liberalization period, achieved positive total factor productivity growth leading to substantial expansion of sugar sector all over the country. Economic viability of the sector at the farm and mill levels is evident from the trend. Fluctuations in TFP growth in different states for particular durations may be ascribed to local weather, state government policies and input supply situations. Given this, the factors that can further enhance TFP of sugarcane in India are: science led technological support to minimize the influence of weather; farmer friendly government policies including marketing of sugarcane and sugar; and improved input and credit availability.

2.5 Cost of sugarcane production and income to farmers

It would help to examine the current level of farmers' income and opportunities available in sugarcane farming to increase farm profits, so as to frame appropriate action plan 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. The 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 at state and all-India levels. 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 and Fertilizers Association of India (FAI). Based on CIPI thus constructed, the Commission has projected CoP for 2017-18 sugar season and the same is given in Table 2.9.

Table 2.9 Calculation of farmers' income based on CACP data (2017 -18)

State	Cost ₹/quintal	SAP for 2017-18/quintal	Average yield (Q/ha)	Income (₹/quintal)	Farmers income (₹/ha)
Andhra Pradesh	213	260.0	776	47	36,472
Haryana	278	305.0	732	27	19,764
Karnataka	172	261.5	880	90	78,760
Maharashtra	183	273.3	797	90	71,969
Tamil Nadu	212	285.0	1041	87	75,993
Uttar Pradesh	234	315.0	723	81	58,563
Uttarakhand	222	315.0	594	93	55,242

Source: DFI Committee Estimates Based on data compiled from Commission for Agricultural Costs and Prices (CACP)

It can be inferred that the cost of cultivation ranges from Rs.172 per quintal in Karnataka (lowest) to Rs. 278 per quintal in Haryana which is the highest. The challenge here is identification of the best way to address this wide variation in the cost of cultivation and increase the profitability, particularly in states like Tamil Nadu, where the average yield of the state has already crossed 100 t/ha. The strategy needs to address issues like reducing the cost of cultivation on one hand and realising the potential yield under farmers' condition, on the other. Simultaneously, there is need to explore opportunities for additional income generation potential of the crop in terms of fuel, fodder and value addition.

Cost of sugarcane production, generation of revenue and the income earned by a farmer at the all India level was calculated using the base data on the projection and estimates. The information is presented below (Table 2.10).

Table 2.10 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)/ (₹/ha)	Fair and remunerative price (₹/tonne)	Farmers revenue (₹/ha)	Income earned by farmers (₹/ha)
All India	71.0	2270	161170	2550	181050	19,880

Source: DFI Committee Estimates Based on data compiled from Commission for Agricultural Costs and Prices

A sugarcane farmer in India spends on an average Rs. 1.61 lakh per ha of land and earns a meagre amount of Rs. 19,880/ha as net profit. This is unfair and focussed attention is urgently needed to double this net profit within a stipulated time frame. Two important reasons for low profit margin are high cost of production and stagnated crop yield. The feasibility of doubling the net profit from Rs.19,880/ha by 2022 therefore needs a holistic way to integrate precise resources for synergistic effect. In order to understand the potential profit opportunity available for the sugarcane farmers, a critical analysis of inter-crop price parity is discussed hereunder.

2.5.1 Inter-crop price parity

To appraise inter-crop price parity, the CACP computes per hectare returns of different crops that substitute 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, it is seen, that relative returns for sugarcane in reference to other three crops is higher (Annexure A). 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 in sugarcane during 2012-13 to 2014-15 at all India level compared with paddy (12 per cent), cotton (15 per cent) and wheat (27 per cent). It is however important to bear in mind, 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 are 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, disparities are observed in incomes among sugarcane farmers in the country (Annexure A). Lowest farmers' income has been recorded in Uttar Pradesh, Uttarakhand and Andhra Pradesh and maximum in Tamil Nadu, Maharashtra and Karnataka. Whereas, of the total cane area cultivated in the country, 40 per cent area is in UP state, which realised lowest income. Considering all these facts and figures, three possible means/strategies are discussed keeping in mind both 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 presented in Table 2.11.

Table 2.11 Approaches for 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 machineries 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 stresses.	Effective disease management, use of IPM practices, periodical weather advisory and crop advisory during drought 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

2.6 Issues with Price Recovery from Sugar Mills

The first important feature of the Indian sugar policy is the price of sugarcane. It has to be sufficiently attractive to motivate the farmers to grow cane and ensure that the sugar mills will have sufficient cane to crush. The process of establishing a price for sugarcane is organized through a dual price scheme - the Central Government notifying Fair and Remunerative Price (FRP), and the State Government recommending State Advised Price (SAP). Citing differences in cost of production, productivity levels and also as a result of demand from farmers' groups, some states declare SAP over and above the FRP. The price of sugar, the main product, and the revenue from by products like molasses and bagasse are many a times not suitably factored in by the states while doing so.

Various Committees like Tuteja committee (2004), Thorat committee (2009) and Nanda Kumar Committee (2010) have been appointed by the Government from time to time for rationalize sugarcane pricing formula and bridge the mismatch between the prices of sugar and sugarcane, and to also balance the needs of farmers and sugar mills. In 2013, Rangarajan Committee appointed by the Government of India with the objective of reforming Indian sugar policy, recommended to establish a link between the sugarcane price and the price of sugar on the domestic market. The lack of a link has been a major issue within the system, which is responsible for exacerbated natural cyclicality and regularity of imbalance between supply and demand in the Indian sugar market.

Besides this, another challenge is low price and delayed payment to the famers which are pushing sugarcane growers into crisis. It has been observed, that while payment for the raw material in other industries is made in advance of its processing, in sugar industry, the price is not paid in advance. It is paid after 14 days when the processed product (sugar) has been sold. Not only this, the payment of cane price is usually delayed by several months and sometimes years (as reported), disincentivising the cane growers, particularly the younger generation.

Lack of transparency in the age old manual marketing transactions also influence farm-factory relations. The integration of farmers with sugar mills could be done through price and non-price factors or by developing effective tools to improve the farm-factory relations which as of now leave much to be desired. In addition, sugar mills need policy support for sugar exports to negotiate price slacks on rising from domestic surplus and a market intervention mechanism by creating a buffer stock.

2.7 Strategy for Improving Cane yield and Sugar Recovery

2.7.1 Increasing sugarcane yield

The yield-gap analysis reveals substantial gaps between the potential and realized yield and between the highest district yield of a state and actual state average yield of sugarcane. Current average yield in the country is hardly 21 per cent of the technical and economic yield potential of the sugarcane crop (339.42 t/ha). The yield gap is as high as 80 t/ha in the tropical and 65 t/ha in sub-tropical regions of the country (Annexure C).

CACP recommends a Fair and Remunerative Price (FRP) for sugarcane to be Rs. 255/q for 2017-18 sugar season at 9.5 per cent sugar recovery level. With every additional increase in recovery by 0.1 percentage point, the FRP will increase by Rs. 2.68/q (Annexure B). The average sugar recovery was 10.62 per cent during 2015-16. Disparities in yield and sugar recovery levels significantly affect income of the sugarcane farmers in different sugarcane growing states of the country (Annexure C). So, the approach to double the income of sugarcane farmers must aim at increasing yield and sugar recovery, with no further increase in the cost of cultivation. The warranted growth of yield and sugar recovery to double the income of the farmers by 2022 is detailed in the Table 2.12.

Table 2.12 Current sugarcane yield and the yield warranted by 2022

Unit	Baseline 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 by 2022 by increased yield (Rs/ha)
All India	71.0	78.8	19,880	39,760

Source: DFI Committee

Assuming the same value (demand-supply status remains static), in order to account for expected inflation, the yield must grow beyond 78.8 t/ha to at least 80 t/ha.

2.7.2 Sugar recovery

Every 0.1 per cent increase in sugar recovery is equivalent to one unit yield improvement in terms of revenue and cane yield. Increasing yield coupled with sugar recovery is a pragmatic approach to double the farmers' income by 2022. The baseline sugar recovery, expected sugar recovery and yield equivalent are given here (Table 2.13).

Table 2.13 Current sugar recovery, yield equivalent and expected income by 2022

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

Source: DFI Committee

2.7.3 Combination of yield and sugar recovery

Increasing yield by over 10 per cent of the existing yield within a span of five years will be a daunting task due to various biotic and abiotic stresses influencing sugarcane production system. Nevertheless, increasing the cane yield by 50 per cent of the targeted yield increase works out to 75 t/ha and this in combination with 0.4 unit improvement in sugar recovery is possible with the adoption of suitable varieties along with improved production cum protection technologies recommended by research institutions.

This strategy will help in doubling the net income from sugarcane cultivation with this, both short & medium terms plans of action are discussed in the following sub-sections.

2.7.4 Strategies for yield and recovery improvement

The status of sugarcane over the last 2-3 decades in the country has remained static with respect to production, productivity and sugar recovery. The concern is, that yield has remained unchanged for the last 20 years. It appears that new varieties and production technologies, though developed have not reached the field or have not been able to prove themselves in the major cane growing states. The potential is not in dispute, considering that many progressive farmers have been able to realise yield levels of 290 t/ha. Since scope for cane yield improvement in sub-tropical India is greater and wider the technological recommendations to increase the yield and recovery for sub-tropical (Table 2.14) and tropical states are given here under (Table 2.15).

Table 2.14 Recommended technological interventions for increasing yield and recovery in sub-tropical states

Technological	Recommended Technologies	Problems addressed and Expected Outcome
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, Co 09022, CoLk 94184, CoLk 09204	➢ High yielding and high sugar recovery variety. ➢ Expected increase in yield by 15t/ha over that of existing varieties. ➢ Improvement of sugar recovery by more than 1 per cent. ➢ Ideal for sub –tropical climatic conditions.
Planting system	Bud chip/ cane node settling transplanting technique (STT) Trench planting	➢ 12,500-25000 settlings per hectare are required in case of bud chip planting against 40000 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 (up to 25%) over conventional flat method of planting. ➢ Saves water because trenches are irrigated and not the whole field. ➢ Trench system of planting in saline soils and salt water irrigated areas recorded improved yields of around 15 per cent.
Nutrient Management	Split application of N and K fertilizer; two or three splits, band application covering with soil and irrigation	Sugarcane, a long duration crop having huge biomass production potential demands large amounts of water, nutrients and sunlight. It is always better to apply manures and fertilizers based on soil test recommendations.
	Need based application of nutrients like S, Fe and Zn	Crop yields are drastically reduced when the nutrient concentration fall below the critical limits.
Water management	Drip irrigation	Adoption of surface and sub-surface drip results in 40 per cent reduced water application with 20 per cent increase in yield. Supply of nutrients through drip (fertigation) enhances the nutrient use efficiency that leads to saving of 20 per cent of the recommended nitrogen dose.
Ratoon management	Multi-ratooning, bio-manuring and mechanization	➢ Ratooning is more remunerative than plant crop. ➢ Taking more number of ratoons enhances the overall income and profitability. ➢ Regular bio-manure addition improves the soil health that supports more number of ratoons in a plant-ratoon system. ➢ Mechanization of ratoon initiation, off-barring, nutrient application and inter-culture improves ratoon yield by 25 per cent.

Source: DFI Committee

2.7.5 Adoption of new and improved variety

Co 0238 for higher cane yield and sugar recovery in sub-tropical India:

Co 0238 was evaluated at seven locations under the AICRP (Sugarcane) during 2006-08 in North West Zone (NWZ). It ranked number one in cane yield (81 tonnes/ha) in comparison to CoJ 64, a well-known early maturing variety of North West Zone (NWZ). The *jaggery* from

Co 0238 is of fine 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, it has crossed the boundaries of the zone to reach Eastern UP, Bihar, Madhya Pradesh and Odisha. During 2016-17, about 34 per cent of the total cane area of 26,26,030 ha in North India was covered under 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 been gaining higher yields from this variety. Prior to release of Co 0238, the cane varieties cultivated in northern India were all 'medium-thin', with an average stick diameter of 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 yield of 80 tonnes / hectare for Co 0238 works out to be 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 per cent due to Co 0238. So, farmers could earn an additional income varying from Rs.47,250 to Rs.63,000 per hectare. **Adoption of Co 0238 variety would double the farmers' income by 2022 with proper package of practices prescribed during varietal release.**

Co 86032 (Nayana) - a popular sugarcane variety for Tropical India

Sugarcane variety Co 86032, released for commercial cultivation in the Peninsular Zone in 2000, is the most popular sugarcane variety in the tropical India. It 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 Odisha.

There was appreciable increase in sugar production as well as sugar recovery (increasing from 0.5 to 1.0 unit) in tropical India. It contributed to an average yield improvement of over 10 t/ha. However, in recent past, yield and sugar recovery have reduced due to varietal degeneration. Disease free healthy seed material is the immediate need for reviving yield and sugar recovery in tropical India.

Under Indian scenario, mosaic and YLD are the serious viral diseases. These occur in all sugarcane growing regions and varieties under cultivation, exhibiting varying intensities of affliction. Due to vegetative propagation, these viral pathogens along with other pathogens causing ratoon stunting disease (RSD) and grassy shoot disease (GSD) gradually increase 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 is referred to as **'varietal degeneration'**. Due to this, longevity of many elite sugarcane varieties has seen reduction 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 per cent and juice yield by 34 per cent. Tissue culture derived planting materials (virus free setts) always maintain a better crop stand compared to conventional planting materials.

The recommended technologies for increasing yield and recovery in tropical states are presented in Table 2.15.

Table 2.15 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, 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 of Tamil Nadu, Karnataka, Maharashtra and Gujarat.
Planting system	Wide row planting	➢ Facilitates better spacing ➢ Conducive for intercropping ➢ Ideal for mechanization 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 ₹ 15000 – ₹ 20000 of cost of cultivation.

Source: DFI Committee

2.8 Strategies for Reducing Cost of Cultivation

High cost of cultivation of sugarcane has resulted in reduced profits for farmers and in a few districts it has led to substitution by other remunerative crops like banana, peppermint and aromatic rice. Cultivation of sugarcane being labour and input intensive has experienced a northward trend in its cost of production mainly due to increase in cost of labour and inputs. Hence, the need for farm mechanisation and simultaneously, it is important to develop varieties and technologies that are machine-friendly. A number of farmer-friendly equipments have been designed and developed by ICAR-Indian Institute of Sugarcane Research (IISR) that can be promoted for large scale adoption.

Modern sugarcane machinery and labour saving devices introduced on large scale to reduce dependency on labour and complete the farm operations in time has proved its superiority, over manual operations. It helps in reducing cost of production and achieving efficient utilization of resources with better work output. These include sugarcane planter, ratoon management device, mechanical weeder and harvester. Cost saving measures for different operations of sugarcane cultivation are given in Annexures D, E, and F.

The number of irrigations applied in sugarcane crop vary between the states and regions within the state. It depends upon rainfall pattern/climatic conditions, soil types and source of irrigation water. On an average, the number of irrigations in tropical India is 35–40, and in sub-tropical region it is 8-10. The cost of irrigation can be effectively saved through drip irrigation. The cost saves the labour for water application that is about one-tenth of that in furrow method of irrigation (Annexure E). In addition, it helps farmers to apply fertilisers 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.

Area under mechanical harvesting needs to be increased to at least 50 per cent by 2021–2022 sugar season to reduce the cost of cultivation.

2.8.1 Ratoon management

Ratooning is a regular practice in sugarcane cultivation, and is more profitable as compared to plant crop as investment in land preparation, planting operation and seed is not required. In India, about 60 per cent of sugarcane area is under ratoon crop annually. However, despite the advantages like early and synchronous tillering and fast initial growth allowing longer duration for cane elongation compared to plant crop, average productivity of ratoon crop in India is around 45 t/ha, much below the average plant crop productivity of 70 t/ha. Further, not only does the ratoon mature earlier than the plant crop, but also its sugar content remains higher at any given stage compared to the plant crop of similar age.

Any strategy to enhance the number of ratoon crops in plant –ratoon system and adoption of improved techniques for high ratoon yield is useful in cane productivity and production. This has the potential to raise the farmers' income. This requires some policy incentive. Technological options for raising ratoon yield include timely initiation, cane harvesting flush to the ground, followed by off-barring to get rid of suberized roots, supply of nutrients close to the root zone and effective management of weeds that perpetuate over the years. Use of machines like ratoon management device (RMD), ratoon promoter and ratoon manager developed by research institutions may be useful. Bio-manuring for sustaining the soil fertility and overall health along with mulching of trash from previous plant crop adds to ratoon yield positively. RMD performs all the initial operations in one pass and effectively saves labour cost incurred on different operations. 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 per cent lesser than manual practices followed for ratooning of sugarcane.

2.9 Enhancing Input Use Efficiency for Productivity Improvement

2.9.1 Saving on seed cost

In sugarcane cultivation, seed-cane is the costliest of its inputs. However it is seldom factored in, as farmers mostly use their own seed from standing cane crop. Depending on method of planting, variety and agro-climatic conditions the seed rate varies from 4-8 t/ha. Conventional planting of sugarcane with three-bud setts requires about 6.0 t/ha planting material. There is scope for utilizing bud-chips and single-bud settlings as seed material. Only 12,500 settings per hectare are required in case of bud chip planting. Using bud chips and raising settings in a nursery can save 80 per cent of the seed material compared to three budded setts.

2.9.2 Soil test based plant nutrition management

Management of nutrients in crop in general and in high nutrient requiring crops like sugarcane in particular is very important for targeting the income enhancement in any of the agro-ecosystems. Not only is the cost factor addressed through this, but also soil health and bio-diversity issues that influence factor productivity get corrected. Adopting fertilizer prescription based on soil test minimizes the risk of uneconomical use of fertilizers.

Alternates to chemical fertilizers are also beneficial in soil health management. Application of green manures, farm wastes and factory-wastes along with bio-fertilizers is found to be useful in supplementing in-organic fertilizers and in maintaining cane productivity, as well as soil fertility. Soil test based integrated plant nutrient system is always advised. Blanket recommendation may be applied only when other means of assessing exact dosage is not available. Advantages of including bio-manures in the nutrient management schedule for sugarcane in terms of higher B: C ratio is evident from the Table 2.16.

Table 2.16 Cane yield and benefit: cost (B: C) ratio as influenced by different treatments

Treatment	Cane yield (t/ha)					B:C ratio				
	P	R_1	R_2	R_3	R_4	P	R_1	R_2	R_3	R_4
NPK (150:60:60 Kg/ha)	76.1	78.2	71.7	66.0	64.3	1.2	2.1	1.8	1.9	1.7
Farmyard manure (10 t/ha)	70.9	70.7	68.3	63.3	63.0	1.2	2.1	1.9	1.9	1.8
Biogas slurry (10 t/ha)	71.9	70.4	66.6	63.5	63.2	1.2	2.1	1.8	1.9	1.8
SPMC (10 t/ha)	75.3	77.9	72.5	67.4	67.3	1.2	2.3	1.9	2.0	1.9

Source: Srivastava et al., (2012).

P, Plant crop; R1, Ratoon I; R2, Ratoon II; R3, Ratoon III; R4, Ratoon IV; SPMC, Sulphitation press mud cake (a sugar factory by product used as bio-manure)

2.9.3 Adoption of location-specific recommended 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. ICAR- Sugarcane Breeding Institute is engaged in varietal improvement programme. At present 23 research centers located in almost all major sugarcane growing regions of the country take part in sugarcane breeding programmes and identifying new clones for testing in different locations of five agro-climatic zones under the AICRP.

2.9.4 Wide row planting & inter-cropping short duration pulses and vegetables

Harvesting of sugarcane in India is largely done manually requiring more than 100 man-days. Labour is not only not available in time, but is also a drudgery. 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 also facilitate inter-cropping during initial stages of sugarcane growth, which will generate additional income. When sugarcane is grown adopting closer row spacing of about 90 cm, it takes about three months for closing of the canopy while it takes longer time under wide row spacing. The availability of adequate space and sunlight for a longer duration of time under wide rows facilitates growing of inter-crops without any adverse effect on sugarcane. The yield and additional returns from inter-crops will also be more compared to inter-crops grown in closed spaced sugarcane.

Growing of legumes as inter-crops can also result in improvement in soil fertility. Generally, short duration crops which can be harvested before the final earthing up are recommended. Green gram, black gram, soybean, sun hemp, *Sesbania*, potato, garlic, onion and pulses could be raised as inter-crops in sugarcane. The expected net income from inter-crop is in the range of Rs. 10,000 to 40,000 per acre (Table 2.17). Market led vegetable cultivation as inter-crop can be highly remunerative to the sugarcane farmers. With vegetable inter-cropping, farmers would get an additional income supplementing the total income from the farm.

Table 2.17 Economic evaluation of sugarcane based intercropping systems in sub-tropics

Intercropping system	Sugarcane yield (t/ha)	Intercrop yield (t/ha)	CEY* (t/ha)	Net Returns (₹/ha)	B: C ratio
Autumn Sugarcane					
Sugarcane sole	85.2	-	85.2	50199	1.63
Sugarcane + rajmash	86.8	1.94	132.8	89884	2.54
Sugarcane + lentil	76.5	1.16	99.0	59629	1.73
Sugarcane + maize (Green cobs)	78.6	82412**	125.9	83815	2.34
Sugarcane + potato	90.6	28.9	179.4	106736	1.67
Sugarcane + cabbage	103.00	3.47	166.10	98560	2.52
Sugarcane + onion	104.00	8.69	121.00	69462	2.79
Spring Sugarcane					
Sugarcane sole	77.3	-	77.3	42696	1.38
Sugarcane + cowpea (Green pods)	75.2	2.90	90.4	51261	1.48
Sugarcane +greengram	76.6	0.57	91.6	52765	1.54
Winter Initiated Ratoon					
Sugarcane ratoon sole	73.2	-	73.2	42440	1.40
Sugarcane ratoon + berseem	79.4	56.8	109.3	73542	2.43
Sugarcane ratoon + shaftal	77.9	54.7	106.7	71072	2.35
Sugarcane ratoon + Lucerne	72.6	41.2	94.3	59292	1.96

Source: DFI Committee

*Sugarcane equivalent yield, ** No. of green cobs

2.9.5 Irrigation management

Sugarcane is cultivated in India under widely varying conditions of soil types, rainfall patterns, temperature regimes and water availability. Water requirement of sugarcane varies from 1,200 to 3,600 mm depending on yield level, crop duration and climatic conditions. Water requirement varies from 1,200-1,800 mm in the subtropical zone, while it is 1,600-3,600 mm in tropical belt. Sugarcane performs well when soil moisture is close to field capacity. It has been found that, for sugarcane, irrigation is to be given at 50 per cent depletion level of available soil moisture during the vegetative phase (from planting to 270 days stage) and at 75 per cent depletion level 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 economize water use in sugarcane (Table 2.18). There are two types of drip irrigation systems, namely, 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.

Table 2.18 Effect of irrigation methods on yield and water use efficiency at Lucknow

Irrigation method	Irrigation water applied (ha-cm)	Sugarcane crop performance	
		Irrigation water use efficiency (Kg/ha-cm)	Sugarcane yield (t/ha)
I1= Sub Surface Drip at 75% PE	40.2	1994.61	80.18
I2 = Sub Surface Drip at 100% PE	53.6	1575.68	84.46
I3 = Sub Surface Drip at 125% PE	67.0	1363.54	91.36
I4=Farmers practice surface irrigation	88.0	704.23	61.97

Source: DFI Committee

2.9.6 Water conservation technologies

Dried sugarcane leaves from previous crop (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 that helps in improving germination and better tiller survival. In a multi-location trial in Tamil Nadu, 36 per cent higher germination was observed under trash mulching compared to control when sugarcane was planted during hot weather period. This ultimately led to 20 per cent higher stalk population and 10 per cent 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 3 t/ha immediately after ratooning results in conservation of soil moisture resulting in better development of roots and increased cane yields in a ratoon crop.

Table 2.19 Recommended technological interventions for enhancing input use efficiency

Technological	Recommended Technologies	Problems addressed and Expected Outcome
Land preparation	Laser leveller	➢ Traditional methods of levelling are cumbersome, time consuming and with 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 per cent 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 per cent. 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, sun hemp, *dhaincha*, 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 per cent saving water and 25 per cent 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 economic yield loss if 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.

Technological	Recommended Technologies	Problems addressed and Expected Outcome
		➢ Timely intercultural operations ➢ Saves considerable amount of labour ➢ Reduces cost of cultivation ➢ Improvement in cane yield and sugar recovery

Source: DFI Committee

2.10 Region/ State-wise Approach to Doubling Farmers' Income

2.10.1 Plan of action for tropical India

Tropical states produce higher cane yield and better sugar recovery, thanks to favourable climatic factors and socio-economic status of cane farmers. Maharashtra, Karnataka and Tamil Nadu are leading sugarcane producers along with Gujarat and Andhra Pradesh. While Tamil Nadu ranks first in yield, Karnataka and Maharashtra rank second and third respectively in the country. Average level of productivity and net income are 80t/ha and Rs.70, 000/ha respectively. To double income of the farmers, average yield has to be increased to 80-100 t/ha with other conditions remaining same. This is a daunting task, but, it is not beyond the achievable. Yield and sugar recovery improvement could be possible by focussing on the following:

i) Adaptation of tissue culture derived seeds/setts of improved varieties
ii) Mechanisation of farm operations including harvesting
iii) Deployment of micro-irrigation along with fertigation
iv) Ratoon management

2.10.2 Plan of action for sub-tropical India

Stagnant cane yield and low sugar recovery have come to seriously affect cane cultivation in sub-tropical India. Technological intervention is needed to improve both yields and incomes. Some of the proven varieties and technologies developed exclusively to suit sub-tropical India are explained in the following paragraph.

2.10.2.1 Adoption of high yielding and better sugar recovery varieties

With 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 AICRP (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. 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 the varieties in the recent past, Co 0238 (Karan 4) is a high yielding and high sugar content variety, and was evolved at the Sugarcane Breeding Institute, Regional Centre, Karnal. An early maturing variety for commercial cultivation in North-West Zone (NWZ) comprising the 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 and enhance farmers' income in sub-tropical India.

Trench method of sugarcane planting produces significantly higher cane yield. Trenches are made with the help of sugarcane trench planter machine or trenchers. This method also saves water, because only trenches are irrigated and not the 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. The adoption of trench method along with popular varieties is recommended to increase farmers' income in the region.

2.10.3 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 lower 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 per cent 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.

2.10.4 Drip irrigation and Fertigation

Production of sugarcane depends on use and combination of different inputs such as labour, land, capital, management practices and various other factors. The variations in use and combination of different factors of production affect the sugarcane yield. Furthermore, there is a broad gap between the yields of farmer's field and experimental stations indicating sub-optimal use of inputs.

It has been estimated that, on an average sugarcane cultivation in the country uses about 20,000 kilo litres of water per hectare. In India sugarcane is an irrigated crop; and from 1980 to 2006 sugarcane coverage under irrigation increased from 80 per cent to 93 per cent of the total sugarcane-cultivated area. Sugar-producing regions utilise more than 80 per cent groundwater irrigation through deep-well pumping. The Inter-Parliamentary Panel on Climate Change (IPCC) 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 21st century.

Rising temperatures associated with climate change will also affect water resources by decreasing snow cover and accelerating the rate of snow melt. Under this 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, yielding additional stress on water availability for irrigation. This will call for adopting suitable technology to negotiate expected water stress. 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 to achieve higher water use efficiency; trash mulching to check evapo-transpiration loss of water; and universal adoption of micro-irrigation system.

Nutritional efficiency is the ability that the cultivar possesses to incorporate and use the nutrient in the production of economic yield. Sugarcane cultivars differ in absorption and use of nutrients. It would help to select efficient cultivars for efficient 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. Just about 10 to 20 per cent of applied phosphorus (P) is utilized, which is much lesser than in the case 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 its usage by the crop. In case of sugarcane, the entire quantity of phosphorus is applied as basal dose. Potassium is usually applied in splits along with nitrogen as top dressing to improve uptake of nutrients and reduce the loss.

2.10.5 Diversification

Cane cultivation can be made more profitable by adopting practices that support efficient inter-cropping. Pulses, oilseeds & vegetables can be inter-cropped by taking up autumn planting of sugarcane. Dairy is another supplementary activity that can be promoted as part of cane cultivation.

2.11 Cane Arrears of Farmers – An Unresolved Issue

Farmers have generally had issues in the matter of receiving timely payments on the delivery of their sugarcane to the sugar mills. The following table highlights this issue.

Table 2.20 Cane price arrears, sugar season 2011-12 to 2017-18

(Figure in crore Rs.)

Season	Position as on	Total price payable	Total price paid	Arrears	% of arrears on price payable
2016-17	30/09/2017	57,205.83	55,204.66	2,001.17	3.50
2015-16	30/09/2016	60,282.38	56,992.92	3,289.46	5.46
2014-15	30/09/2015	65,934.39	57,880.17	8,054.22	12.22
2013-14	30/09/2014	58,130.21	52.173.04	5,957.20	10.25
2012-13	30/09/2013	60,008.57	56,807.64	3,200.93	5.33
2011-12	30/09/2012	51,917.00	50,949.67	967.33	1.86

Source: NIC-FCA INFOSYS Division

Some of the reasons include: fluctuations in market price for sugar from year to year; while the input cost is fixed by the government, the cost of output is left to the market forces; and inefficiency of sugar production at mill level. The market is subject to excess over demand. For example, the sugar production in the country stood at 320 lakh MT, as against the demand of 250 lakh MT.

2.11.1 Cane price fixation and associated issues

Sugarcane price fixation mechanism which is an important ingredient of Indian Sugar Policy has been a debatable issue for long. Notwithstanding the recommendations of several committees constituted for the purpose, the issue still remains unresolved with both mills and farmers aspiring for sugarcane price fixation as per their convenience. In India, minimum price, known as Fair & Remunerative Price (FRP) payable for sugarcane is announced by the Central Government based on the recommendations of CACP (Commission of Agricultural Costs and Prices) at the beginning of each season. However, under the provisions of various State Sugarcane Control Order(s), some of the State Governments also fix their own State Advised Prices (SAP) over and above FRP. While fixing SAP, over and above the FRP, due considerations with respect to cost of production of sugarcane and revenue earnings by the millers are not considered rationally. Under the regime of SAP, the payment is made on the basis of quantity of the sugarcane supplied. Hence, farmers do not pay desired attention towards improving quality of the sugarcane.

Various committees were appointed by the Government to rationalize sugarcane pricing formula and bridge the mismatch between sugarcane and sugar prices, with a view to imparting sustainability to sugar industry. These include Mahajan Committee (1998), Tuteja Committee (2004), Thorat Committee (2009) and Nand Kumar Committee (2010). Further, Dr. Rangarajan Committee in 2013 recommended that it would be fair to share the revenue pot of value created in the sugarcane value chain between the farmers and millers in the ratio of their relative cost. It suggested, that this value sharing ratio should apply not only for the revenue generated from sugar but also considering that generated from saleable primary by-products realised during the process of sugar production; and that farmers in all circumstances be paid the Fair and Remunerative Price (FRP) as the minimum. However, the recommendations have not been adopted by many sugar producing states and the sugarcane prices are being paid as SAP (which includes FRP also).

In making payment on the basis of SAP, it is the inherent weakness of this system that persists. These include (i) inadequacy rewarding or penalising the farmers on the basis of the quality of sugarcane they supply to the mill; and (ii) for the inefficient plant operation resulting in higher sugar losses and lower sugar recovery, the farmers are taxed when payments are made on the basis revenue sharing or FRP. This situation indicates the need for having a hybrid formula for sugarcane price fixation, which is not merely dependent upon revenue, but also has elements of sugarcane quality and factory efficiency, as are being practiced in some of the sugar producing countries.

On account of the various factors discussed above, and when sugarcane price fixation mechanism results in mismatch in the prices of sugar and sugarcane, particularly, when sugar prices rule below par, the sugar mills fail to earn adequate profit, rendering them incapable of making timely payments to the farmers, the principle stakeholders in the value chain. The outcome is a situation of mounting cane arrears. Further, the cyclical nature hinder investments in the farm for achieving higher productivity of sugarcane.

Other hindrances to efficiency are lack of transparency in the age old manual marketing transactions, impacting farmer-miller relations. Additionally, the environment comprising cyclical ups and downs of sugar productions and global sugar scenario, sugar mills need policy support to negotiate prices and also a market intervention mechanism which calls for creation of buffer stocks. As of now, there is no consistency with regard to buffer creation. The last buffer created was in the year 2007-08 and the government has decided only recently (May 2018) to create a buffer stock of 30 lakh tonnes of sugar. Parellelly, sugar mills are required to get more efficient and responsible in making optimal utilization of the resources and convert "single product factories" to "multi product factories". This will bring in greater operational efficiency and higher revenues helping both the stakeholders – the farmers and the mills.

2.11.2 Related policy options

The annual demand for sugar in India is estimated at 25 million tonnes. The per capita consumption of sugar in the country has largely remained steady at around 20 kg. over the last decade. The year 2017-18 saw a production of about 32 million tonnes of sugar. The output can only be expected to rise further, with newer varieties possessing higher cane yield and sugar recovery potential. This suggests that India will be able to meet the domestic demand, even if it goes beyond the current estimate of 25 million tonnes, providing scope for cane diversion for non-food purpose, namely, ethanol.

i. **Juice to ethanol –** Sugarcane is considered as a source of bio-mass for processing into a range of valuable products (including food, feed, molasses and chemicals), and energy (fuels, power and heat) offering thereby multiple options. Energy is a critical input for socio-economic development of a country. The energy strategy of a country aims at efficiency and security, that is also environment-friendly and adopts an optimal blend of primary resources for energy generation. Since, conventional or fossil fuel resources are limited and polluting, they need to be used prudently. In contrast, renewable energy resources are indigenous, non-polluting and virtually inexhaustible.

The crude oil price fluctuations in the world market and escalations of crude oil prices constitute a threat to the economy's fiscal policy. India's energy security would remain vulnerable until alternative fuels to substitute/supplement petro-based fuels are developed based on indigenously produced renewable feed-stock. Bio-fuels are environment-friendly fuels and their utilization would address global concerns about containment of carbon emission. The transport sector has been identified as a major polluting sector, where use of bio-fuels is assuming a critical role. Ethanol is a proven and environmentally safe alternative to fossil fuels, and its use in transport industry is increasing. The World Energy Council (WEC) expects that the transport fuel demand in the next 15 years will come mainly from countries such as China and India, which are projected to experience a demand growth of 250 to 300 per cent. 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.

At present, mandatory blending of ethanol with petrol is at @10 per cent in the country, which is lesser than in Brazil (No.1 in sugar production) where vehicles are operated with either 25 per cent ethanol blend or on 100 per cent ethanol. The current estimated ethanol requirement is 3.2 billion litres per annum based on the mandatory 10 per cent ethanol blend. This requirement is not achievable unless feed stocks other than molasses are used. Possibilities of producing ethanol directly from the cane juice can be explored, which has also been endorsed in the National Bio-fuel Policy 2018, during the course of surplus sugar production in the country. However, in doing so, two challenges shall have to be overcome:

a) Development of adequate distillation capacities and required changes in the existing distilleries for facilitating conversion of cane juice to ethanol

b) Economics of ethanol production considering sugarcane price, ethanol price and yield of ethanol per ton of sugarcane. Under the present scenario, the preposition is workable only when some price premium is provided for the ethanol produced directly from cane juice.

Presently, about 1.13 billion litres of ethanol is produced in the country. As many as 140 sugar mills in the country have distilleries attached to them. As of now, ethanol is being produced from C-heavy molasses. It is, however, also possible to produce ethanol in two other ways, namely, B-heavy molasses and sugarcane juice directly when the latter two routes are adopted, there will be impact on sugar production, as it will amount to diversion of sugar containing sugarcane juice and B-heavy molasses (which also contains some amount of sugar) for non-food production item. In Brazil, one of the major sugarcane grower, almost all the ethanol they produce is directly from sugarcane juice.

ii. **Other feed-stocks from sugar industry for producing ethanol (Ethanol from B-Heavy molasses)** – In case of India, where sugar prices are not good enough to cover costs and generate profits enough to ensure timely payment to the farmers as per notified Fair Average Price (FAP), it may be useful to examine promotion of ethanol production from B-heavy molasses and sugarcane juice, besides C-heavy molasses, which alone is in practice now. Besides the option of producing ethanol from cane juice, a better option may be producing the same through diversion of intermediate process liquor i.e. B-heavy molasses. In case B-heavy molasses is diverted for production of alcohol, minimum changes will be required at the sugar factory and distillery ends. Keeping in view the fermentation and distillation efficiencies, the recovery of ethanol per ton of invert sugar shall be about 600 litres. Such controlled diversion while on the one hand will result in curtailing the sugar production to the desired extent, on the other hand will result in increase in capacity utilization of the molasses based distilleries reported to be about 65-70 per cent only at present. Such diversion will depend upon the relative economics of producing sugar or ethanol and hence, policy interventions shall be required.

iii. **Ethanol from bagasse** – Ethanol production from lignocelluloses (generally termed as 2G ethanol) is being discussed abundantly, and bagasse can be an important feed-stock for the purpose. At present, bagasse is by and large used by the sugar factories as fuel for generation of power. However, with growing competition in power tariffs offered for the power generated through non-conventional energy sources, and issues related to signing of power purchase agreements by the state governments, the bagasse based cogeneration may not be so lucrative in future. Therefore, after meeting the captive requirements of the sugar plant, the surplus bagasse can be used as a source for production of the ethanol where technological breakthrough shall be required to make the cost of production cheaper and competitive.

It is, therefore, suggested that after robust projections of outputs of sugarcane & sugar, the estimates of sugar demand over the next decade, Government may examine to permit ethanol production from B-heavy molasses, as also directly from sugarcane juice. In order to promote such a production, it would be necessary to determine suitable prices on each of these and also provide a stable policy support. With reduction in sugar surpluses in the country, this is likely to result in a supply-demand equilibrium for sugar at a higher level. This will increase the revenue pot of the sugar mills and enable them to make timely payment on the sugarcane sold to them.

2.11.3 Sugar factories

Most of the sugar factories in India produce plantation white sugar and only about 7 per cent of the operational units follow raw – refined sugar route. At present, only about 40 per cent of the sugar factories are carrying out power export, while the number of sugar units having distilleries attached to them are still lower. Utilization of by-products in the most generalized manner i.e. by producing ethanol from molasses and power from bagasse, can improve the financial health of the sugar industry and also help in meeting the energy requirements of the country.

In India, the production of plantation white sugar is done by age old conventional 'Double Sulphitation Process', whereas, globally the sugar is accepted and traded as raw or refined sugar. The first step towards value addition and better liquidity may be conversion of existing plantation white sugar factories to raw-refined sugar factories. Production of refined sugar will open the doors for production of many other value added special sugars viz. cube sugar, candy sugar, icing sugar, castor sugar, liquid sugar and pharmaceutical sugar etc. Sugar industry has to accept that sugar, molasses and bagasse can no longer be considered as the final product from sugar mill. Value addition, conversions of waste (so considered now) to wealth, diversifications and integrations are to be vigorously investigated as possible routes to new market and making sugar industry less dependent upon the single commodity.

Sugar industry, has to be upgraded as a hub producing not only sugar but various types of sugars as per market demand and many other value added products. The 'Sugar Factory' has to be transformed into 'Sugarcane Bio-refinery'. While host of high value industrial chemicals can be produced from sugar, many downstream chemicals and other products are also possible through molasses and ethanol route (e.g. yeast, aconitic acid, itaconic acid, citric acid, lactic acid, anti-oxidants and vinegar etc.). Even another by-product i.e. filter cake, can be used for production of bio-gas, bio-fertilizer and wax. Bagasse in addition to its use as fuel and possible ethanol production can be used for production of value added products like surfactants, furfurals, xylitol and edible mushroom etc. While sugar is the most commonly used sweetener, it is also a raw material in the production of a host of industrial chemicals, and nearly 10,000 technically feasible products have been developed from sucrose in laboratories, and tested at pilot plant scale.

It is also pertinent to note that the duration of the crushing season of sugar factories in India has in general reduced and averages at 120-140 days per year currently. Thus, huge infrastructural facilities remain idle for rest of the days. There exists scope for integrating sugar industry with food processing industry including dairy products, vegetable and fruit pulping and packaging etc. Such transformation of standalone Sugar Factories into Bio-refineries to Agri-business Complexes will help in increasing the revenue pot of the sugar industry and then they will be better placed in making higher and timely payments to the sugarcane farmers.

The concomitant requirement of the above suggested transformation will require pre-requisite changes in the cane cultivation practices. The currently in vogue, 'cane-cultivation for sugar' will need to diversify into 'sugarcane plantations', energy plantations', sugarcane bio-farms' and the like. Hence, the scientists will need to re-orient their research & development to meet this dynamic need.

In order to beat the dogged vicious cycle of low profits at mill level and cane arrears at farmers' level, there is need for a fundamental transformation. Sugar factory has to be transformed into sugarcane agro-complex, wherein sugar is only one of the products. Further, sugar itself has to find use not just as a sweetener, but as a raw material for multiple industrial products.

2.12 P-E-S-T Analysis for creating Enabling Environment

Table 2.21 Political, economic, social and technological factors - sugarcane farming

Political (Governance)	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 areas. Labour demand in non-agricultural sector is 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 and blue bulls.	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 to farmer interaction and FIGs (Farmer Interest Group) in sugarcane for organizing farmer-led extension programmes.

Source: DFI Committee

Various factors (Table 2.20) 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.

Addressing these emerging challenges would require a new approach, that is distinct from the one followed hitherto. Sugarcane research and extension therefore need to emphasize on the following new dimensions:

- Focus on gene revolution, emphasizing application of bio-technology - tissue culture for multiplication of elite germplasm, GM crops, marker assisted breeding etc.
- Emphasize on 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.
- Adopt 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 mechanization, and farmer friendly tools, machineries and devices.
- Care for quality in addition to quantity in cultivation.
- Protect IPR (Intellectual Property Rights) and farmers' rights.
- Integrate agro-enterprises with sugarcane production and application of advances in information technology.
- Transform stand alone 'Sugar Mills' into 'Sugarcane Agro Complexes' to enhance the revenue pot of the sugar sector.

2.13 Annotation

Sugar industry, using sugarcane as a sole raw material has registered tremendous growth since 1930-31 as evident from increase in the number of sugar mills from 29 to 526 (2015-16). Corresponding expansion in sugarcane area (1.17 to 4.96 million ha), production (37 to 348.44 million tonnes) and yield (31 to 70.7 t/ha) stands as testimony to the favour the crop has been receiving among the farmers.

Capability to sail through weather adversities during its growth and development, and assumed purchase by sugar mills, sustains its cultivation both in tropical and sub-tropical regions of the country. Varied uses of sugarcane and its by-products for sweeteners, paper industry, animal feed, pharmaceuticals & agrochemicals, and soil amendments add to its value. Increasing utilization of sugarcane for electricity generation and bio-fuel production is strengthening the sector by enhancing its economic viability.

Rising input and labour costs along with climate change induced farming hardships, as in other crops, have however emerged as challenges to the profit margin of sugarcane cultivation. This can be addressed effectively by large scale adoption of equipments developed to mechanise various operations for plant and ratoon crops, bringing larger extent of area under recently released high sugar yielding varieties, strengthening of soil health with bio-manures, popularisation of drip irrigation to save water and promotion of higher number of ratoons after a plant crop.

It is not enough to increase the cane yield. It is necessary to bring in diversification in cane cultivation, so that cane is cultivated for multiple products - energy, sugar as sweetener, sugar as raw material for various industrial products etc. This will help in increasing the revenue pot of the sugar industry, and make it possible to pay the sugarcane cultivators adequately and in time. This is the only long term solution to persistent situation of cane arrear payments to the farmers.

Key Extracts

- Area under sugarcane increased from 1.17 million ha in 1930-31 to 4.93 million ha during 2015-16; production increased from 37 million tonnes to 348.44 million tonnes and yield substantially from 31 t/ha to 70.7 t/ha during the corresponding period.
- Continued mono-cropping of sugarcane without crop rotation and organic recycling has brought about soil salinity, diseases like smut, wilt and yellow leaf disease (YLD) and pests (particularly borer pests) affecting sugarcane productivity in the country.
- Climate change has emerged as one of the biggest environmental challenges, significantly affecting sugarcane production system across the country with frequent incidence of droughts, floods and diseases. Approximately 2.97 lakh ha of sugarcane area is prone to drought, affecting the crop growth during its formative phase causing 30-50 per cent reduction in yield.
- There exists great scope for making sugarcane cultivation cost effective, especially by promoting resource conserving crop production technologies such as precise irrigation methods, site-specific fertilizer application and adoption of soil health sustaining nutrient management techniques.
- Supporting the farmers with timely weather forecast, weather and crop advisories, ICT based technology backstopping and farmer-centric credit system and site-specific insurance scheme can help in negotiating the emerging challenges.
- There is need for promotion and adoption of location-specific improved technologies, cultivation of tissue culture derived healthy seeds; and scaling up of transplanting technique for settings.
- Technology transfer through effective communication system, market led inter-cropping in sugarcane and market intelligence based sugarcane production system will go a long way in augmenting the income of sugarcane growers.
- Adopt improved cropping systems-diversification, mechanization, resource use efficiency, micro-irrigation, need based irrigation schedule, crop protection technologies and the like.
- Market-led inter-cropping; market-intelligence based cane production; and effective communication will help in augmenting incomes of cane growers.
- From the income enhancement perspective, sugarcane may be grown as a plantation crop, by diversifying it as 'sugarcane plantation' (for sugar) 'cane energy plantation' (for ethanol), 'sugarcane bio-farms' (for industrial chemicals) etc.
- A permanent solution to situations of cane payment arrears to the farmers lies in converting 'sugar factories' into 'agro-bio-complexes', where cane is used for producing sugar', bio-fuel and multiple other products; and where sugar is manufactured not only for use as sweetener but also for the purpose of using it as feedstock for various industrial products.

Annexures VIII-B

Annexure A

Economics of sugarcane production

Crop and State	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 (₹/ha.)	Per Month Gross Returns over A2+FL (₹/ha)	Per Month Net Returns (₹/ha)
	₹/ha.				₹/ha. (Col.6-Col.3)	Percent (Col.7/ Col.3* 100)	₹/ha. (Col.6-Col.4)	Percent (Col.9/ Col.4 *100)	₹/ha. (Col.6-Col.5)	Percent (Col.11/ Col.5 *100)			
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Sugarcane													
All- India	61985	76429	118746	180556	118571	191	104127	136	61810	52	9881	8677	5151
Uttar Pradesh	36853	51150	90898	153014	116161	315	101864	199	62116	68	9680	8489	5176
Karnataka	54336	66616	109394	174732	120396	222	108117	162	65338	60	10033	9010	5445
Maharashtra	111359	127264	176753	236205	124846	112	108940	86	59452	34	10404	9078	4954
Paddy													
All- India	25179	33631	47547	53242	28063	111	19611	58	5696	12	7016	4903	1424
Punjab	30983	36013	62313	87006	56023	181	50993	142	24692	40	14006	12748	6173
Haryana	29633	37156	60828	91310	61677	208	54154	146	30482	50	15419	13538	7620
Andhra Pradesh	36219	42466	66088	75060	38841	107	32594	77	8972	14	9710	8149	2243
Uttar Pradesh	21563	29522	43024	51255	29692	138	21733	74	8232	19	7423	5433	2058
Karnataka	36003	42183	60514	78069	42066	117	35886	85	17554	29	10516	8971	4389
Cotton													
All- India	37266	46208	64931	74519	37253	100	28311	61	9588	15	9313	7078	2397
Gujarat	34929	44670	61160	80688	45759	131	36018	81	19527	32	11440	9005	4882
Maharashtra	43583	51672	68740	71689	28106	64	20017	39	2949	4	7027	5004	737
Wheat													
All- India	22742	28879	45814	58340	35598	157	29461	102	12527	27	8900	7365	3132
Punjab	25587	28184	52169	72748	47160	184	44564	158	20579	39	11790	11141	5145
Haryana	25364	33380	58462	74251	48887	193	40871	122	15789	27	12222	10218	3947
Uttar Pradesh	24191	30338	46774	53370	29179	121	23032	76	6595	14	7295	5758	1649
Maharashtra	28442	34677	46122	46814	18372	65	12137	35	692	2	4593	3034	173

Annexure B

Recommended FRP and its linking with recovery rate (RR), sugar season 2017-18 (₹/q)

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

Source: DFI Committee Estimates based on data compiled from Commission for Agricultural Costs and Prices (CACP)

Note: With every increase in recovery by 0.1%, the FRP will increase by Rs. 2.68/qtl.

Annexure C

Calculation of farmers' income based on CACP Data (2017-18)

State	Cost (C2)/quintal	SAP at 2017-18/quintal	Average yield (q/ha)	Income (₹/quintal)	Farmers' income (₹/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	315.0	723	81	58,563
Uttarakhand	222	315.0	594	93	55,242

Source: DFI Committee Estimates based on data compiled from CACP

Annexure D

Average yield, sugar recovery SAP/ FRP in major sugarcane growing states

S. No	States	Average yield	Sugar recovery	State advised price (SAP)/FRP 2017-18
1	Andhra Pradesh	77.6	9.62	255 (FRP)
2	Bihar	51.9	9.14	255 (FRP)
3	Gujarat	69.4	10.64	NA
4	Haryana	73.2	9.75	305
5	Karnataka	88.0	10.89	261.5
6	Madhya Pradesh	43.8	9.94	255 (FRP)
7	Maharashtra	79.7	11.44	273.3
8	Punjab	73.1	9.43	295
9	Tamil Nadu	104.1	8.79	285
10	Uttar Pradesh	72.3	10.61	315
11	Uttarakhand	59.4	9.19	315

Annexure E

Economics of furrow and drip method of irrigation in Tamil Nadu

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

Annexure F

Economics of manual and mechanical harvesting in Tamil Nadu 2017-2018

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

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