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Towards sustainable, productive and profitable agriculture:

Case of Rice and Sugarcane

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List of Abbreviations

BCM	Billion Cubic Metre
BCR	Benefit Cost Ratio
CACP	Commission for Agricultural Costs and Prices
CAG	Comptroller and Auditor General of India
CGWB	Central Ground Water Board
CSS	Centrally Sponsored Scheme
CWC	Central Water Commission
DBT	Direct Benefit Transfer
DES	Directorate of Economics and Statistics
DIM	Drip Irrigation Method
ET	Evapo-Transpiration
FHP	Farm Harvest Price
FIM	Flood Irrigation Method
FRP	Fair and Remunerative Price
FY	Financial Year
GoM	Government of Maharashtra
GoP	Government of Punjab
IWP	Irrigation Water Productivity
JISL	Jain Irrigation Systems Limited
LTIF	Long Term Irrigation Fund
LUS	Land Use Statistics
MH	Maharashtra
MP	Madhya Pradesh
NABARD	National Bank for Agriculture and Rural Development

NASA	The National Aeronautics and Space Administration
NCIWRD	National Commission on Integrated Water Resource Development
NHB	National Horticulture Board
NMMI	National Mission on Micro Irrigation
NMSA	National Mission for Sustainable Agriculture
NPV	Net Present Value
NPW	Net Present Worth
NRLD	National Register on Large Dams
NSSO	National Sample Survey Office
OECD	Organisation for Economic Co-operation and Development
PBP	Pay Back Period
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
SAP	State Advised Price
TN	Tamil Nadu
UDAY	Ujjwala Discom Assurance Yojana
UN	United Nations
UP	Uttar Pradesh
WB	West Bengal

Preface and Acknowledgement

This paper looks at the issue of sustainable agriculture from the point of view of irrigation water use. In doing so, it examines productivity and profitability of two of the most water consuming crops in Indian agriculture, namely rice and sugarcane, which together consume more than 60 percent irrigation water of the country. We look at their productivity not only on per hectare basis but also on per cubic meter of irrigation water applied. Our focus on rice, especially in Punjab, and sugarcane in Maharashtra, brings out "distortions" in cropping patterns that are not in line with the water endowment of these regions. No wonder that they are putting undue pressure on scarce irrigation water supplies, and thus questions are being raised about their sustainability. We hope this research will provoke people to think a little differently about Indian agriculture, and in due course, will promote sustainable agriculture that is also productive and profitable.

In carrying out this research we have gained immensely from a number of experts in the field. We express our sincere gratitude to Dr. Vipin Sharma (Former Cane Commissioner, Commissionerate of Sugar, Pune) and Mr. Pandurang Shelke (Former Joint Director (Development) Commissionerate of Sugar, Pune), Mr. Jalinder Pangare (Deputy Director of Agriculture, Maharashtra) and Mr. Abinash Verma (Director General, Indian Sugar Mills Association) for providing us with important statistical data and critical insights necessary for fine tuning our research. We would like to thank Dr. Soman (Senior Vice President (Projects), Jain Irrigation Systems Limited) for his valuable interactions regarding precision agriculture and micro irrigation practices.

We sincerely thank our reviewers Mr. D.K. Jain, Additional Chief Secretary, Finance Department, Government of Maharashtra; Mr. T.K. Nandakumar, Senior Visiting fellow, ICRIER and former NDDB Chairman; Mr. Siraj Hussain, Senior Visiting fellow, ICRIER and former Union Agriculture Secretary; for their invaluable comments and feedback, which has helped in enriching the paper. Dr Yamini Gupt was associated with this study in its early stages, and we express our thanks to her. ICRIER agriculture team also gave us insightful suggestions and comments during our internal presentations for which we are grateful to them. Needless to say, the responsibility of facts, figures, analysis and views expressed in this paper fully rests with the authors.

Abstract

Indian agriculture is estimated to be consuming about 78 percent of total fresh water resources available in the country. Yet, more than half of the gross cropped area is still dependent on rains. Extremely skewed allocation of scarce irrigation water amongst crops and inefficient use of the allocated water are major reasons behind this paradox. Water guzzler crops like rice and sugarcane, occupying about one-fourth of the gross cropped area, consume more than 60 per cent of irrigation water available in the country. Hence if sustainable agriculture water-use has to be ensured, economics (productivity and profitability) of at least these two crops needs to be studied thoroughly to see how best higher productivity and profitability can be achieved with lesser amounts of irrigation water. This is what is attempted in this paper. The study shows that regions like Punjab and Haryana, which have high land productivity of rice, fall way below in ranking of irrigation water productivity. Instead, eastern states like Bihar, eastern UP give better results, highlighting the need to shift rice cultivation from north-western states to eastern states. Similar results are obtained for sugarcane in Maharashtra, Tamil Nadu and Karnataka, which are high on land productivity but low on irrigation water productivity, suggesting that sugarcane cultivation needs to shift from tropical to sub-tropical states of Bihar and Uttar Pradesh. In order to encourage such cropping pattern shifts, both in rice and sugarcane, one will have to undertake reforms related to water/energy policies, institutions and technologies related to irrigation water use. Some of our policy suggestions are: 1) Implement price policies that reflect the scarcity and economic value of water and power use in agriculture, while improving the quality and timely availability of these to farmers 2) Strengthen marketing opportunity of sugarcane and procurement policies of rice in the water abundant states of eastern region. At the same time, set the markets right (reduce market risk) for the less water intensive crops that give much higher value per cubic meter of irrigation water applied in water scarce states 3) Direct Benefit transfer of water and power subsidies to farmers 4) If price reforms with DBT of water and power subsidies are not possible, ration irrigation water and power used in agriculture on per hectare basis, and then let the water markets operate amongst farmers 5) Adopt irrigation technologies and practices that encourage water savings, such as micro irrigation system in sugarcane and rice.

Keywords: *Water Guzzler Crops, Irrigation Water Productivity, Sustainability, Profitability, Cropping Pattern, Water Stress.*

JEL classification: *O13, Q01, Q15, Q18, Q25*

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Executive Summary

Water in agriculture – The sustainability issue

Water is going to be a bigger binding constraint than land in India's agriculture development. With a population of more than 1.3 billion in 2017, India is likely to surpass China's population and emerge as most populous country in the world by 2024 (UN Revised Population Projections, 2017)[1]. Supporting more than 17 per cent of the global population on 2 per cent of world's land area (11% of global arable land) and 4 per cent of fresh water resource will be a herculean task. On an average an Indian household still spends about 45.5 percent of its expenditure on food (NSSO, 2011). As such, with per capita incomes likely to rise by about 6 percent per annum for the coming decade or so, demand pressures on food, feed and fiber are going to increase rapidly. Almost 46 per cent of land area and about 78 per cent[2] of water resource is already diverted towards agriculture production in India. Despite this large supplies of water towards agriculture, more than half (52%) of Indian agriculture is still rainfed, resulting in underachievement of potential productivity and profitability. This situation emerges primarily due to highly skewed distribution of irrigation water amongst crops. More than 60 per cent of water available for agriculture use in the country is diverted towards irrigating two water guzzler crops, rice and sugarcane, having a share of just 24 per cent in gross cropped area. This skewed water allocation and inefficient irrigation practices like flood irrigation, are raising flags regarding sustainability of water use in Indian agriculture. If Prime Minister's vision of "*har khet ko pani*" (water to every field), and "per drop, more crop" is to be achieved within a reasonable time frame, one needs to look at the economics of agriculture (its productivity and profitability) with a different lens. It must shift its focus from land productivity and profitability to irrigation water productivity and profitability. This has to be done for at least two crops, rice and sugarcane.

Our approach

In this paper, we focus on two crops in two regions -rice in Punjab and sugarcane in Maharashtra- where they pose a major paradox in terms of their productivity and profitability, when measured on the basis of per unit of land and per unit of irrigation water applied. The two states also display classic paradox of cultivating water guzzler crops in the midst of water crisis. Punjab is facing groundwater depletion at an alarming rate of 70cm to 120 cm per year (The World Bank, 2010), but it is the frontrunner in terms of rice productivity per unit area. Maharashtra faced acute water shortage during the 2014-15 drought, and even trains (*Jaldoot express)* had to be put in service to ferry drinking water to quench the thirst of its people, but it stands high (third) on sugarcane land productivity.

In our study we estimate irrigation water productivity (crop output produced per unit of irrigation water applied by farmers) of rice and sugarcane crops to bring out the mis-alignment existing in cropping pattern and irrigation water use across major states. The

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1 https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html

2 Another estimation in source (CWC, 2015) puts this figure even higher at 85 percent in 2010.

economic water productivity (expressed as Rs./m^3) has also been worked out to understand in value terms the crop output produced per unit of irrigation water applied. Further, the profitability of the two crops across the states has been compared to map out policies to promote sustainability without compromising profitability. In case of Maharashtra, we have attempted to compare the Irrigation Water Productivity (IWP), Economic Water Productivity (EWP) and profitability across major crops grown in the state, in order to highlight the inequity in irrigation water allocation across crops in the state.

The Inconvenient Truth

Paddy in Punjab: An irrational choice?

The analysis of irrigation water productivity across states for rice reveals that Punjab lags behind major rice growing states. For example, it uses almost two times more irrigation water than West Bengal, and three times more irrigation water than Bihar, for producing one kilogram of rice. Bihar recorded the highest irrigation water productivity of 56 kg per lakh litres of irrigation water supplied while Punjab produced just 19 kg rice from the same quantity of irrigation water applied. The EWP also shows similar results with Punjab emerging as the most inefficient in paddy cultivation producing paddy output worth Rs. 3.81/ m3 of irrigation water applied while the eastern states of West Bengal and Bihar producing output worth three times more than that of Punjab from the same quantity of water applied. Thus, cultivating paddy crop in Punjab totally based on irrigation water emerges as an anomaly from the point of view of ensuring sustainable water use in Punjab agriculture. But because of robust procurement policy coupled with highly subsidized power (almost free), the profitability of paddy cultivation on per hectare basis remains very high in Punjab. This is what encourages farmers to cultivate this crop despite high social cost incurred in terms of fast depleting water table, which will impact the sustainability of agriculture and welfare of future generations in Punjab.

Sugarcane in Maharashtra – A paradox?

A similar analysis for sugarcane across major sugarcane growing states showed that the irrigation water productivity in traditional sub-tropical sugarcane region (Uttar Pradesh and Bihar) was almost three times more than the tropical region comprising of Maharashtra, Tamil Nadu and Karnataka, while it was the other way round when land productivity (per unit area basis) was considered. Despite the existence of better established cooperative sugar mills in Maharashtra, the per month profitability of the crop (after adjusting crop duration) when compared across states showed sugarcane cultivation in Uttar Pradesh to be more profitable than in Maharashtra. On comparing the economic productivity (value of crop output produced per unit of irrigation water applied) of sugarcane with other major crops grown within Maharashtra showed the less water intensive cotton, tur and groundnut to be more efficient. However, it is an irony that sugarcane occupying 4 percent of gross cropped area in Maharashtra takes away almost two-thirds of irrigation water of the state. And this happens when overall irrigation cover in Maharashtra is just 19 percent compared to about 48 percent at all India level. These clearly indicate that cultivation of a water guzzler crop like sugarcane stands out as a paradox in water stressed state like Maharashtra. But due to the full irrigation coverage in sugarcane and higher profitability due to assured marketing through sugar mills, the sugarcane farmers in Maharashtra are mostly reluctant to shift their cropping pattern to other crops. Hence emphasis should be laid upon improving the existing flood irrigation practice to drip irrigation so that water saved from sugarcane cultivation could be supplied for irrigating other crops in the area. For instance, the water saved through drip technology in one ha of sugarcane area can bring an additional 2.29 ha area under conventional irrigation and double this area, if drip irrigation is adopted in cotton. From this additional 2.29 ha irrigated area under cotton, if other things remain constant, output worth up to Rs. 1.95 lakh can be produced (considering farm harvest price and yield data of 2014-15). This would help improve the prosperity of farmers cultivating those crops too. Further, investment friendly climate must be created to set up new sugar mills and rejuvenate the sick sugar mills in states like Bihar having high potential for sustainable sugar production.

Specific Policy recommendations emanating from the study

- Shifting water intensive crops to water abundant regions

Rice and sugarcane exhibit serious misalignment between the cropping patterns and hydrological suitability in the major cultivating states. Rice cultivation needs to be shifted from the north-western water stressed states like Punjab to the water abundant eastern region while sugarcane needs to be shifted from the water scarce tropical region (Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh) to the traditional water abundant sub tropical region of UP and Bihar. These changes are needed not as zero-one game, but at the margin, to restore the balance between irrigation water available and demand for that water by these crops so that a sustainable cropping pattern can be encouraged in line with water availability.

- Marketing opportunities for sugarcane and procurement policies of rice must be strengthened in the water abundant states. At the same time in the water scarce states, marketing risks of less water intensive crops must be reduced.

- Implementing efficient price reforms in water and power use in agriculture: Effective pricing of water and power in sync with their improved quality and timely availability is essential to ensure judicious use of these inputs for sustainable agriculture development.

- Direct Benefit transfer of water and power subsidies: The price based subsidy existing for inputs at present must shift to direct income support policies, wherein the input subsidies/benefits must be directly transferred to the farmer’s account rather than getting reflected in the distorted (very low) prices of these particular inputs.

- In case it is not possible to carry out price reforms in water and power sector, rationing mechanism in supply of irrigation water from canal system through a ‘warabandi’ type system, and metering mechanism in supplying power for irrigation through separate dedicated feeder and distribution line for irrigation must be implemented. Farmers can be given these inputs on per hectare basis, and thereafter allow a water market amongst farmers themselves.

- Adopting irrigation technologies like micro irrigation for improving water use efficiency.

Other Supporting policies

- Efficient implementation and scaling up of drought proofing schemes like Nanaji Deshmukh Krishi Sanjivani Yojana and Jalyukt Shivar Yojana (Maharashtra) in other water scarce states.

- Promote cultivation of HYV of sugarcane crop in water abundant states like UP and Bihar which may increase the profitability of sugarcane farmers in the state.

- Export of water guzzler crops like rice and sugarcane (sugar) results in virtual export of water, which needs to be contained by correcting power/irrigation water pricing. And if that is not feasible, one can consider an export tax of say 5 percent on these commodities, especially rice, while allowing their imports at zero or low duty. This would help dovetail the objective of sustainable water use in agriculture in India's trade and tariff policy.

- Lessons can be learned from nations like Israel regarding their water pricing policy and water governance, which has led to effective adoption of the precision irrigation technology in the country.

- Promoting micro irrigation in regions with no regular electricity supply (particularly in the eastern regions) is a major challenge. In such places, Solar-micro irrigation system may be encouraged with a provision to feed in the surplus power back to grid. This would not only cut down the cost of diesel based irrigation in these regions, but also provide a regular income from solar power supplied to the grid.

Towards sustainable, productive and profitable agriculture: Case of Rice and Sugarcane

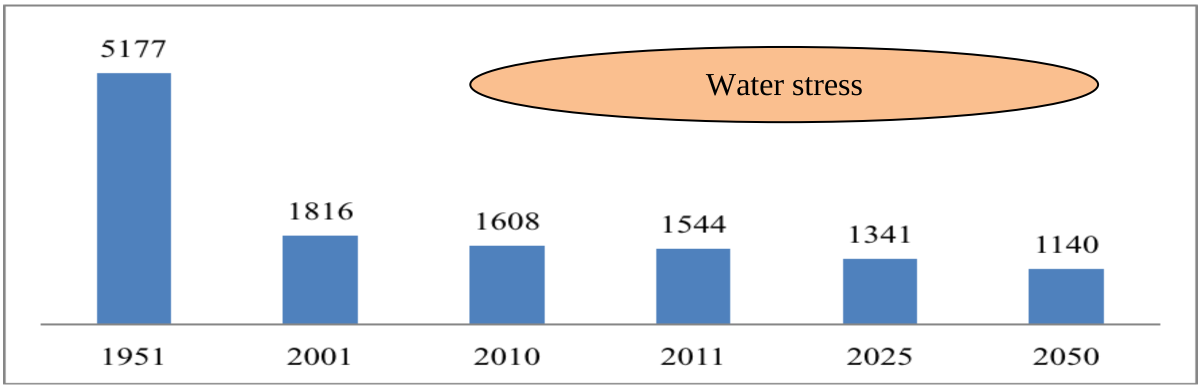
Ashok Gulati and Gayathri Mohan

1. Introduction

1.1 Why emphasize sustainability in agriculture water use in India?

With a population of 1.3 billion today, India is likely to overtake China by 2024[3] and emerge as the most populous country in the world. Supporting more than 17 per cent of the world's population on 2 per cent of global land area, about 11 percent of world's arable land, and 4 percent of global fresh water supplies will be a herculean task. An average Indian household still spends about 45.5 percent of its expenditure on food (NSSO, 2014). As such, with per capita incomes likely to rise by about 6 percent per annum for the coming decade or so, it is obvious that demand pressures for food, feed and fiber are going to increase in India. Thus to combat the pressure coming from rising population, increasing purchasing power, urbanization and industrialization, there is a need to increase land as well as water productivity in agriculture. At present, about 46 per cent of the land area and 78 per cent[4] of water resource is already diverted towards agriculture in India (CWC, 2014; LUS, DES). But owing to the current water stress[5] faced by the country, with the per capita water availability reported as 1544 cubic metre (cu.m) in 2011 (CWC, 2013), water is going to be the bigger binding constraint than land in India's agriculture development (Figure 1). Though increasing land productivity has been closely scrutinized by researchers and policy makers, the emphasis towards the improving water productivity, particularly in terms of irrigation water applied by farmers, has been very limited.

Figure 1: Annual per capita water availability in India (cubic meter)



Note: National Commission on Integrated Water Resource Development (NCIWRD) (1999) estimated that the water availability may drop to 1341 and 1140 cubic meter by 2025 and 2050 respectively emphasizing the magnitude of water crisis awaiting the country (CWC, 2015).

Source: (CWC, 2013) (CWC, 2015)

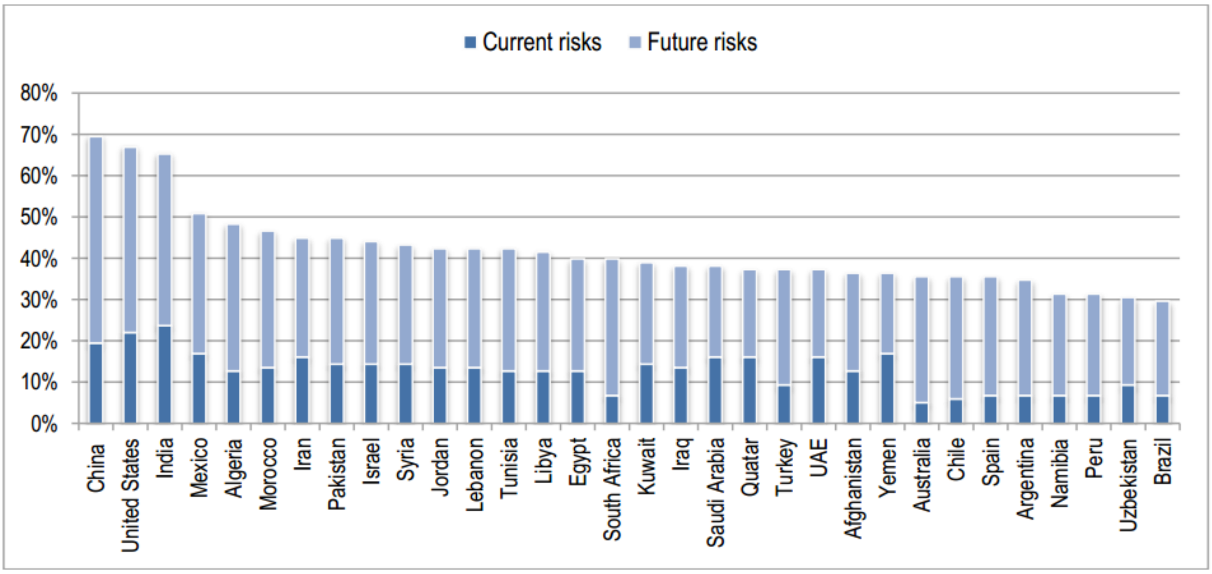
3 https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html

4 Water used for diffent activities in India is given in appendix 1

5 As per the Falkenmark water stress indicator, a country is termed as water stressed if the annual per capita water availability is less than 1700 cubic meter and water scarce if the same is less than 1000 cubic meter (http://environ.chemeng.ntua.gr/WSM/Newsletters/Issue4/Indicators_Appendix.htm).

Large inequities existing in crop water use has left more than half (52% of GCA) of Indian agriculture still dependent on the erratic monsoons resulting in underachievement of potential productivity and profitability. Based on our estimation, it was found that more than 60 per cent of the irrigation water available in the country is used for irrigating two crops – rice and sugarcane, having a share of just 24 per cent of the gross cropped area. In addition to this the inefficient flood irrigation method majorly practiced in the country, leads to an overall water loss of 60-65 per cent, resulting in only one third of the water released from the dam actually reaching the farmer's field (Appendix 2) (CWC, 2014). In the recent years, the gap between the irrigation potential created and utilised has widened significantly further aggrevating the concern of proper utilisation of canal water in agriculture (Gulati & Banerjee, 2016).The untimely and inadequate water supply through surface irrigation system has made farmers to increasingly adopt the alternate irrigation source, groundwater. Over the last 4 decades, the area brought under groundwater irrigation has increased at the rate of 2.87 per cent, while surface irrigation increased at a mere 0.54 per cent per annum. In 2013-14 out of the total net irrigated area, the share of groundwater irrigated area was 62 per cent and canal irrigated area was 24 per cent. This shift has led to serious sustainability issues, with groundwater exploitation taking place at an alarming rate in many parts of the country. The Central Ground Water Board has reported that as on 31 st march 2013, almost 16 per cent of the groundwater assessment units in India were under the over exploited category (CGWB, 2017). The percentage share of over exploited blocks were found to be relatively higher in states like Punjab, Rajatshan and Haryana. . An assessment of the future water risks hotspots by OECD identifies India (particularly North West India) as one of the three leading countries most exposed to future water risks posing significant negative impact on agriculture production with broader food security and socio- economic consequences (OECD, 2017) (Figure 2).

Figure 2: Proportion of water risk for leading countries



Source: (OECD, 2017)

In our paper we focus upon agricultural sustainability, productivity and profitability from the water use perspective, for two of the major water guzzler crops rice and sugarcane, across states and attempt to raise an alarm to the concerned stakeholders, alerting to look beyond land and prioritise upon irrigation water productivity for sustainable agriculture development.

1.2 Our approach

We have attempted to capture the water challenges in ensuring agriculture sustainability by drawing results from two case studies - paddy cultivation in Punjab and Sugarcane in Maharashtra. Punjab and Maharashtra respectively are front runners in terms of land productivity (production per unit area) of paddy and sugarcane respectively. However considering the water profile of the states, cultivation of these water guzzler crops point towards the issue of unsustainable agriculture development

In our study we have estimated and compared the irrigation water productivity and economic water productivity of rice/paddy and sugarcane across the major cultivating states. Irrigation water productivity (IWP), expressed as kg/m3, gives account of the quantity of crop output produced per unit of irrigation water applied by the farmer in their field for the cultivation of the crop. Many hydrologists have evaluated the water productivity of crop with respect to the total consumptive water use (considering the evapo-transpiration rate and effective rainfall in the region). But in order to capture the sustainability issue, we have adopted the IWP approach, which indirectly takes into account the application inefficiencies associated with the commonly practiced irrigation method. The data pertaining to the volume of irrigation water applied for the crops, considered in the study (particularly paddy and sugarcane), are taken from the CACP price policy reports (Kharif price policy report for Paddy and Sugar price policy for sugarcane). These are assumed to be the quantity of irrigation water applied by a farmer in a normal rainfall situation.

In regions where the irrigation is highly subsidized either in the form of power/diesel subsidy or where flood irrigation is the norm, the irrigation water applied in field can be way higher than the actual water requirement of the crop as evaluated by evapo-transpiration method. This may result in inaccurate economic policy implications. Economic water productivity gives value of crop output produced per unit of irrigation water applied and is expressed in Rs./m3. Optimum irrigation increases the productivity of the crops. For instance, irrigated yield for most of the cereal crops is found to be more by around 50 per cent than the unirrigated yield. The increase in yield for pulses in irrigated condition over unirrigated condition was not very significant, though for red gram the increase noted was almost 18 per cent. In case of oilseeds like groundnut, rapessed-mustard and sesamum the irrigated yield was found to be higher than unirrigated yield by 30 per cent, 90 per cent and 140 per cent respectively ((NSSO, 2013-14). Thus, diverting more water towards cultivating a single crop leads to lower productivity of other major crops grown, particularly in water stressed regions. In Maharashtra, only 19 per cent of the GCA is under irrigation, of which the major proportion of water gets diverted towards irrigating sugarcane crop leaving other crops devoid of irrigation water availability in the region. To understand the situation better, we have compared the irrigation and economic water productivity and profitability of major crops grown in Maharashtra with that of sugarcane, to give an account of the opportunity cost of cultivating sugarcane in water stressed region like Maharashtra.

1.3 The tale of two states: Rice in Punjab and Sugarcane in Maharashtra

1.3.1 Rice cultivation in Punjab

Punjab is the seat of green revolution in India. The state records the highest gross irrigated area ratio in the country with almost 98.5 per cent of its gross cultivated area (GCA) under irrigation (2013-14)[6]. However, almost 80 per cent of the irrigation requirement of the state is met from the groundwater source, which is now depleting at an alarming rate (70 cm to 120 cm a year, (The World Bank, 2010)). The Central Ground Water Board (CGWB) reports that almost 76 per cent[7] of the administrative blocks in Punjab have over-exploited groundwater situation. Paradoxically, around 36 per cent of the state's Gross cropped Area (GCA) is under paddy, which requires more than 200 lakh litres per hectare of water for irrigation. The tube wells in Punjab are going deeper and deeper drawing water from even 300 – 400 feet at several places raising the pumping costs. However with the full economic offset of electricity costs in agriculture since 1997 and the effective rice procurement policy (74% rice procured in Punjab) in place, the demand for water shows no sight of any significant downturn. Thus, cultivating a water guzzler crop like Paddy in a water stressed state like Punjab appears to be an anomaly from the water sustainability outlook.

1.3.2 Sugarcane cultivation in Maharashtra

In the year 2014 and 2015, India witnessed the fourth consecutive drought in the last 115 years since 1900. According to the Ministry of Water Resources, around 68 per cent of the country is prone to drought in varying degrees, of which 35 per cent is drought prone (annual rainfall between 750 mm to 1125 mm) while 33 per cent is chronically drought prone (annual rainfall < 750 mm)[8]. Marathwada region of Maharashtra is one such chronically drought prone region which faced acute water shortage in the 2014-15 and 2015-16 droughts, with an annual rainfall deficiency of 33 per cent and 35 per cent respectively from the normal rainfall. A ripple effect to this was witnessed between 12th April to 9th August 2016 when special trains called *"Jaldoot Express"* had to transport almost 2595 lakh litres of water to Latur district of Marathwada at a state expenditure of Rs. 5.23 crores, to meet the drinking water shortage of the region (GoM, 2017) .

However it is of great concern to note that Marathwada region is also in the sugarcane growing region of Maharashtra, with almost 23 per cent share of sugarcane area in the state[9]. Sugarcane crop consumes almost three times more irrigation water than cotton, the major crop of the state. Ironically 100 per cent irrigation cover exists for sugarcane crop in

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6 http://eands.dacnet.nic.in/LUS_1999_2004.htm

7 As per the (CGWB, 2017), out of total 138 assessment blocks, there are 105 blocks were over exploited (groundwater stage >100%), 4 critical (>90 to <=100%), 3 semi critical (>70% to <=90%) and 26 safe <=70%).

8 http://wrmin.nic.in/forms/list.aspx?lid=312

9 http://mahaagri.gov.in/level3detaildisp.aspx?id=6&subid=11&sub2id=1

Maharashtra while cotton has only 3 percent irrigation cover. The overall 4 per cent area under sugarcane crop in the state thus consumes almost 64 per cent of the total irrigation water available. Latur district, one of the worst water scarcity affected region in the 2014-15 and 2015-16 drought of Maharashtra, recorded the highest share of sugarcane area (20 % in 2015-16) in the Marathwada region. This skewed irrigation-water allocation limits the scope for higher agriculture productivity and profitability for the other principal crops of the state, driving the agricultural development to a highly water unsustainable situation.

1.4 Scope, Limitation and Structure of Paper

Using the two case studies addressing water productivity issues of rice cultivation in Punjab and sugarcane cultivation in Maharashtra, the paper aims to analyze and provide policy suggestions to promote sustainability, productivity and profitability of Indian agriculture from the irrigation water use perspective. It is expected that the results of the study will flag the need to re-align the cropping patterns, especially of rice and sugarcane in sync with the water profile of the regions.

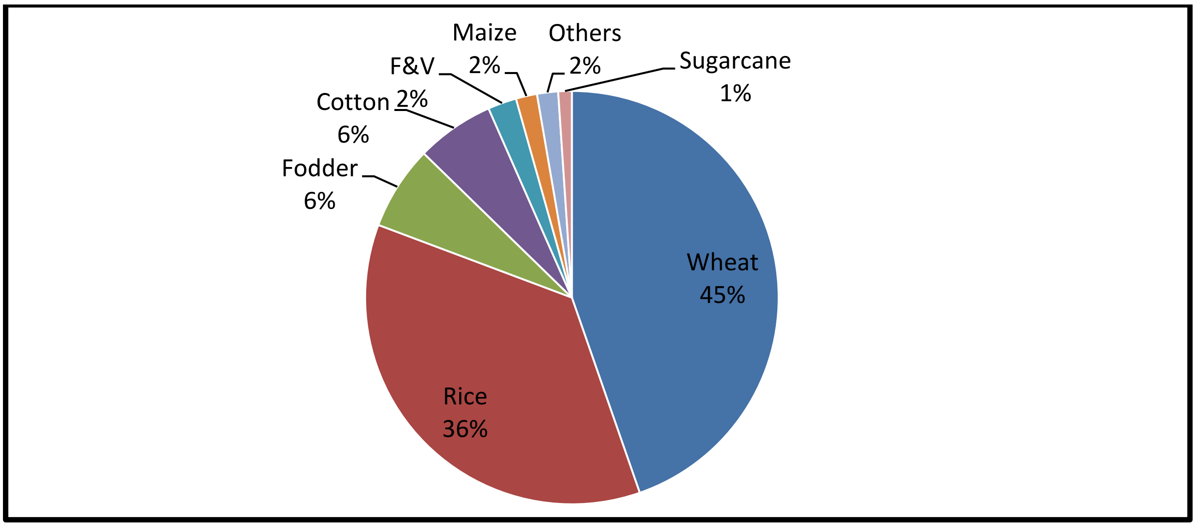
It may be noted that for sustainable agriculture, addressing soil health and climate change issues are also a very critical. However, we have not taken these issues in this paper and have concentrated mainly on water issues.

The paper is organized in the following manner: section 2 deals with the case study of Punjab, highlighting the issue of paddy cultivation in the midst of depleting ground water resource. Section 3 details the case study of Maharashtra, which presents a similar yet different story of unsustainable sugarcane cultivation in the water scarce state. Section 4 includes the conclusion and policy suggestions specifically emerging from the study as well as some supporting policies to achieve agriculture sustainability, productivity and profitability from the water use perspective.

2. Punjab: A case of rice cultivation in the midst of depleting water resource

Punjab with its largest contribution to wheat and rice to the Central Pool is the “food basket of the country”. More than 80 per cent of area in Punjab state is under agriculture with gross cropped area of 7.85 million hectare. Apart from wheat (45%) and rice (36%), fodder crops (6%), cotton (6%), fruits and vegetables (F&V) (2%), maize (2%) and sugarcane (1%) occupy major share in the GCA of the state (Figure 3).

Figure 3: Share of major crops in gross cropped area of Punjab (%) (TE 2013-14)



Source: (LUS, DES)[10]

The state records the highest irrigation ratio (98.5%) in the country with well developed irrigation infrastructure dating back to the green revolution era. It has been reported that over the last four decades, the traditional maize-wheat cropping pattern has been replaced by the wheat-rice cropping pattern, increasing the irrigation demand (Gupta, 2009). Rice being a water guzzler crop, consumes over 200 lakh litres of irrigation water per hectare, while maize consumes only one fifth of this quantity. For meeting the increased irrigation water demand, the canal irrigation system has also over the years gradually paved way to groundwater irrigation, with 81 per cent of gross irrigated area under the latter source in TE 2013-14 (Figure 4a). The high food production supported by intensive groundwater irrigation is incurring a huge cost to the state's ecology, especially due to paddy cultivation. This is evident from the prevalence of the over-exploited groundwater development stage[11] across the paddy growing region (Table 1). At present the groundwater development stage in Punjab is at 149 per cent (CGWB, 2017). While ground water is depleting at an alarming rate at the fresh water region (Central and Northern districts), severe water logging and soil salinity haunts the south-western parts of the state (Planning Commission, 2013). However the case study in our paper will focus on the declining groundwater issue and thereby the sustainability issue.

The economic offset of electricity cost in agriculture since 1997 also catalysed groundwater extraction for irrigation purpose, thereby triggering the rate of groundwater depletion (Figure 4b). About 76 per cent of the ground water assessment blocks in the state were in the over exploited stage[12] in 2011(Figure 5) compared to 53 per cent in 1999 and 45 per cent in 1984.

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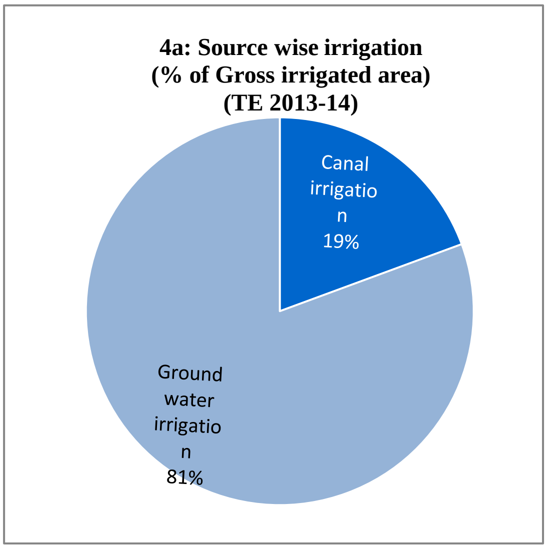
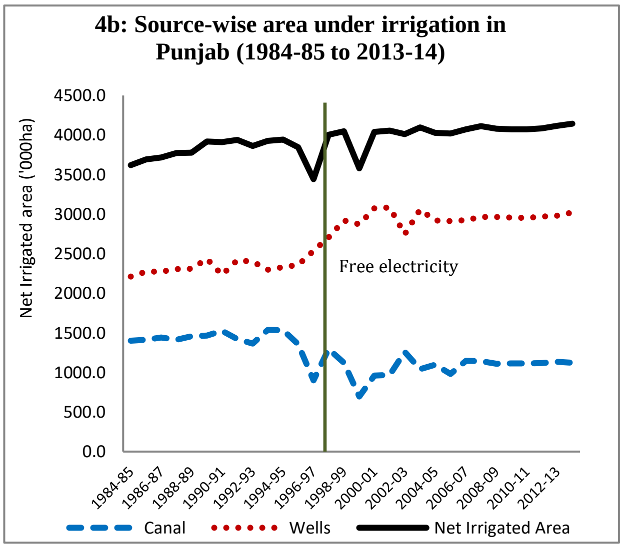
10 http://eands.dacnet.nic.in/LUS_1999_2004.htm

11 The groundwater development stage is defined as the ratio of annual ground water draft to net annual ground water availability expressed in percentage.

12 As per the Central ground water board (North western region, Chandigarh, 2016), out of total 138 assessment blocks, there are 110 blocks were over exploited (groundwater stage >100%), 4 critical (>90 to <=100%), 2 semi critical (>70% to <=90%) and 22 safe (<=70%).

Figure 4: Irrigation status in Punjab





Note: Gross irrigated area = 7.8 million hectare; Net irrigated area = 4.1 million hectare in TE 2013-14)

Source: (LUS, DES)[13]

[13] http://eands.dacnet.nic.in/LUS_1999_2004.htm

Table 1: District-wise stage of ground water development in Punjab

District	Region	Stage of groundwater development (%) (2011)	Share of rice area in GCA (of district/state@) (t/ha) (TE 2014-15)
Amritsar	Central	180	44
Barnala	Central	204	43
Fateh Garh Sahib	Central	210	15
Jalandhar	Central	231	40
Kapurthala	Central	234	43
Ludhiana	Central	167	43
Mansa	Central	208	22
Moga	Central	202	46
Nawan Shahr	Central	115	30
Patiala	Central	196	45
Mohali (SAS Nagar)	Central	103	26
Sangrur	Central	283	43
Tarn Taran	Central	182	45
Hoshiarpur	Kandi	102	20
Pathankot**	Kandi		28
Ropar	Kandi	110	26
Gurdaspur	Kandi (partly)	127	42
Bathinda	South West	119	20
Faridkot	South West	160	42
Fazilka*	South West		45
Muktsar	South West	69	27
Ferozepur	South West	147	48
State@		172	36

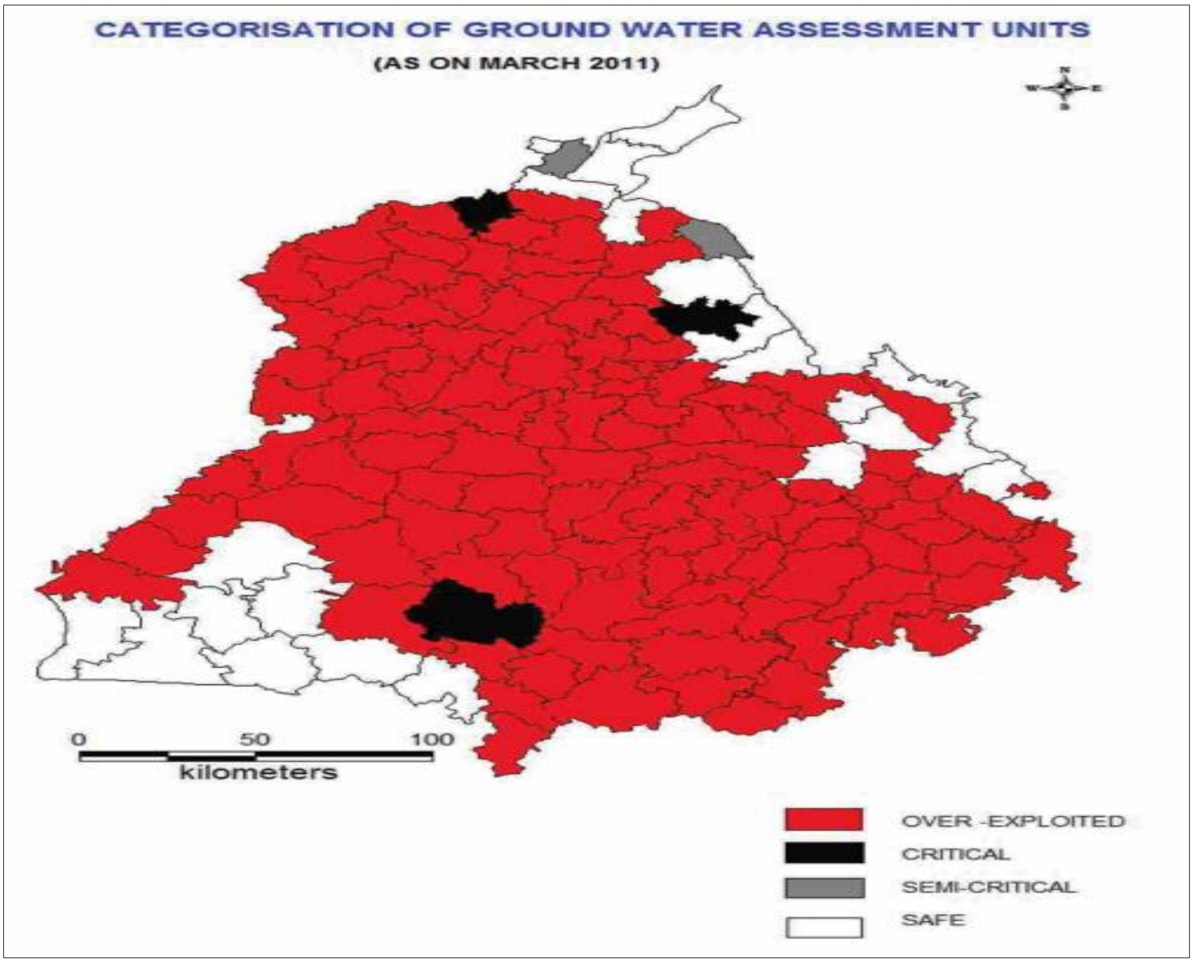
Note: *Fazilka was a part of Ferozpur before 2011 ; ** Pathankot was a part of Gurdaspur before 2011;

Map of Punjab given in Appendix 3

Source: APY, DES[14]; (CGWB, 2014)

14 http://aps.dac.gov.in/APY/Public_Report1.aspx

Figure 5: Map showing dark blocks of Punjab



Source: (CGWB, 2014)

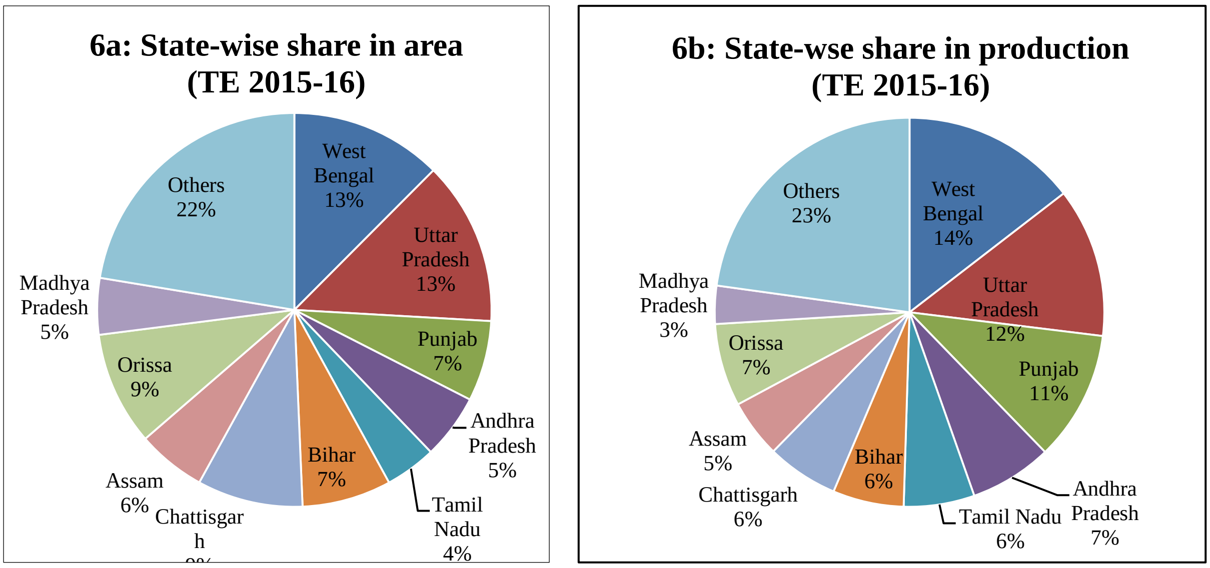
The recent ICRIER study on Punjab's agriculture reports that agriculture growth in the state, which stood way above the national average during the green revolution era, has shown a declining trend over the years and has come down to almost half of the all India average in the period 2005-06 to 2014-15 (Gulati, Roy & Hussain, 2017). It has been suggested in their study that in order to bring the state back on track, emphasis should be laid upon diversification from common rice, encouraging food processing industries and most importantly promotion of sustainable agriculture with respect to water use efficiency. Thus in the Punjab case study discussed here we have attempted to reason out why paddy cultivation is unsuitable in Punjab from water use perspective.

2.1 Productivity: Comparative land and water productivity of rice

2.1.1 Land productivity of rice across states

In 2015-16, although West Bengal, Uttar Pradesh and Punjab stood as the top three states in terms of area and production of rice in the country (Figure 6) but when compared in terms of land productivity (production per unit area), Punjab topped pushing West Bengal and Uttar Pradesh to the 4th and 5th position respectively (Figure 7) (DES, 2016).

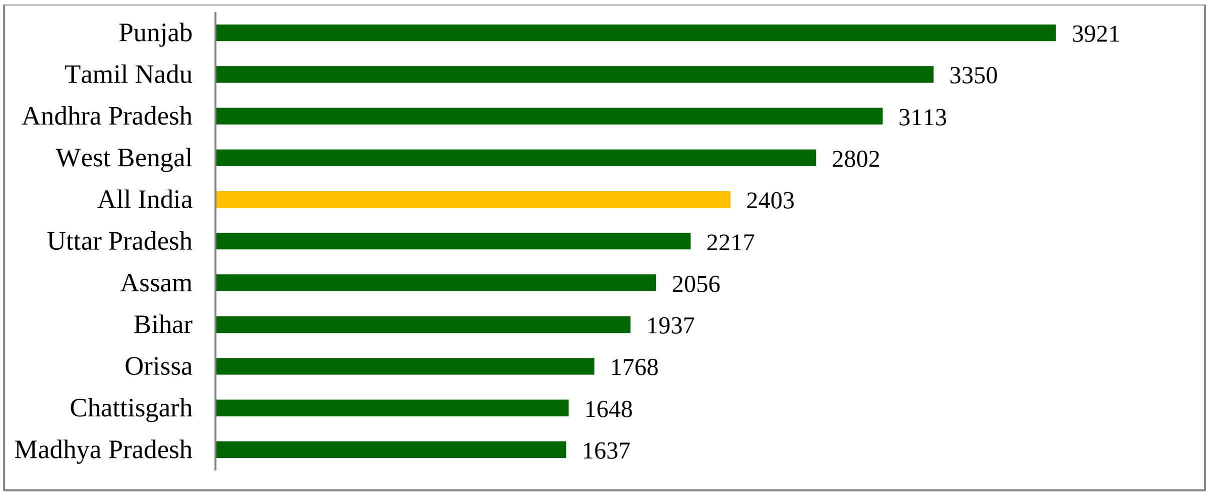
Figure 6: Top ten rice growing states in India (based on area and production)



Source: APY, DES[15]

This is obvious as Punjab has 100 per cent irrigation cover under rice, when compared to the other major rice growing states (Appendix 4). At all India level on an average only 59.6 per cent rice area is under irrigation cover. So in order to capture the sustainability issue, the comparison needs to be attempted from a different perspective measuring productivity in terms of unit irrigation water consumed, which can be called as the "*irrigation water productivity*".

Figure 7: Land productivity in major rice growing states in TE 2015-16 (kg/ha)



Source: APY, DES, 2016

15 http://eands.dacnet.nic.in/PDF/Foodgains&Oilseeds,2015-16.pdf

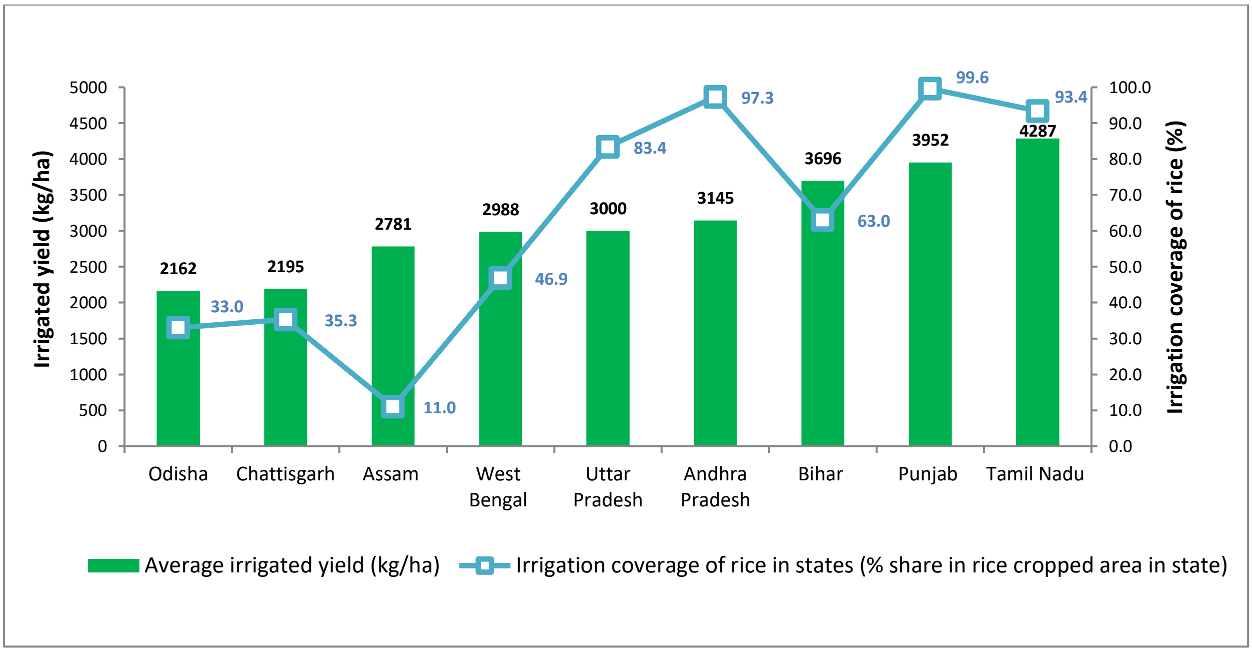
2.1.2 Irrigation water productivity of rice across states[16]

Considering the different levels of irrigation coverage under rice across states, it should be noted that the irrigation water productivity needs to be estimated taking into account specifically the irrigated yield[17] of the crop. When compared across major rice growing states, Tamil Nadu tops the list in irrigated yield of rice (Figure 8).

Depending upon the hydrological suitability of the region in terms of annual rainfall the irrigation water requirement for paddy cultivation is different across the states (Table 2). Punjab, Uttar Pradesh and Andhra Pradesh owing to their low rainfall status, depend highly on irrigation water when compared to the West Bengal, Assam Bihar and Odisha bestowed with ample rainfall, yet equally exposed to the vagaries of monsoon. In Tamil Nadu the major rice growing season is the Kharif season, which does not coincide with its high rainfall of North East monsoon, demanding more irrigation water for the crop cultivation.

The irrigation water productivity across the states is displayed in Figure 9. Punjab slips to the bottom in comparison to the other major rice growing states indicating that Paddy in Punjab is certainly not a wise man's crop in terms of irrigation water productivity. It can be seen that West Bengal can produce almost 42 kg of rice from one lakh litres (equivalent to 100 cubic metres) of irrigated water while Punjab can produce only 19 kg of rice from the same quantity of water. More precisely, Punjab consumes almost two times more water than West Bengal and almost three times more water than Bihar for producing the same one kg of rice. Bihar tops the ranking with highest productivity of rice per unit of irrigation water consumed (56 kg/ lakh litres).

Figure 8: Irrigated yield and irrigation coverage of rice crop across states (2013-14)



16 Methodology with formula used in calculation given in Annexure 1

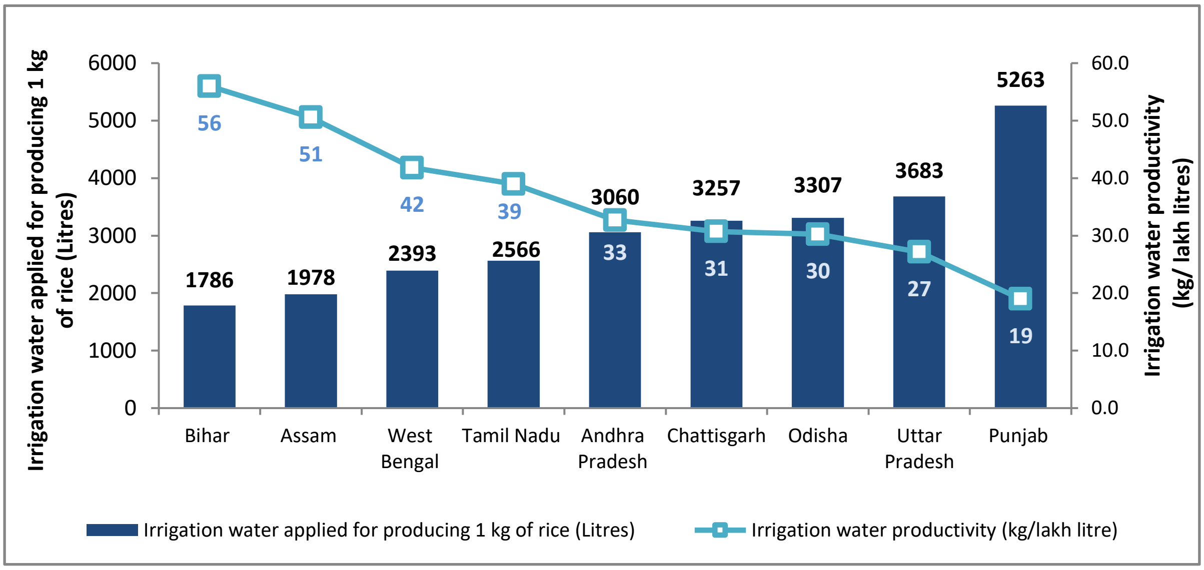
17 Irrigated yield and irrigated land productivity have been used synonymously in the paper and convey the same meaning (crop output produced per unit of irrigated land area)

Table 2: Irrigation water requirement of rice across states

States	Average Irrigation water requirement (lakh litres/ha)	Percentage area under (TE 2015-16)		Normal monsoon Rainfall (mm)	Remarks
		Kharif	Rabi		
West Bengal	71.5	73.6	23.7	1390.4	Regions bestowed with rainfall.
Assam	55.0	83.6	16.4	1523.4	
Bihar	66.0	97.3	2.7	1027.6	
Tamil Nadu	110.0	91.5	8.5	317.0	Majority of area under Kharif season but TN is bestowed with NE monsoon thus increasing irrigation water need due to low rainfall in Kharif season
Punjab	208.0	100.0		491.9	Low rainfall region (especially during rice growing season) demanding more irrigation
Uttar Pradesh	110.5	99.5	0.5	846.1	
Andhra Pradesh	96.25	65.7	34.3	608.9	

Source: Irrigation water requirement: Kharif price report 2013-14; Percentage area under Kharif and Rabi season: DES, APY, 2015-16; Normal monsoon rainfall (average of rainfall between the period 1951 to 2000): IMD

Figure 9: Irrigation water productivity (kg/lakh litres) and irrigation water applied for production of 1 kg of rice (Litres) (2013-14)

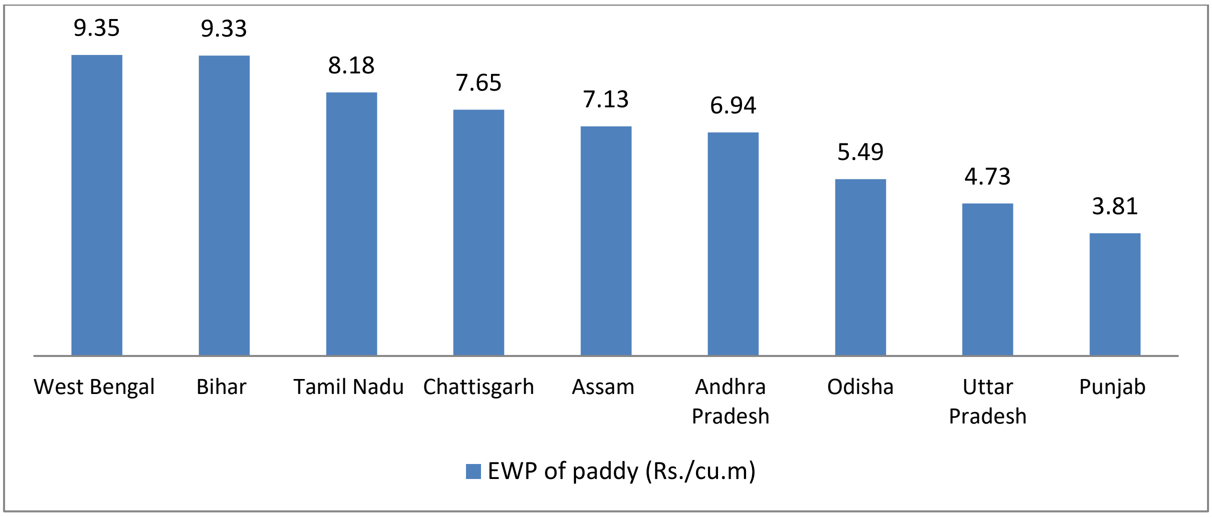


Note: The water productivity in terms of the incremental yield due to irrigation for states like Andhra Pradesh, Tamil Nadu, West Bengal, Bihar and Assam where the irrigation ratio for rice is less than 95% is included in Appendix 5

Source: (NSSO, 2013-14); Author's calculation using data from (CACP, 2013-14), Status paper of rice, UP.

The economic productivity of paddy (irrigation water productivity expressed in monetary terms) again shows Punjab to be in the lowest position among the other states compared. West Bengal tops among the rice growing states followed by Bihar both having economic productivity almost thrice that of Punjab (Figure 10). All other states, except Bihar (Rs.11.16/kg), Assam (Rs.9.45/kg), , Odisha (Rs. 12.17/kg) and Uttar Pradesh (Rs.11.68/kg), received farm harvest price (averaged across major growing season) higher than the minimum support price (MSP)[18] of Rs.13.10/kg for kharif marketing season (KMS) in 2013-14. Owing to the higher IWP, despite fetching a lower farm harvest price, the economic water productivity (EWP) of paddy in the eastern states of Bihar and Assam are higher. This indicates the hydrological suitability of the crop in these states with respect to irrigation water application

Figure 10: Economic productivity of paddy based on irrigation water applied (Rs/cubic metre) (2013-14)



Note: FHP[19] of Punjab is taken as Rs. 13.45 per kg which is the FHP existing in 19 out of 24 districts cultivating paddy (as the state weighted average value of FHP was incorrect in the data source). For other states the FHP taken is the weighted average across major cultivating states.

Source: DES, 2013-14 [20]; (NSSO, 2013-14); Author's calculation using data from (CACP, 2013-14)

This result thus points to the fact the states with a lower land productivity recorded higher water productivity as well as economic productivity indicating their suitability for rice cultivation from the sustainability point of view. Hence it can be said that Punjab does not support sustainable paddy cultivation and hence need to shift its cropping pattern towards less water consuming crops.

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18 Minimum support price (MSP) of paddy (Variety: Common) in 2013-14 = Rs. 13.10/kg

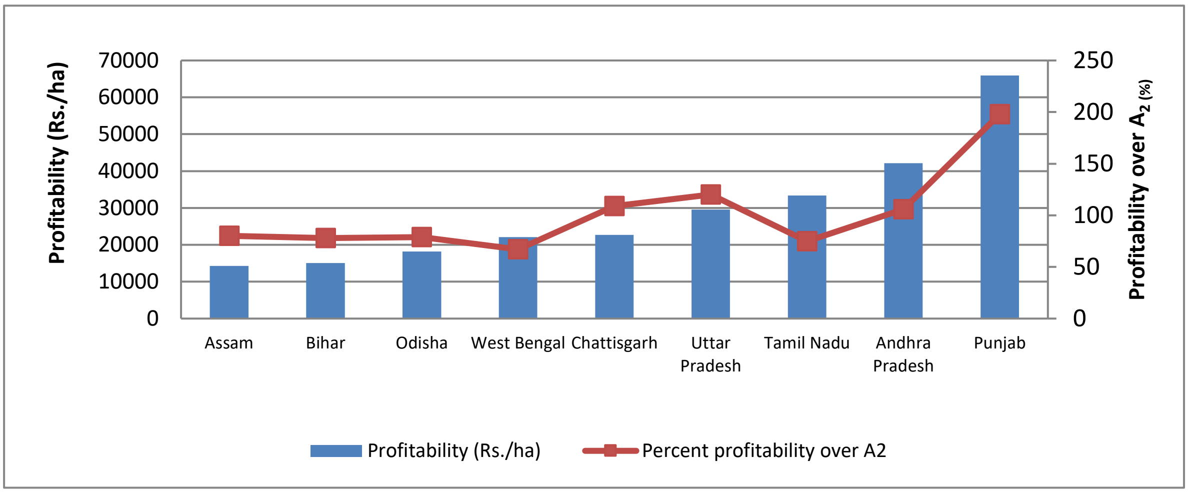
19 Farm Harvest Price (FHP) refers to the average wholesale price at which commodity is disposed off by the producer to the trader at the village site during the specified marketing period after the commencement of harvest (DES, MoA)

20 http://eands.dacnet.nic.in/fhprice/FHP2013-14.pdf

2.2 *Comparative profitability of rice across states*

Unfortunately, the states like Assam and Bihar with high irrigation water productivity do not have efficient procurement system for rice and hence their farmers often receive paddy prices which are way below the corresponding minimum support prices (MSPs). The net result of such a policy environment is that their profitability remains much lower (Figure 11). In Punjab since almost three-fourth of the rice being produced is procured, majority of the farmers receive assured MSP, if not more. Owing to 100 per cent irrigation cover and robust procurement policy for Paddy in Punjab, profitability of paddy cultivation over the farmer's paid out costs (Cost A2) is the highest for the state. And it is this high profitability which promotes the farmers to cultivate paddy crop despite the high social cost incurred from depleting water table, burning of paddy straw etc.

Figure 11: Profitability in paddy cultivation over paid out costs (cost A2) across major paddy growing states (Triennium average ending 2014-15)



Source: (CACP, 2017-18)[21]

2.3 *Sustainability: Promoting Sustainable water use*

Paddy has not been the traditional crop of Punjab. The increased irrigation infrastructure facilities since the green revolution era, the free electricity policy for agriculture since 1997, the favourable Government procurement policy of rice were the factors which have contributed towards the crop becoming an integral part of Punjab's agriculture. Though Punjab Government and farmers realize that paddy cultivation is not sustainable, yet the high profitability of the crop is making them reluctant for a shift in the cropping pattern. In order for the farmers to switch to any other crops, they need to be assured with similar profitability levels as that of the paddy crop.

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[21] CACP (2017-18). *Price Policy for Kharif Crops.* Ministry of Agriculture and farmers Welfare, Department of Agriculture Cooperation and farmers Welfare, Commission for Agricultural Costs and Prices. Government of India.

The enactment of Punjab Preservation of Subsoil Water Act, 2009 was initiated by the Punjab Government as a step towards promotion of sustainable water use. This act is directed towards delayed sowing (prohibited before 10^{th} May) and transplanting (prohibited before 10^{th} June) of the paddy crop with a view to save depleting ground water table. As Punjab agriculture is dependent on groundwater irrigation with ample power subsidy, the farmers have the tendency to start paddy cultivation almost a month earlier than the usual kharif season which starts with the advent of south west monsoon. This period is usually the hottest and driest period of the month demanding more irrigation water compared the usual season (Johl and Ray, 2002). This in turn has resulted in wastage of water for agriculture use in a large scale aggravating the ground water depletion. The act has been helpful in restricting the early cultivation of paddy, but is not enough to turn Punjab away from paddy or even to arrest depleting water table. Hence more focused steps need to be adopted for any significant turn-around.

The first and the foremost step towards this can be to reorient the policy of free power for agriculture and shift it towards Direct Benefit Transfer (DBT). More than 88 per cent of the tube wells in Punjab are electric operated which are running free of cost resulting in uneconomical and unregulated extraction of groundwater for agriculture use (GoP, 2015). In Punjab almost 27 per cent (Statistical abstract of Punjab, 2015) of the total electricity consumed went to agriculture sector in 2014-15, higher than the all India average share of 21 per cent. The subsidy on electricity for agriculture in Punjab came to around Rs. 6958 crores in 2013-14 and on per hectare of GCA the subsidy amount came around Rs.8863 (Planning commission, 2014) (Gulati, Roy & Hussain, 2017). The problem is not just the issue of subsidy burden to the State Government but also the form in which it flows and its ultimate effect. The power subsidy given to the farmers leads to reduction in their cost of cultivation, which in turn results in a lower MSP on paddy. During the TE 2014-15, almost 73 per cent of the rice cultivated in Punjab was procured by the Government at MSP to feed the central pool (DES, 2016). Thus the subsidy supposed to benefit the farmers actually benefits the consumers who purchase rice at the lower issue price. Rather than making electricity free, power subsidies may be transferred to farmer's bank account (DBT), thus providing the farmers incentives to reduce electricity and groundwater consumption.

Also for ensuring power and water use efficiency, electricity use must be metered and charged. The Punjab State Power Corporation Ltd has already joined the Ujjwala Discom Assurance Yojana (UDAY) in 2016 to improve the operational and financial efficiency of the Punjab DISCOM. Metering of the feeder and distribution transformers is one of the main aims of the scheme.

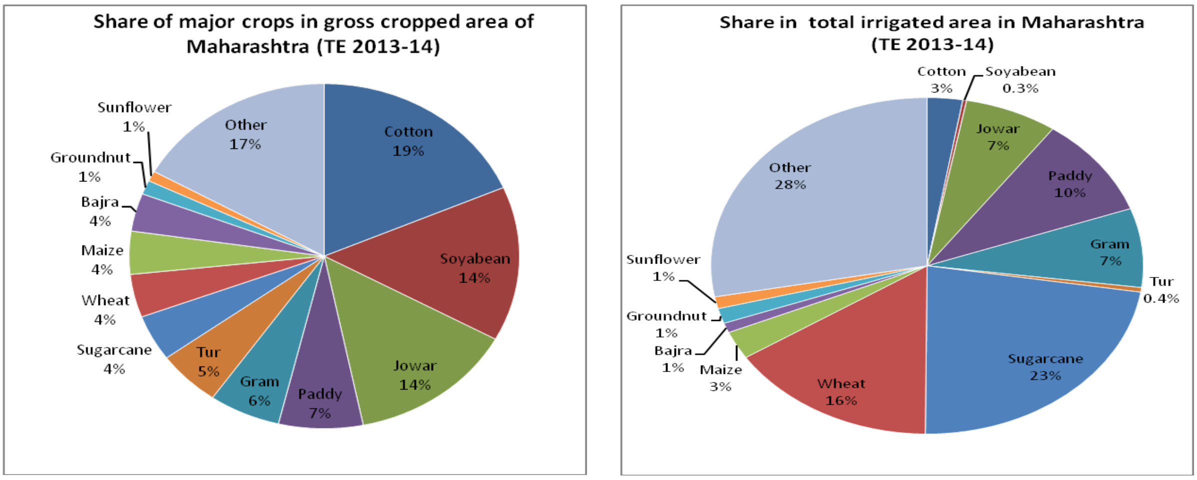
The next best step could be to adopt efficient irrigation methods to reduce water loss. There are recommendations that there is no need to keep paddy fields flooded all the time. One can irrigate paddy every three or four days in a manner that standing water is fully used before next irrigation. This itself can save almost one-fourth of irrigation water, and also power use. Pilot studies are also being carried out to understand the feasibility of drip irrigation technology in rice cultivation. The manufacturers of drip system who are carrying these pilots with Punjab Agriculture University, have recorded data from these pilots. Their claim is that it saves irrigation water by 66 per cent, reduce electricity consumption by 52 per cent and increase yield by 50 per cent.

Johl Committee had recommended crop diversification in Punjab way back in 1986. It has been suggested that if subsidies are given for shifting paddy area to other crops, the objective of crop diversification could be achieved easily. Further the source for the subsidy amount can be realized from the farmers by appropriately charging them for the power and irrigation water used (Johl & Ray, 2002). The ICRIER study on Punjab recently (Gulati, Roy & Hussain, 2017) also suggests diversification away from paddy to maize (corn), livestock and fruits and vegetables (F&V). Maize uses one-fifth of water needed for paddy irrigation. That means it can save 80 percent of power subsidy of the state on per ha basis when farmers shift from paddy to maize. This saving of power subsidy that will accrue to government, can be used to promote maize based value chains, from incentivizing feed mills, silage units, and starch factories based on corn. During TE 2014-15, the profitability (gross returns over cost A2) of Maize was Rs. 18693 per hectare, about 30 per cent less than that of paddy in Punjab. Farmers must be assured of at least same profitability for maize as in paddy, if not more. For this, if the state government has to intervene in maize markets for some time, it may do so to protect its depleting water table. The way will be to identify blocks where water table is worst affected, and encourage farmers to grow maize and procure it, if needed, and discourage procurement of paddy in those blocks. Further, Punjab has currently less than 3 percent area under F&V compared to 8 percent at all India level. Punjab can encourage farmers towards F&V duly supported by cold chains and processing units, but this process has to be demand driven, i.e., first identify the markets and then usher in change in the production systems. Only then Punjab farmers can raise their incomes and make agriculture sustainable and productive.

3. Maharashtra: A case of sugarcane cultivation in a thirsty state

Sugarcane in Maharashtra is a classic example of unsustainable cropping pattern in a water scarce state. The state has GCA of about 22.5 m ha (TE 2013-14). Of this only 19 percent is irrigated and the rest is rain fed (Appendix 7). Interestingly, while sugarcane which occupies less than 4 percent of GCA is 100 percent irrigated,- cotton which occupies 19 percent of GCA is only 2.7 percent irrigated (Figure 12, 13). Such a skewed irrigation cover results in massively skewed income distribution within agriculture. No wonder, most of the farmer suicides in Maharashtra take place in the cotton region. Soyabean and Jowar the second and third most cultivated crop in the state also have very meager area under irrigation of 0.3 per cent and 7 per cent respectively. A substantial increase in productivity of these crops can be achieved by bringing more area under irrigation and breaking the distortion in irrigation share under various crops in Maharashtra.

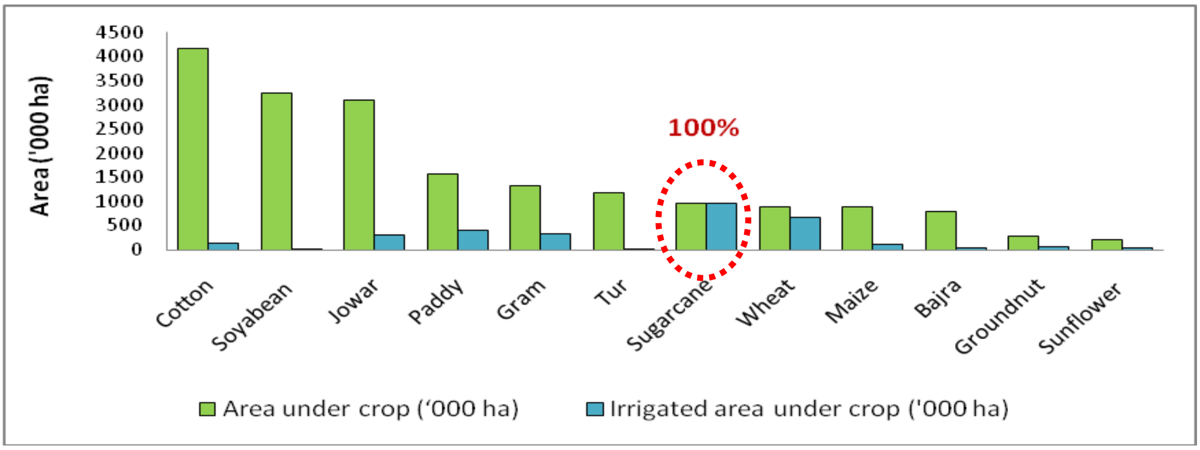
Figure 12: Share of major crops in gross cropped area and gross irrigated area (TE 2013-14)



Note: Gross cropped area (GCA) = 22.5 million hectare; Gross irrigated area (GIA) = 4.26 million hectare

Source: (LUS, DES)[22]

Figure 13: Cropped area and irrigated area under the major crops in Maharashtra (TE 2013-14)



Source: (LUS, DES)[23]

The Kelkar committee report (GoM, 2013) has classified the divisions of Maharashtra into different categories based on the water availability per hectare of cultivable area, according to which the Aurangabad division (Marathwada region) and the Amaravati division (part of Vidharbha region) are categorized as water deficit regions (**Table 3**). This indicates that the two revenue divisions lag behind in the per hectare availability of stored water, necessitating the need for efficient water saving technologies as well as re-cycling and re-use of water. It is however paradoxical to note that almost 23 per cent share (Figure 14) of the sugarcane grown

22 http://eands.dacnet.nic.in/LUS_1999_2004.htm

23 http://eands.dacnet.nic.in/LUS_1999_2004.htm

in Maharashtra is in Marathwada region, pointing towards the stress that is created by the crop on the irrigation status as well as agriculture of the region.

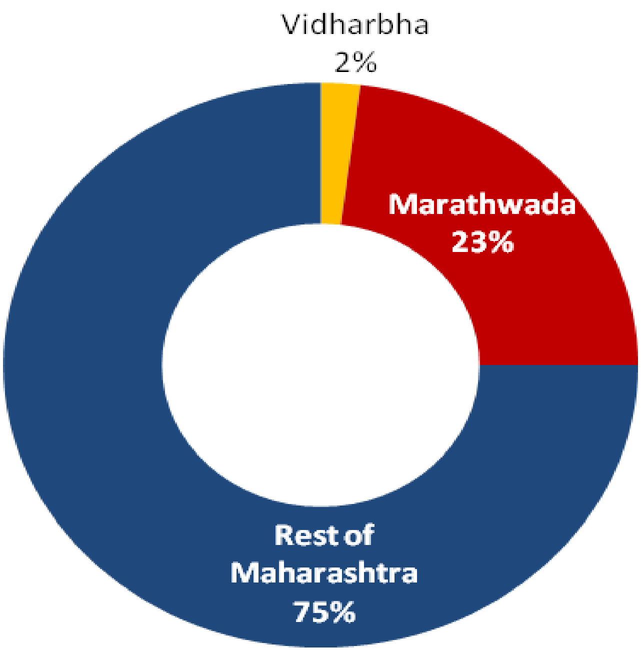
Table 3: Classification of regions based on annual water availability per hectare

Division	Region	Annual Water Availability (cum/Ha)	Category as per Water availability
Aurangabad	Marathwada	**2572**	**Deficit**
Amravati	Vidharbha	**2755**	**Deficit**
Nagpur		8968	Abundant
Konkan	Konkan	35968	Very high
Nashik	Western Maharashtra	4352	Normal
Pune		7176	Normal
Maharashtra		7267	Normal

Note: The annual water availability is calculated by evaluating the surface irrigation water available from different irrigation projects per unit of cultivable command area covered under the projects.

Source: (GoM, 2013)

Figure 14: Share of sugarcane area across the different regions (%) (TE 2015-16)



Note: Districts covered in each region given in Appendix 6

Source: (Department of Agriculture, GoM)[24]

Maharashtra has not been a traditional sugarcane growing region in India. It was mainly due to the preference given to the cooperatives in Industrial Policy (licensing policy from 1948 to 1998) that led to the rapid development of the sugar factories especially in the cooperative

[24] http://mahaagri.gov.in/level3detaildisp.aspx?id=6&subid=11&sub2id=1

sector of Maharashtra**.** Under the Industrial Policy Resolutions of 1948, the Government of India started giving preference to licensing of new sugar factories in the cooperative sector. This policy was reemphasized in all the subsequent Industrial Policy Resolutions made by the Government till the de-licensing of the sugar industry in 1998[25].

Though in terms of sugarcane productivity per unit area Maharashtra boasts its top position, but whether the state is actually suitable for cultivation of the crop in midst of water stress is a concern from the sustainability front. In the light of this persistent question we analyse, in a similar approach that we adopted in the preceding Punjab case study, the suitability of cultivating the water guzzler sugarcane crop in Maharashtra, a state where a *Jaldoot express* had to shuttle to quench the thirst of its people.

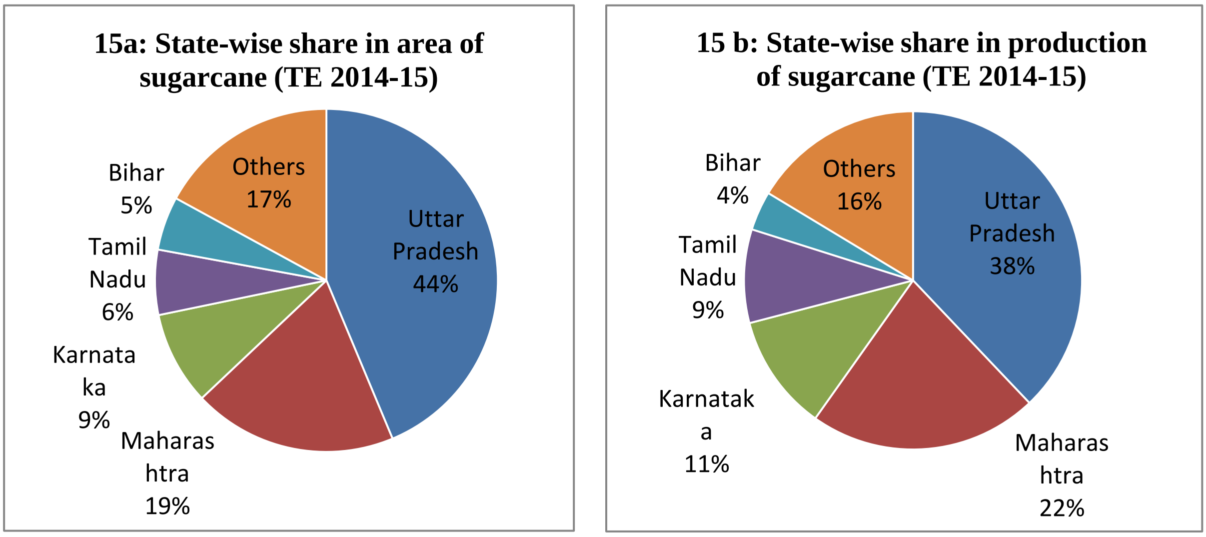
3.1 Productivity: Comparative land productivity of sugarcane

3.1.1 Land productivity of Sugarcane

The top five sugarcane-growing states in terms of area and production are displayed in figure 15a and 15 b respectively. It may be noted that Uttar Pradesh ranks first in terms of area (44%) and production (38%) of sugarcane in India, followed by Maharashtra with a share of 19 per cent and 22 per cent in all India area and production status. The other major sugarcane states are Karnataka, Tamil Nadu and Bihar. The land productivity (production per unit area) of sugarcane across these states is displayed in Figure 16. Among these states, Tamil Nadu has the highest land productivity (103 t/ha) for sugarcane. Sugarcane productivity in Uttar Pradesh (61 t/ha) and Bihar (52 t/ha) are seen to be far below Karnataka (89 t/ha) and Maharashtra (80 t/ha). Thus on comparison with respect to per unit of land cultivated, sugarcane in Tamil Nadu, Karnataka and Maharashtra are more productive compared to Uttar Pradesh and Bihar. These values however creates the impression that the traditional sugarcane growing sub tropical region comprising of Uttar Pradesh and Bihar is less suitable for cultivation of the crop whereas the adopter tropical region comprising of Maharashtra, Tamil Nadu and Karnataka turn out to be the more productive producers of the water guzzler crop.

[25] Detailed history of sugarcane and sugar in India is included in Annexure 2

Figure 15: Top 5 sugarcane growing states in terms of area and production (TE 2014-15)



Source: (APY, DES)[26]

A detailed look at the efficiency of the productivity of sugarcane across these states in terms of duration of crop, recovery rate of sugar and irrigation water use tells us a very different story. It is important to account for these parameters in order to understand the regional suitability of crop from the sustainability point of view.

3.1.2 Adjusted land productivity of Sugarcane

The sugarcane-growing region in India, broadly classified as the tropical and sub tropical sugarcane regions exhibit significant differences in the characteristics of the sugarcane crop cultivated in these regions (Table 4). It can be seen from the table that a wide variation exists in the duration of crop, irrigation water intake and sugar recovery rate[27] across the states. The average duration of the crop in Uttar Pradesh is around 9.6 months while in Maharashtra it is 13.5 months. The number of standard irrigation requirement for the sugarcane crop per hectare in Maharashtra, Karnataka and Tamil Nadu are about 26, 34 and 40 respectively compared to the lesser requirement in Uttar Pradesh (7.6) and Bihar (5). The sugar recovery rate also shows high variation among the states. Maharashtra has the highest recovery rate of 11.3 per cent while Bihar and Tamil Nadu are at 9 per cent. The varying recovery rate reflects the variation when the sugar productivity (sugar being the final product of sugarcane) per unit area and per unit of irrigation water applied in sugarcane cultivation is compared across states (CACP, 2015-16). The high recovery rate of sugar and irrigation water requirement for the crop cultivation in Maharashtra may be due to the longer duration of the crop. Hence land productivity of sugarcane across the states without adjusting for these parameters is not comparable. There is need to adjust the production per unit area with respect to duration and recovery rate of sugar and then compare the adjusted land productivity calculate the irrigation water productivity to enable meaningful comparison.

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26 http://eands.dacnet.nic.in/APY_96_To_06.htm
27 Sugar recover rate: The percentage of sugar produced from total quantity sugarcane crushed.

Table 4: Sugarcane characteristics across major sugarcane growing states

States	Region	Duration of crop (months)	Irrigation water requirement in Lakh Litres/ha (equivalent no. of standard irrigations)*	Sugar recovery rate (%) TE (2014-15)
Uttar Pradesh	Sub tropical regions	9.6	57.2 (7.6)	9.40
Bihar		12.0	37.5 (5)	9.03
Andhra Pradesh	Tropical regions	10.9	202.5 (27)	9.60
Maharashtra		13.5	196.1 (26.2)	11.30
Karnataka		13.1	256.0 (34.1)	10.73
Tamil Nadu		10.8	297.0 (39.6)	9.00

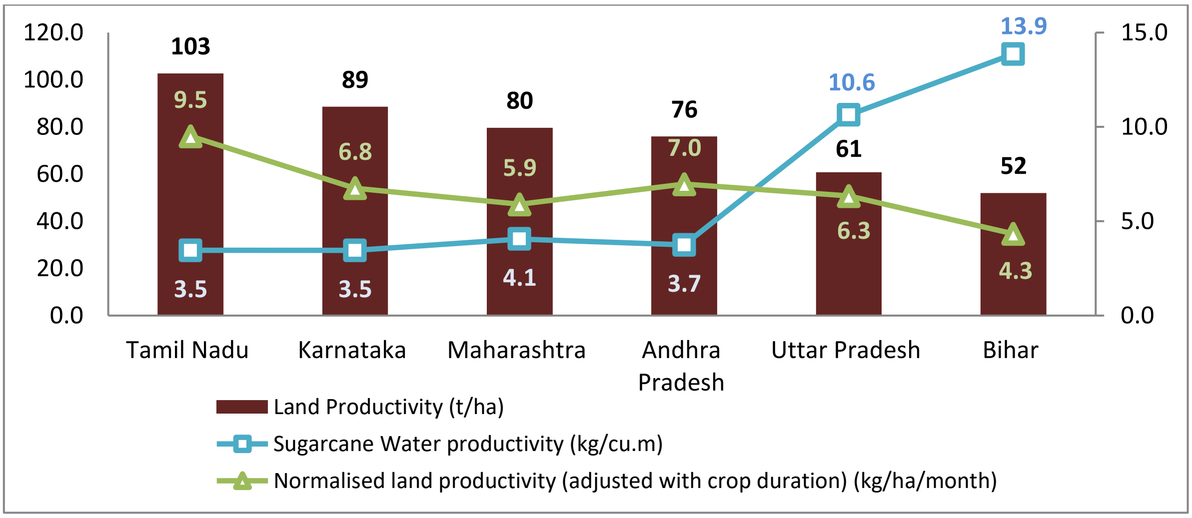
*Note: Number of standard irrigation refers to the number of times a farmer provides irrigation water to the crop in a crop-season. Each irrigation is provided at a depth of 7.5 cm per hectare

Source: (CACP, 2015-16)

3.1.3 Irrigation water productivity and Economic water productivity: Comparison across states

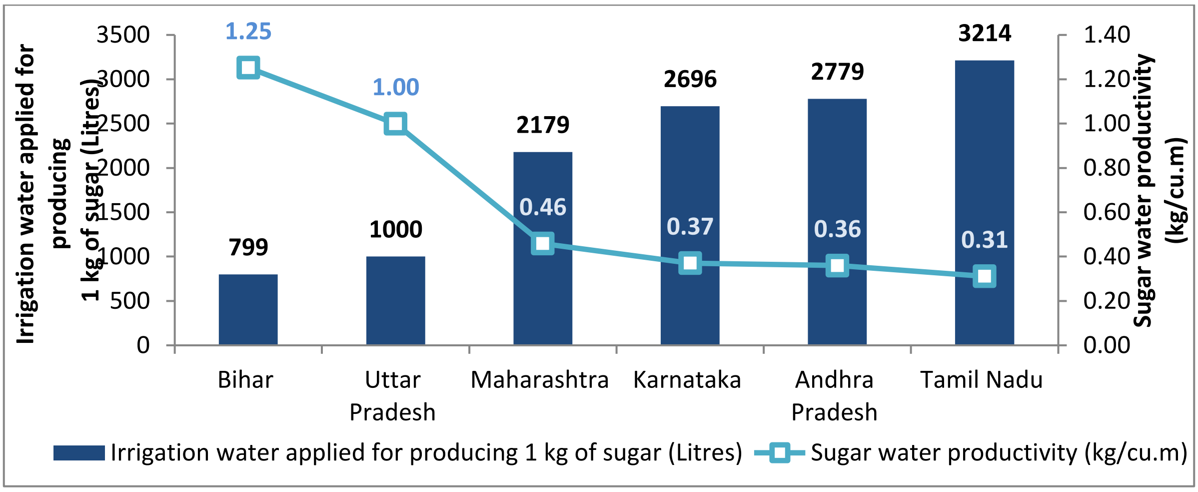
The irrigation water productivity shows that Bihar and Uttar Pradesh have more than twice the productivity of Tamil Nadu, Maharashtra and Karnataka (Figure 16). Bihar records the highest irrigation water productivity (13.9 kg/cu.m) and lowest is observed for Tamil Nadu and Karnataka (3.5 kg/cu.m) and this ranking is seen to be in exact contradiction to the land productivity values of the states.

Figure 16: Comparison of sugarcane land productivity, normalized land productivity and irrigation water productivity across the major sugarcane growing states



The irrigation water productivity of sugar isestimated after adjusting the land productivity of sugarcane with irrigation water applied and recovery rate. The comparison of the estimates across major states shows that Bihar (1.25 kg/cu.m) and Uttar Pradesh (1.00 kg/cu.m) are at par and more efficient than Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka (where productivity is less than one-third that of the sub-tropical states). Thus for production of 1 kg of sugar three to four times more irrigation water need to be applied in the sub tropical regions of Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra when compared to the tropical regions of Uttar Pradesh and Bihar (Figure 17).

Figure 17: Irrigation water productivity of sugar and irrigation water applied for production of 1 kg of sugar (TE 2014-15)

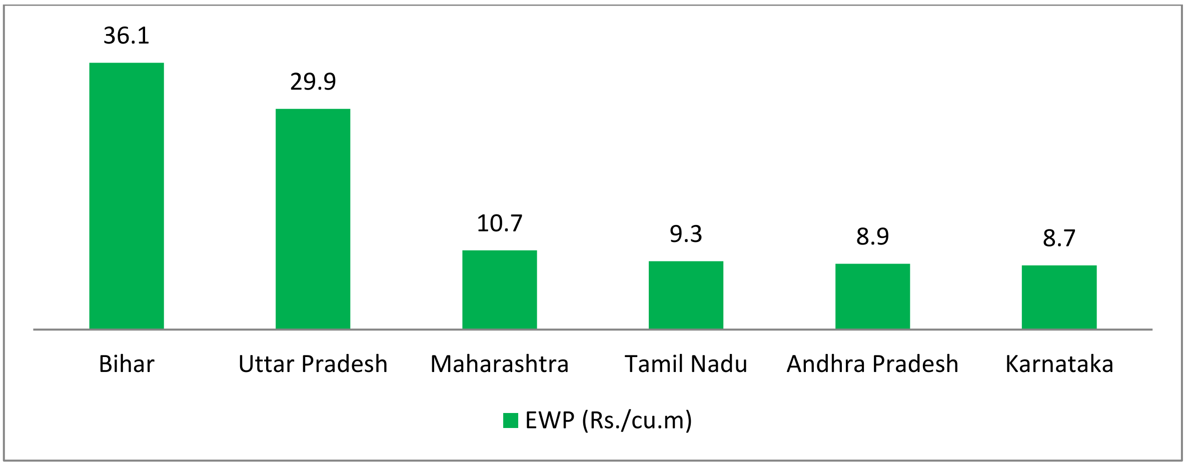


Source: Author's calculation using data given in CACP (2015-16) and Directorate of Economics and Statistics[28]

Considering the price existing (FRP/SAP) in the major states under consideration (Appendix 8), it can be observed that Uttar Pradesh and Bihar outstand Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka in terms of economic productivity (irrigation water productivity expressed in monetary terms) also (Figure18). In Bihar, one cubic metre of irrigation water applied produces sugarcane worth Rs. 36, while in Maharashtra it produces sugarcane worth Rs. 10.7 and in Karnataka as low as Rs. 8.7. Thus it is established that the traditional sub tropical sugarcane region is more efficient in terms of sugarcane and sugar productivity than its tropical counterpart.

Though the central Government fixes the cane price with respect to an average recovery rate of 9.5 per cent termed as the "Fixed and Remunerative Price" (FRP), yet varied pricing mechanism called the "State Advice Price" (SAP) is followed by many states like Uttar Pradesh, Tamil Nadu, Haryana, Punjab and Uttarakhand. This has lead to the competitive populism of the pricing mechanism where farmers are the end sufferers in most cases. For instance, the mounting up of cane arrears particularly in Uttar Pradesh is one ill effect of the SAP affecting the farmers.

Figure 18: Economic water productivity of sugarcane in terms of irrigation water applied across the states (Rs./cu.m) (2014-15)



Source: Author's calculation using data given in (CACP, 2015-16)

3.1.4 Economic productivity (in terms of irrigation water use) of major crops in Maharashtra

A similar incomparability exists when we compare the land productivity across the different major crops grown in Maharashtra. The land productivity, duration and water requirement of major crops in Maharashtra is given in Table 5.

As in the previous section, the irrigation productivity of crops after adjusting the crop duration is calculated to bring out comparable results. But owing to the variations in the weights of the crop output (for example sugarcane and cotton have huge variation in the physical weight of output which is incomparable), it is always suitable to express the irrigation productivity of crops in monetary terms which can be called as economic productivity (with respect to irrigation water use). In Figure 19, it can be seen that crops like cotton, arhar and groundnut which are usually grown in rainfed condition (cotton with 3%, arhar with 2% and groundnut with 21% irrigation cover) in Maharashtra, have almost twice the economic water productivity of sugarcane, when grown under irrigated condition. The economic water productivity of cotton is found to be 1.9 times higher than sugarcane in Maharashtra, but it can go up to 2.9 times (Figure 19) if we consider the incremental yield of irrigated cotton in Gujarat where the irrigation coverage in cotton (56%) is highest in the country. And this is what we expect if water can be saved from sugarcane and given to cotton in Maharashtra. Among the other crops compared except sunflower, all other crops produce higher value of output than sugarcane per unit of irrigation water applied in one hectare. Unlike the case of sugarcane, providing two to three protective irrigations in pulse crops and oilseeds can ensure higher productivity without compromising the principle of sustainable water use.

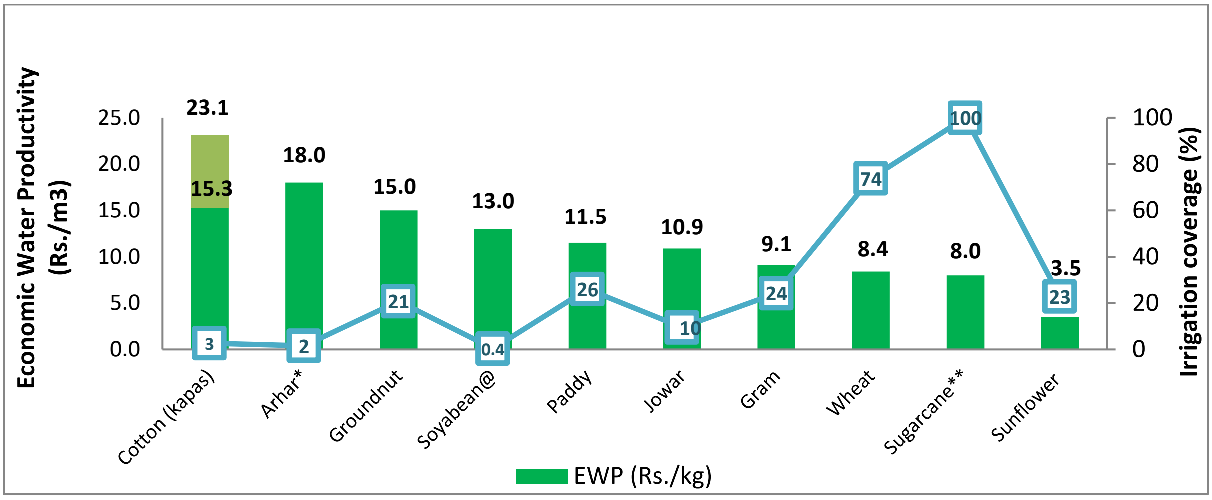
Table 5: Land productivity, duration and water requirement of major crops grown in Maharashtra

Crops	Land Productivity (kg/ha) (2010-11)	Irrigated yield (kg/ha) (2010-11)	Duration of crop (months)	Irrigation water applied (cu.m/ha)*	Farm Harvest price (2010-11) (Rs./kg)
Sugarcane**	89000	89000	13.5	18750	1.68
Sugar $	10021	10021		18750	25.93
Paddy	2661	3724	4.5	3750	11.53
Wheat	1761	1824	5.0	3000	13.84
Groundnut	1289	1394	4.6	2250	24.27
Jowar	851	1148	4.0	2250	21.29
Gram	904	1010	6.0	2250	20.23
Soyabean@	1581	1498	3.5	2250	19.57
Arhar*	750	1079	7.0	2250	37.48
Sunflower	613	358	4.0	2250	21.8
Cotton (Kapas)	966	1488	6.0	4500	46.12
Cotton (Kapas)^	966	2251	6.0	4500	46.12

Note: Irrigation water applied for different crops taken as given in Price policy for Sugarcane, CACP, 2014-15. Number of standard irrigation = Irrigation water requirement (cu.m/ha) ÷ [7.5 *100] ; 75% of the water used in sugar processing comes from sugarcane crop (extracted juice used for processing). Hence the water requirement for sugar is assumed to be equal to that of sugarcane. Recovery rate of sugar in 2010-11= 11.26%; 2010-11 was the latest year for which irrigated yield for all crops were available. * Since arhar/tur is cultivated as a rainfed crop in Maharashtra, the irrigated yield in Gujarat is taken as proxy. @ Since Soyabean is cultivated as a rainfed crop in Maharashtra, the irrigated yield in Rajasthan is taken as a proxy **Sugarcane prices correspond to Fair and Remunerative Price (FRP) of 2010-11. $Sugar price correspond to Ex-mill sugar price for 2010-11 *(Source: CACP, 2017-18); Source: (Department of Agriculture, GoM)*[29]. ^Irrigated yield of cotton corresponds to that of Gujarat. In Gujarat with 56% irrigation coverage., the incremental yield due to irrigation is 2.33 times that of unirrigated yield, which has been taken here as the existing upper limit for incremental yield in cotton due to irrigation.

[29] http://mahaagri.gov.in/level3detaildisp.aspx?id=6&subid=11&sub2id=1

Figure 19: Economic water productivity (EWP) of major crops with respect to irrigation water applied (Rs./cu.m) (2010-11)



Note: The irrigation water requirement considered for sugarcane in Figure 15 and Figure 16 are different (as mentioned in section 3.2.1) considering effectiveness of comparison. Also the data period are different in the two cases. ($^{\$,*,**,@}$ denotions as given in note of table 5)

Source: Author's calculation

Thus sugarcane is not the most efficient crop in Maharashtra as far as irrigation water application is concerned.

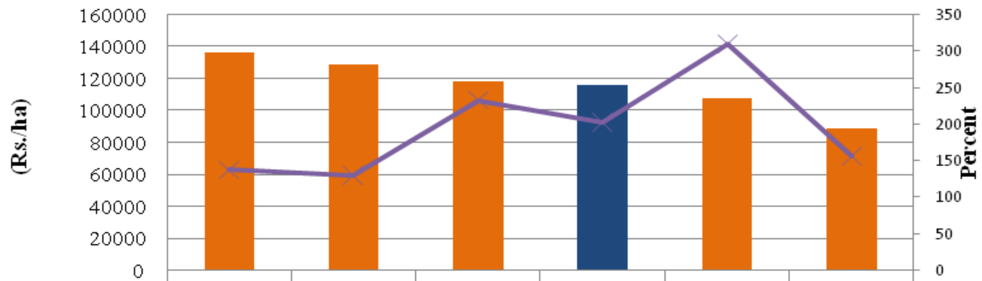
3.2 Comparative profitability of sugarcane (across states and among crops)

The profitability of sugarcane is compared across the major producer states and with the major crops grown in Maharashtra. The profitability used in the study corresponds to the gross returns from the crop over cost A_2 (based on the cost concept of Commission for Agricultural Cost and Prices (CACP)). The concept of cost A_2 is used as it gives account of all the cost paid in cash and kind by the farmer, excluding all the imputed costs, thus giving an account of the actual cost paid off by the farmer. The rate of return over the cost A_2 is also used for the comparison of profitability.

The profitability of sugarcane is also compared across the major crops cultivated in Maharashtra. Being a fully irrigated crop, the profitability of sugarcane will be higher than the rain-fed crops. It is known that productivity of a crop increases with irrigation, which is substantiated in the Kharif and Rabi price reports of CACP (CACP, 2016-17a) (CACP, 2016-17b), according to which at all India level, with every 10 per cent increase in the productivity, the real cost of production decreases by 1 percent for paddy, 2.9 percent for groundnut, 0.1 for jowar, 5.3 percent for soyabean, 4 percent for arhar, 3.4 percent for cotton, 2.5 percent for sunflower 3.7 percent for gram and 3.3 percent for wheat. Hence it may be said that with irrigation productivity increases which in turn results in increase in profitability.

The figures 20a and 20b respectively represent the profitability of sugarcane across the states before and after adjusting for the crop duration. Before adjusting the crop duration the profitability was found to be highest for Maharashtra (Figure 20a). Due to the shorter duration of crop, the irrigation water applied for sugarcane cultivation in states like UP is relatively lesser compared to Maharashtra. On adjusting the profitability of sugarcane across states with their respective crop duration Tamil Nadutops the list followed by UP and Maharashtra . Thus it can be said that the cultivation of comparatively shorter duration sugarcane crop in states like UP bestowed with better water endowments is more profitable when compared to Maharashtra.

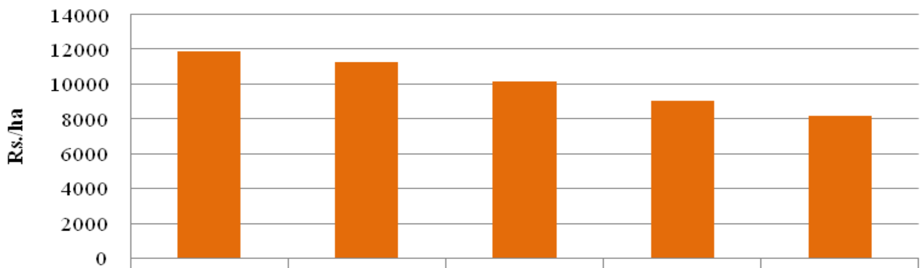
Figure 20a: Profitability across major sugarcane growing states (Rs./ha) (TE 2013-14)



	Maharashtra	Tamil Nadu	Karnataka	All India	UP	AP
Gross returns Over A2 (Rs./ha)	136854	128707	118856	115998	108092	88964
% over A2	137	129	233	202	311	157

Source: (CACP, 2015-16)

Figure 20b: Per month profitability across states (Rs./ha*month) (TE 2013-14)

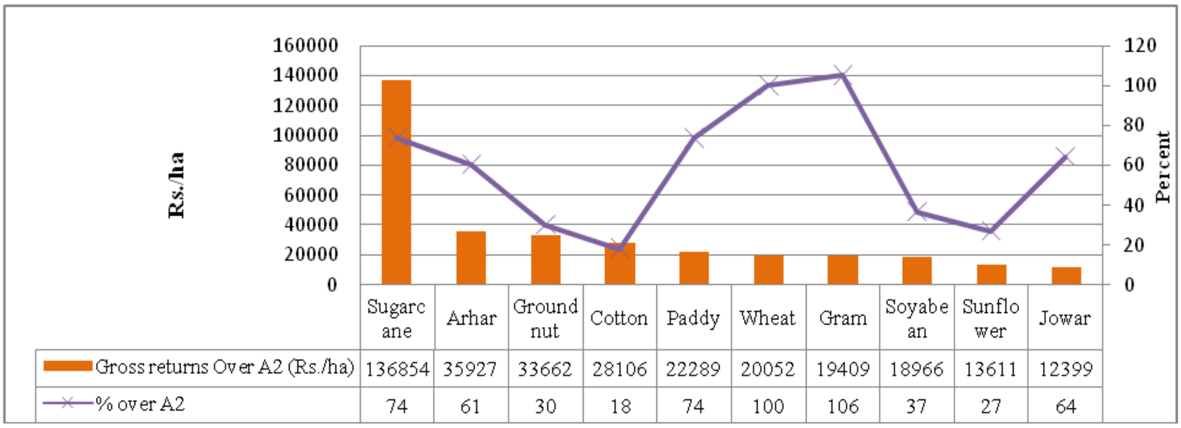


	Tamil Nadu	UP	Maharashtra	Karnataka	AP
Per month profitability (Rs./ha)	11917	11260	10137	9073	8162

Source: Author's calculation based on data from (CACP, 2015-16)

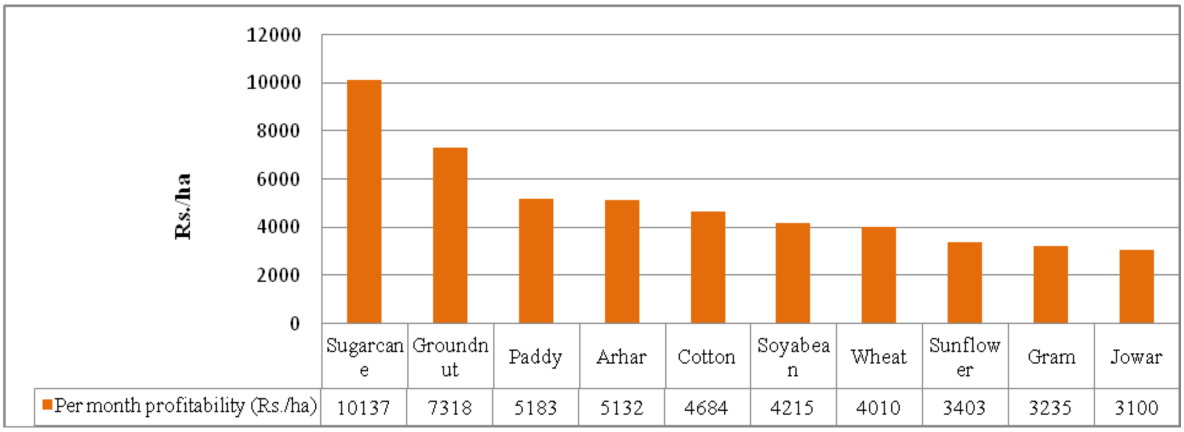
When we compare the profitability among the crops in Maharashtra, we find that sugarcane crop has higher profitability than the other major crops both before and after adjusting for the crop duration (Figure 21a and 21b). This is mainly due to the 100 per cent irrigation cover in sugarcane. If the irrigation cover for other crops is increased, their yield will increase subsequently, reducing to some extent the gap in their profitability with sugarcane.

Figure 21a: Profitability across crops in Maharashtra (Rs./ha)(TE 2013-14)



Source: (CACP, 2016-17a) (CACP, 2016-17b) (CACP, 2016-17)

Figure 21b: Per month profitability for different crops in Maharashtra (Rs./ha*month) (TE 2013-14)



Source: Author's calculation based on data from (CACP, 2016-17a) (CACP, 2016-17a) (CACP, 2016-17)

3.3 Sustainability of water use in sugarcane cultivation

As discussed in section one, over 64 per cent of irrigation water is diverted to sugarcane cultivation in Maharashtra, which occupies only 4 per cent of the total cultivated area. The widely practiced method of irrigation in sugarcane is the flood irrigation method which has an application efficiency of only 65 per cent resulting in a water loss of almost 35 per cent. A shift in cropping pattern towards less water consuming crop can save huge quantity of water for irrigation which can be used for increasing the irrigation cover under other crops thereby increasing their productivity and profitability.

However Maharashtra state has prospered with sugarcane cultivation and has good infrastructure in terms of processing industries, research and development institutions etc. The farmers and the economy as a whole has not been warming up to the idea of changing the cropping pattern which ultimately leaves us with the need for exploring options for better water management practices like the micro irrigation technology. The micro-irrigation systems namely drip system and sprinkler system exhibits almost 90 percent and 85 per cent efficiency respectively, bringing down the water loss during application to a tremendous level (Appendix 2). Studies have reported that drip irrigation system, which is the suitable micro irrigation technique for sugarcane crop, saves up to 65 per cent of water used for irrigation over the traditional flood irrigation method apart from other added benefits (Table 6).

Table 6: Benefits of drip irrigation technology in Sugarcane

Benefits	Quantity saved/ gained over conventional irrigation method		
	Source of data: JISL	Source of data: Others*	Source: From NMMI report, 2014**
Water saving	65%	44%	20%#
Yield increase	33%	20%	39%
Fertilizer saving through fertigation	25%	-	29%
Power saving	-	44%	38%
Excess labour	-	Negligible	5.26%

Source: (JISL); (Narayanamoorthy, 2004); ** (NMMI, 2014); # (NMSA, 2014)*

Ensuring piped water facility connecting the dams and the micro irrigation system in the fields may reduce water loss and increase the conveyance efficiency and application efficiency leading to almost 90 per cent overall water use efficiency.

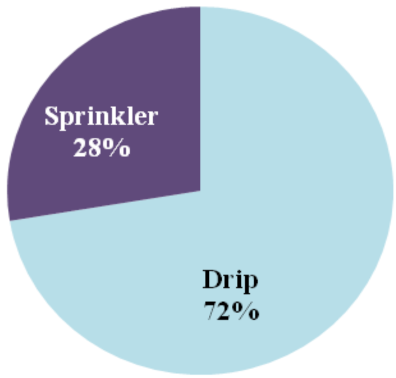
3.3.1 Drip irrigation system in sugarcane in Maharashtra

The area brought under micro irrigation in Maharashtra up to 2015 is 1.89 million hectares (Department of Agriculture, GoM)[30], out of which 72 per cent of the area is under drip irrigation and the remaining 28 per cent is under sprinkler irrigation (Figure 22)

Up to 2014-15, only 22 per cent of sugarcane area had been brought under drip irrigation in Maharashtra, accounting for 17 per cent of the total area under drip irrigation in the state. Out of the 2.25 lakh hectares of drip irrigated sugarcane area in the state, 70 per cent is in Western Maharashtra, followed by 29 per cent in Marathwada and one percent in Vidharbha (Figure 23a). However the proportion of drip irrigated to non-drip irrigated sugarcane area is highest in Marathwada region (30%), followed by Western Maharashtra and Konkan region (20%) and Vidharbha region (11%) (Figure 23b).

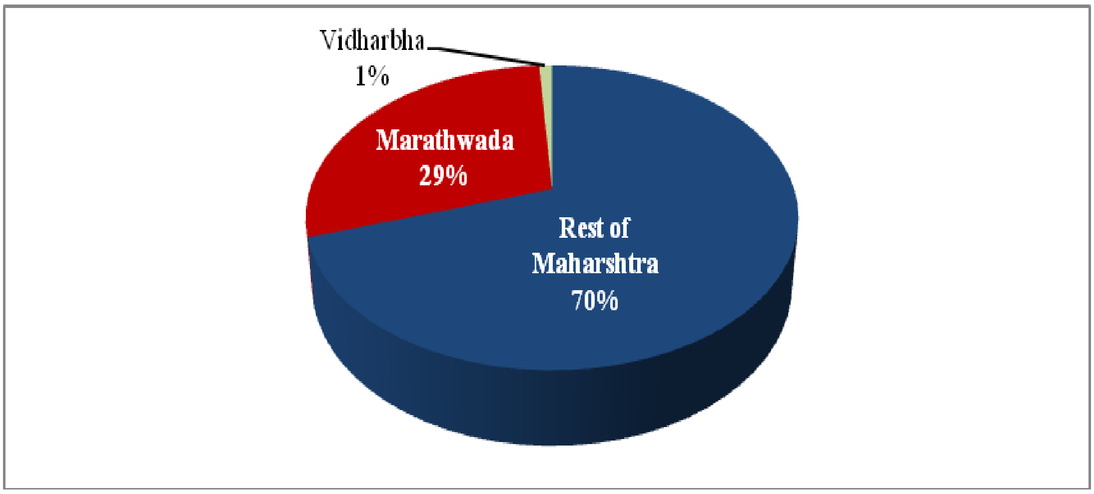
[30] *Based on data collected from Micro Irrigation Scheme Implemenation, Department of Agriculture, Pune, GoM.*

Figure 22: Share of area under drip and sprinkler irrigation in Maharashtra (%)



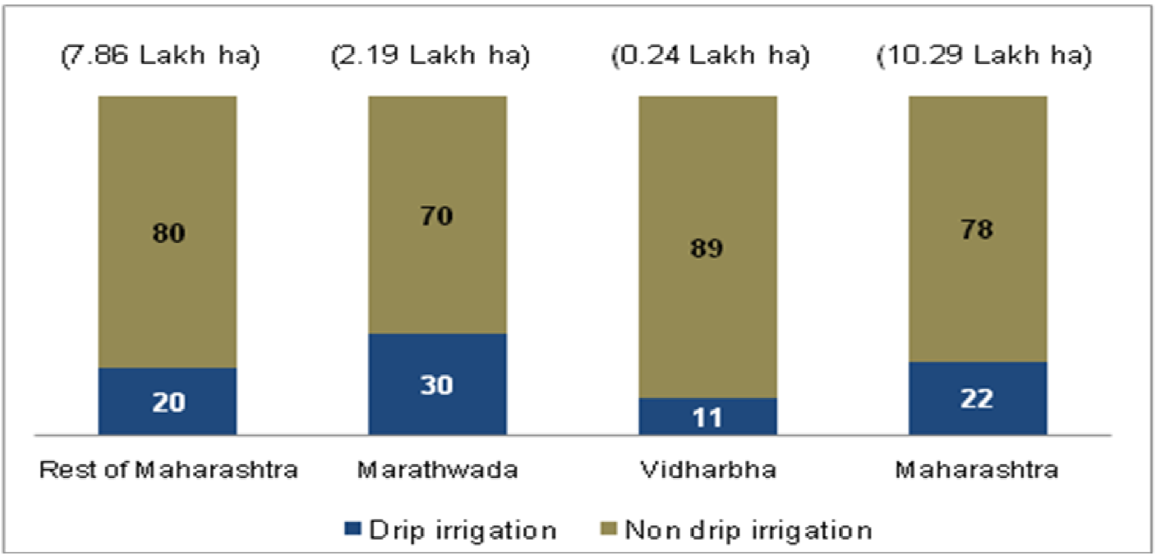
Source: Based on data collected from Micro Irrigation Scheme Implemenation, Department of Agriculture, Pune, GoM.

Figure 23a: Share of drip irrigated sugarcane area across the regions in Maharashtra



Source: Based on data collected from Micro Irrigation Scheme Implemenation, Department of Agriculture, Pune, GoM (Data is from 1986 to March 2015)

Figure 23b: Proportion of sugarcane area under drip irrigation and non-drip irrigation within the regions of Maharashtra (2014-15)



Note: Area under sugarcane pertains to 2014-15 and Area under drip-irrigated sugarcane is the cumulative data from 1986 to March 2015; Figures in parentheses represent the area under sugarcane across the regions in 2014-15.

Source: Based on data collected from Micro Irrigation Scheme Implemenation, Department of Agriculture, Pune, GoM

The Government of India has been working on enhancing water use efficiency in the agriculture sector through implementing Centrally Sponsored Scheme (CSS) on Micro-irrigation. The CSS was launched by the Department of Agriculture, Co-operation and Farmer's Welfare, Ministry of Agriculture on 20th January 2006. Under the scheme subsidies were provided to the farmers from centre and state for the adoption of the technology. The scheme has been modified several times over the years and on July 1st 2015 micro irrigation was included as a component (per drop more crop) under the PMKSY (Pradhan Mantra Krishi Sinchayee Yojana) scheme. There is also a mandate that at least 10% of the command area created using PMKSY - Har Khet ko pani component must be covered under micro/ precision irrigation.

Maharashtra state has been following the central scheme unlike other states like Andhra Pradesh, Haryana etc., which provide additional state level subsidy for the promotion of micro irrigation technologies to the farmers. The pattern of subsidy given through the central scheme is enumerated in appendix 9. Recently, the Government of Maharashtra has targeted towards bringing an additional 3.05 lakh hectare of sugarcane crop under drip irrigation in the next two years and further making drip irrigation mandatory for the crop after 2019 using interest subvention scheme under NABARD.

The analysis of the economic feasibility of adopting drip technology in sugarcane crop in Maharashtra shows that in majority of the cases discussed even in the absence of subsidy drip irrigation technology proves to be a feasible option for water saving for the farmer (Annexure 3). However owing to the high initial investment cost associated with the installation of the technology, subsidies become imperative for its adoption by small and marginal farmers.

The summary of the cases considered and given in Annexure 3 is briefed below:

- The BCR of drip irrigation in sugarcane comes to be higher than 1 even without subsidy intervention in most cases.

- BCR <1 when useful life of drip system = 5 years and incremental yield of sugarcane (on using drip irrigation over conventional flood irrigation method) = 20 per cent, initial investment = Rs. 151906 per hectare and the farmer is investing by taking a loan at 12% ROI. NPW in the above case is negative value. Thus it shows adoption of drip irrigation in this particular case is not feasible for the farmer.

- In all cases where BCR>1, within a period of 3.5 years the total cost incurred can be repaid even without subsidy.

Further water saved by using drip irrigation technology can be used for bringing additional land under irrigation for other principal crops of the region resulting in a multiplier effect in increasing the income of the farmers, through increased productivity of crops under irrigated condition. For instance, the water saved through drip technology in 1 ha of sugarcane area can bring an additional 2.29 ha area under conventional irrigation and double this area, if drip irrigation is adopted in cotton. From this additional 2.29 ha irrigated area under cotton, if other things remain constant, output worth up to Rs. 1.95 lakh can be produced (considering FHP and yield data of 2014-15) (Annexure 4) .

The benefit foregone by farmers by adopting flood irrigation method in sugarcane was evaluated based on the concept of opportunity cost. Opportunity cost (or returns foregone) due to flood irrigation in sugarcane was analyzed by evaluating the returns obtained from the additional land under different crops that is brought under irrigation using the water saved from adopting drip irrigation in one hectare of sugarcane crop. The opportunity cost or returns foregone from alternate crops by using flood irrigation method in one hectare of sugarcane was found to range from Rs.47008 to Rs. 232535. (Annexure 4).

At around Rs. 85400 per hectare cost of installation of drip system, a total of Rs. 6832 crore will be required to bring 0.8 million hectare of sugarcane area under drip irrigation system in Maharashtra. A part of this amount (atleast 35 per cent) needs to be met through the subsidies given under the PMKSY scheme based on land holding size of the farmer (Appendix 9). During 2017-18 the revised budget allocation for Maharashtra under PMKSY micro irrigation scheme was only Rs.380 crore[31](only 5.56 per cent of total cost to be incurred).The overall funding in micro irrigation through budget allocation to PMKSY or floating micro irrigation bonds and provision of institutional support is essential to promote investment in drip irrigation.

[31] http://pmksy.gov.in/microirrigation/Archive/MIAllocation201718.pdf

4. Conclusion

It is increasingly realized that water is going to be a bigger constraint in Indian agriculture than even land. Given that India is going to be most populous nation on this planet by 2024, and its demand for food, feed, fiber is going to accelerate with rising per capita income, both land and water are going to be under tremendous pressure. India has over 17 percent of global population but only 2 percent of geographical area (11% of global arable land) and 4 percent of fresh water resources of this planet. Given the challenges emerging from climate change, which hint towards greater frequency and intensity of droughts and floods, India must focus not only on augmenting its utilizable water resources but more importantly on using scarce water resources more efficiently. The first and foremost thing in that direction is to change the mindset of our policy makers towards measuring water-productivity of agriculture, as agriculture today consumes 78 percent of fresh water resources. The inequity in irrigation water allocation among crops, with more than 60 per cent of it being diverted for cultivation of two water guzzler crops – sugarcane and paddy, add to distress in agriculture water use. Competing demands of water from rapid urbanization and industrialization cannot be met unless agriculture makes a paradigm shift in water use.

The case study of rice in Punjab and sugarcane in Maharashtra throws light on the issue of unsustainable agriculture water use prevalent in two regions with completely different water ecology. Punjab with 99 per cent irrigation cover is facing the issue of depleting groundwater and Maharashtra with just 19 per cent irrigation cover is affected by the issue of inefficient crop-water use.

In case of rice, Tamil Nadu and Punjab reports the high land productivity (kg/ha) for irrigated rice in India. However, when irrigation water productivity of irrigated rice crop is considered Bihar tops the list, producing almost 56 kg of rice from one lakh litres of irrigated water unlike Punjab which slips to the bottom producing just 19 kg. The economic water productivity also shows Punjab to be inefficient in paddy cultivation producing paddy output worth Rs. 3.81 per cubic metre of irrigation water applied relative to the eastern states of West Bengal and Bihar producing output worth three times that of Punjab from the same quantity of water applied. In the midst of the alarming rate of groundwater depletion and the low irrigation water productivity, paddy in Punjab is certainly not a wise choice. However, states with high irrigation and economic water productivity rankings (eastern states of Bihar, West Bengal, etc) report low profitability in comparison to water stressed Punjab. Due to the lack of efficient procurement system for rice farmers often get paddy prices way below the minimum support prices (MSPs), thus reflecting a lower profitability from the cultivation of the crop. On the other hand, the assured procurement policy along with the free electricity supply for agriculture in Punjab ensures ideal conditions for farmers in cultivating paddy crop despite high social cost incurred in terms of fast depleting water table, which will have negative impact on the welfare of the future generation in the state.

In case of sugarcane, owing to the wide variations existing in crop duration, sugar recovery rates and irrigation water applied across states, it is essential to normalize these factors before drawing realistic conclusions on the water productivity of the crop among the major cultivating states. Tamil Nadu has high sugarcane productivity per unit area (103kg/ha), but when irrigation water productivity is evaluated traditional sub-tropical sugarcane region comprising of UP and Bihar emerge to be more efficient. The irrigation water productivity in the traditional sugarcane region (UP and Bihar) is almost thrice that of the tropical region comprising that of Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh. More precisely, one cubic metre of water produces 1.25 kg of sugar in Bihar and 1 kg of sugar in UP while in Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu, as low as 0.46 kg, 0.37kg, 0.36kg and 0.31 kg of sugar are produced respectively from the same quantity of water. Economic water productivity of sugarcane in Bihar and UP are as high as Rs. 36 and Rs. 30 per cubic metre of irrigation water applied. While in Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka, EWP comes to Rs. 10.7, Rs. 9.3, Rs. 8.3 and Rs. 8.7 respectively per cubic metre of irrigation water. Similarly, on comparing the economic water productivity across major crops in Maharashtra, it is observed that cotton, tur and groundnut produce output with value twice that of sugarcane. Among the other crops compared except sunflower, all other crops produce higher value of output than sugarcane per unit of irrigation water applied in one hectare. These results clearly indicate that cultivation of a water guzzler crop like sugarcane stands out as a paradox in water stressed state like Maharashtra with just 18 per cent irrigation coverage. Hence there is a need to re align the cropping pattern keeping in mind the scarcity of irrigation water availability in the state. But due to the full irrigation coverage and higher profitability due to assured markets to sugar mills, sugarcane farmers are mostly reluctant to shift their cropping pattern to other crops. Thus there is a need to have innovative policies and technologies that can save water applied to sugarcane and divert the saved water to other less water intensive and more economically water productive crops.

Specific Policy emerging from study

1. Shifting water intensive crops to water abundant regions

The two most water intensive crops, rice and sugarcane, are being cultivated in large scale in some of the most water stressed regions of the country. The rice cultivation in water scarce north western parts of the country, particularly Punjab, needs to be reconsidered and must be shifted to the eastern regions like Bihar, West Bengal, Assam etc which report higher IWP and EWP. Further, the eastern states must increase their rice productivity per unit land area inorder to meet the loss in production in water stressed states like Punjab. Similarly sugarcane cultivation must shift to the traditional sub tropical regions like UP and Bihar having higher IWP and EWP to ensure sustainability. These changes are needed not as a zero-one game, but at margin, to restore the balance between irrigation water available and demand for that water by these crops, so that a sustainable cropping pattern can be encouraged in line with water availability.

2. Strengthening marketing opportunity and procurement policies

Punjab government as well as farmers do realize that paddy cultivation is not good for their future generations as water table is depleting fast. But the assured procurement of rice discourage the farmers to go for crop diversification. The farmers are ready to switch to any other crops provided their profitability is not less than what they have been getting through paddy cultivation. Promoting less water intensive maize crop linked to processing industry (for food and especially poultry feed) may ensure assured marketing opportunities to farmers, thus encouraging them to shift their cropping pattern from rice. On the other hand there is a need to strengthen the rice procurement policy in the eastern states to make paddy profitable there which may encourage shift in rice cultivation from Punjab to the eastern regions.

In **Maharashtra**, the farmers have been benefited by the sugarcane crop owing to the existence of well established sugar mills providing assured marketing opportunity to the farmers. The market needs to be set right for cotton, pulses like tur and oilseeds like groundnut having higher EWP and IWP than sugarcane, to encourage crop diversification and shift area from sugarcane. Market risks for these crops can be reduced by encouraging private sector to operate and hold stock, spurring futures market and calibrating the trade and tariff policies. Unless higher profitability is ensured for the other crops, farmers will be reluctant to shift their cropping patterns from sugarcane to other less water intensive crops. Sugarcane cultivation must be promoted in the water abundant subtropical regions of UP and Bihar. For this investment friendly climate must be created to set up new sugar mills and rejuvenate the sick sugar mills in states like Bihar having high potential for sustainable sugar production, but recording over 60 per cent of the established sugar mills to be non-operational or closed.

3. Implementing efficient price reforms in water and power use in agriculture

The pricing of water in India should be done such that it reflects its scarcity. In our country water pricing for agriculture is very inefficient with water charges for surface irrigation remaining almost nil in many states for decades. Similarly the highly subsidized agriculture power supply in many states like Punjab, Karnataka, Andhra Pradesh and latest in Telangana, have led to over exploitation of groundwater for irrigation. On the other hand in the eastern regions, there is acute inefficiency in timely availability of power supply leaving most of the land unirrigated. Thus efficient price and supply reforms need to be adopted in water and power sector to ensure sustainable irrigation water use. Water charges for surface irrigation must be raised so that at least the operation and maintenance cost is fully recovered.

4. Direct Benefit transfer of water and power subsidies

As mentioned above, water and power are highly subsidized in agriculture primarily with the aim to support farmers to increase the irrigation coverage under crop. This was a noble attempt from the Government to increase productivity of crops through improvement in irrigation coverage, but this has resulted in negative externalities arising from injudicious use of water resource. Thus there must be a reorientation in the subsidy delivery mechanism of these inputs. The price based subsidy existing for inputs at present must shift to income directed policies, wherein the input subsidies/benefits must be directly transferred to the farmer's account rather than getting reflected in the price of the particular input. This may also help farmers to afford the increased water and power charges, at same time encourage them to judiciously use these resources.

5. Rationing of irrigation water and power used in agriculture

In case the price reforms in water and power in agriculture cannot be implemented, we may focus upon rationing of water and power used in agriculture. The mechanism of rationing the available irrigation water will help to reduce the skewness in irrigation water application among crops. Each farmer must be allocated with definite volume of irrigation water from canal system (as in *warabandi* system in Punjab) per unit of cultivated area and any excess requirement of irrigation water (as for water guzzler crops like paddy and sugarcane) must be purchased from farmers cultivating less water intensive crops like pulses. This helps to incentivize farmers cultivating less water intensive crops in water scarce regions. For rationing power use in agriculture, the system of metering of feeder and distribution lines for irrigation must be ensured.

6. Adopting precision irrigation through micro irrigation system

Precision agriculture and water saving irrigation technology like micro irrigation must be looked upon as the stepping stone for achieving agricultural productivity, profitability and sustainability. Open canal system and flood irrigation existing in the country result in less than one-third of the water released from dams actually reaching crops. Micro irrigation technology (drip and sprinkler) with 85 to 90 per cent application efficiency can solve the issue to a large extent. Further, piped water facility connecting the dams and the micro irrigation system in the fields can reduce water loss and increase the overall water use efficiency to almost 90 per cent. This also ensures availability of pressurized water for effective operation of drip and sprinkler system in canal command areas.

Drip technology has been found to be an economically feasible option in ensuring "per drop more crop" in sugarcane in Maharashtra. Further water saved in the process could be diverted to the other crops maintaining water equity. At present 2.25 lakh hectares of sugarcane area has been brought under drip technology in Maharashtra. To promote farmers to adopt drip irrigation in the remaining 7.6 lakh hectares sugarcane area, implementation of the micro irrigation scheme (PMKSY) must be made through the sugar mills by making it mandatory for the mills to purchase cane from only those farmers who have adopted the drip technology. Recently, Maharashtra Government has come up with pilot schemes to increase area under drip irrigation in sugarcane by 2019, which will be implemented in association with sugar mills and with financial assistance from NABARD. Such policy measures must be adopted by other states also to ensure better water use. Apart from this, Maharashtra Government has formally adopted a policy of pressurized piped distribution system instead of open canal system[32] . This would minimize evaporation losses and would also do away with the need to acquire land for canals.

At an installation cost of Rs. 85400 per hectare, a total of Rs. 6832 crore will be required to bring 0.8 million hectare of sugarcane area under drip irrigation system in Maharashtra. If this amount is raised (through grant, loan and private investment) in two years and if water saved is diverted towards cotton crop, then by 2019 and additional 1.8 million hectare cotton

[32] https://www.maharashtra.gov.in/site/Upload/Government%20Resolutions/Marathi/2015090115513344 27.pdf

area can be brought under irrigation. Thus instead of investing large sums on major and medium irrigation schemes, having a gestation lag of 12 years, it is preferable for Government to invest in drip irrigation system with a pay-back period of less than 3.5 years.

Instead of publicizing micro irrigation as a water saving technology, it must be promoted as a yield augmenting technology with optimum resource use. Studies show that in sugarcane, drip system increases the yield of crop by 20 to 40 per cent, saves electricity for pumping by 38 to 45 per cent and fertilizers by 25 to 30 per cent. Pilot studies on drip irrigation in rice have reported water saving of 66 per cent, electricity saving of 52 per cent and increased crop yield of 50 per cent.

Thus drip irrigation in sugarcane will help to spread prosperity to those growing crops other than sugarcane, help increase the yield of sugarcane crop and above all promote sustainable development of agriculture. A win-win situation for all!

Other supporting policies

1. Efficient implementation and scaling up of schemes for drought proofing

Efforts are being taken up by the Maharashtra Government to make the state drought proof through schemes like Nanaji Deshmukh Krishi Sanjivani Yojana and Jalyukt Shivar Yojana. The Nanaji Deshmukh Krishi Sanjivani Yojana will be taken up by the state as a collaborative project with the World Bank, where in 70 per cent of the project cost (Rs. 4000 crore) will be borne by World Bank. The project aims at improving soil quality, developing climate resilient foodgrain varieties and most importantly effecting necessary cropping pattern changes to suit the water availability of the region. The project period extends between 2018-19 to 2023-24 and will be implemented in 5142 villages across 15 districts.

Jalyukt shivar which has been in practice since its inception in December 2014, was set up with the aim to make 5000 villages drought free every year, through water harvesting and groundwater replenishment, thereby making Maharashtra drought-free state by 2019. These schemes if successful in Maharashtra, may be scaled up and implemented in other water scarce states for drought proofing.

2. Promote cultivation of high yielding varieties of sugarcane

UP records sugarcane yield of 67 t/ha, even lower than the all India average of 71 t/ha, despite being the traditional sugarcane region and having highest share in sugarcane production in India,. Cultivation of improved sugarcane varieties like Co-0238 (cane yield = 84 t/ha in UP and 83t/ha in Bihar)[33] with higher cane yield will improve profitability of sugarcane cultivation in these water abundant states. The extension service for adoption of such HYV can be disseminated through the sugar mills.

[33] file:///C:/Users/Dr.%20Gayathri/Downloads/ImpactofCovarietiesinSubtropicalIndia-Seminar%20(1).pdf

3. Reforming trade policies to reduce virtual water export

Export of water guzzler crops results in virtual water export (export of water used for the production of the output), which is highly infeasible for water stressed country like India. The existing model of food trade within and outside India is that we export rice and sugar from water scarce states to water abundant states and globally import mostly the less water intensive crops like pulses and oilseeds. The existing trade pattern is unsustainable and needs to be corrected by reforming the trade policies in favour of import of water intensive crops and export of water efficient crop, which further needs to be contained by correcting power/irrigation water pricing. If this is not feasible, one can consider an export tax of, say 5 per cent on these commodities, especially rice, while allowing imports at zero or low duty. This will help to dovetail the objective of sustainable water use in agriculture in India's trade and tariff policy.

4. Lessons from Israel

Lessons can be learned from nations like Israel, where the penetration level of micro irrigation technology is 99 percent, in comparison to India, where it hovers around 13 per cent. Israel's proper water pricing policy and good water governance has resulted in the high adoption rate of micro irrigation in the country. In Israel every drop of water is owned by the state and priced taking into consideration the level of scarcity of the resource.

5. Solar irrigation

Promote solar power system to ensure assured and timely irrigation water availability for micro-irrigation. In the eastern regions of India where electricity supply is highly obsolete, irrigation using solar pumps may help to increase the irrigation coverage under crops and thereby higher productivity. "Solar crop" in presence of assured provision to feed-in the surplus power back to grid can additionally act as a source of income insurance to farmers. The challenge of acquiring land for setting up solar panel can be solved through innovative ideas like "Solar as third crop". Solar panels may be set up at a height of 15 feet from the ground on farmers' field as a third crop in addition to the standing kharif and/or rabi crop. The"Solar crop" in presence of assured provision to feed-in the surplus power back to grid, can additionally act as a source of income insurance to farmers at times of crop failure. The *Solar Pump Irrigators' Cooperative* Enterprise (SPICE) in Gujarat is yet another worthwhile model that can be followed and scaled up. Thus in the scenario of water stress faced by the country in order to achieve agriculture sustainability, profitability and productivity, judicious use of water through adoption of suitable cropping pattern, appropriate water and power pricing policies and precision irrigation technology like micro irrigation is imperative.

References

CACP. (2013-14). *Price Policy for Kharif Crops.* Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Commission for Agricultural Costs and Prices. Government of India.

CACP. (2016-17a). *Price Policy for Kharif Crops.* Ministry of Agriculture, Department of Agriculture and Cooperation, Commission of Agricultural Costs and Prices. Government of India.

CACP. (2017-18). *Price Policy for Kharif Crops.* Ministry of Agriculture and farmers Welfare, Department of Agriculture Cooperation and farmers Welfare, Commission for Agricultural Costs and Prices. Government of India.

CACP. (2016-17b). *Price policy for Rabi Crops.* Ministry of Agriculture, Department of Agriculture and Cooperation, Commission of Agricultrural Costs and Prices. Government of India.

CACP. (2016-17). *Price Policy for Sugarcane.* Ministry of Agriculture, Department of Agriculture and Cooperation, Commision on Agricultural Costs and Prices. Government of India.

CACP. (2015-16). *Price Policy of Sugarcane.* Ministry of Agriculture, Department of Agriculture and Cooperation, Commission for Agricultural Costs and Prices,. Government of India.

CGWB. (2014). *Dynamic Ground Water Resources in India (As on 31st March 2011).* Ministry of Water Resources, River Development & Ganga Rejuvenation, Central Ground Water Board. Faridabad: Government of India.

CGWB. (2017). *Dynamic Ground Water Resources of India (As on 31st march 2013).* Faridabad: Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India.

CWC. (2014). *Guidelines for Improving Water Use Efficiency in Irrigation, Domestic and Industrial Sectors.* Ministry of Water Resources, Central Water Commission. Government of India.

CWC. (2013). *Water and Related Statistics.* Water Resources Information System Directorate, Water Planning and Projects Wing, Central Water Commission. Government of India.

CWC. (2015). *Water and Related Statistics, Central Water Commission.* Water Resources Information System Directorate, Water Planning and Project Wing. Government of India.

DES. (2014-15). *Farm Harvest Prices of Principal Crops in India.* Ministry of Agriculture and Farmers Welfare, Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare. Government of India.

DES. (2016). *Agricultural Statistics At A Glance.* Ministry of Agriculture, Department of Agriculture & Cooperation. Government of India.

Gittinger, P. J. (1982). *Economic Analysis of Agricultural Projects* (2nd ed.). John Hopkins University Press.

GoM. (2017). *Economic Survey of Maharashtra 2016-17.* Mumbai: Directorate of Economics and Statistics, Planning Department, Government of Maharashtra.

GoM. (2014). *Report of the Comptroller and Auditor General of India on Management of Irrigation Projects.* Government of Maharashtra.

GoM. (2013). *Report on the High Level Committee on Balanced Regional Development Issues in Maharashtra.* Planning Department. Government of Maharashtra.

GoP. (2015). *Statistical Abstract Punjab.* Government of Punjab, Economic and Statistical Organisation. Economic Adviser to Government, Punjab.

Gulati, A., & Banerjee, P. (2016). Emerging Water Crisis in India: Key Issues and Way Forward. *Indian Journal of Economics, Special Centennial Issue* , 681-704.

Gulati, A; Roy, R; Hussain, S. (2017). *Getting Punjab Agriculture Back on High Growth Path: Sources, Drivers and Policy Lessons.* Indian Council for Reasearch on International Economic Relations (ICRIER), New Delhi.

Gupta, S. (2009). Ground Water Management in Alluvial Areas of Punjab. *Bhujal News Quarterly Journal*

JISL. (n.d.). *Why Drip Irrigation should be considered as Infrastructure Industry?* Retrieved from Jain Irrigation Systems Limited Website: http://jainpipe.com/PDF/Irrigation/why%20drip%20infrastucture.pdf

Johl, S. S., & Ray, S. K. (2002). *Future of Agriculture in Punjab.* Chandigarh: Centre for Research in Rural and Industrial Development.

Narayanamoorthy, A. (2004). Impact Assessment of Drip Irrigation in India: The Case of Sugarcane. *Development Policy Review* , *22* (4), 443- 462.

NHB. (2014-15). *Monthwise AnnualPrice and Arrival Report*. Retrieved from National Horticulture Board Website: http://nhb.gov.in/OnlineClient/MonthwiseAnnualPriceandArrivalReport.aspx?enc=3ZOO8K5CzcdC/Yq6HcdIxJ4o5jmAcGG5QGUXX3BlAP4=

NMMI. (2014). *Impact Evaluation Study Report on National Mission on Micro Irrigation (NMMI).* Report submitted by Global Agri System to Ministry of Agriculture. Government of India.

NMSA. (2014). *National Mission on Sustainable Agriculture - Operational Guidelines.* Ministry of Agriculture, Department of Agriculture and Cooperation. Government of India.

NSSO. (2013-14). *Consolidated Results of Crop Estimation Survey on Principal Crops.* National Sample Survey Office, National Statistical Organisation, Ministry of Statstical and Programme Implementation. Government of India.

NSSO. (2014). *Level and Pattern of Consumer Expenditure 2011-12.* Ministry of Statistics &Programme Implementation, National Sample Survey Office. Government of India.

OECD. (2017). *Water Risk Hotspots for Agriculture.*Organisation for Economic Co-operation and Development (OECD).

Planning commission. (2014). *Annual Report (2013-14) on the Working of State Power Utilities and Electricity Departments.* Planning Commission, Power and Energy Division. Government of India.

Planning Commission. (2013). *Report of the High Level Expert Group on Water Logging in Punjab.* Planning Commission. Government of India.

PMKSY. (2015-16). *Micro Irrigation at a Glance - Maharashtra*. Retrieved from Pradhan Mantri Krishi Sinchayee Yojana Website: http://pmksy.gov.in/microirrigation/AtGlance/MI-Maharashtra.pdf

The World Bank. (2010). *Deep Wells and Prudence: Towards Pragmatic Actions for Addressing Groundwater Over-exploitation in India.* Washington D.C.: The International Bank for Reconstruction and Development/The World Bank.

Annexures

Annexure 1: Methodology for Adjusting land productivity and calculation of irrigation water productivity (IWP) and economic productivity

Part A: Rice

1. **Irrigation water productivity of rice *(kg/lakh litres)* =**

[Irrigated yield of rice (kg/ha)]÷ [irrigation water requirement (Lakh litres/ha)]

2. **Profitability of paddy (net returns) (Rs./ha)** = Gross value of output – Cost A_2

3. **Percentage profitability** = Profitability of paddy ÷ Cost A_2

[Cost A_2 :The paid out cost of farmer]

Part B: Sugarcane

1. Adjusting for crop duration (t/ha*month)

= Land productivity (t/ha) ÷ crop duration (month)

2. Adjusting for water intake (Water productivity) per ha (kg/cu.m)

= [Land productvity (t/ha) *1000] ÷ [irrigation water requirement (Lakh litres/ha) *100]

(Lakh litres = 100 cubic metres)

3. Adjusted Sugar productivity per ha (kg/ cu.m)

= [Land productivity (t/ha)* recovery rate * 1000] ÷ [water requirement (Lakh litres/ha) *100 *100]

For making the comparison in monetary terms, the economic productivity of sugarcane is worked out.

4. Economic Productivity of sugarcane (Rs./ cu.m)

= [{Land productivity (t/ha)* 1000] ÷ [water requirement (Lakh litres/ha) *100}]* [unit price of sugarcane (FRP based on recovery rate or SAP(Rs./t)]

[Note: Fair and remunerative price – FRP; State Advised price – SAP]

5. Economic productivity of other crops (Rs./cu.m)

= [{Land productivity (kg/ha)* 1000] ÷ [water requirement (Lakh litres/ha) *100}]* [Farm Harvest Price (FHP) (Rs./kg)]

6. Profitability adjusted with duration

Net returns (Gross Value of Output - Cost A_2) adjusted for crop duration (Rs./ha) per month = Net returns ÷ crop duration

Annexure 2: History of Sugarcane and Sugar in India[34] [35]

The first sugar plant in India was established by the French in 1824 at Aska in Orissa. However it was in 1903-04, the earliest white sugar manufacturing mills (vacuum pan process sugar plant) came into existence in India in parts of the then State of United province (comprising parts of present Uttar Pradesh (UP), Bihar and Uttarakhand). In the next 30 years many sugar mills came up in UP and Bihar regions particularly in the private sector. However in spite of this, imports were the mainstay for India as the sugar production capacity of 1.2 lakh tones (1930-31) was far below the consumption demand of 12 lakh tones. To meet the domestic demand of sugar, India had to import sugar mainly from Java (Indonesia).

Considering the importance of sugar industry in ensuring an assured income to farmers, Government of India felt the need for enhancing the capacity of domestic manufacturing of white sugar. For this in 1930-31, the tariff board was appointed by Government to cushion the industries from imports. As a result of this, The Sugar Industry (Protection) Act was passed in 1932, by virtue of which the industries were granted 14 years protection up to 1st March, 1948. Protection was granted to the Indian sugar industry by imposing a custom duty of 7.25 per cent plus surcharge of 25 per cent on the sugar imported to India. This led to a spurt in the number of sugar factories in a span of six years, from 29 in 1930-31 to 140 in 1936-37, especially in UP and Bihar. Sugar production also increased by almost eight times during the period. This growth in industry was mostly witnessed in the private sector and in the sub tropical region, comprising of UP, Bihar, Punjab and Haryana.

It was after the 1950s, that sugar factories were installed in the tropical region comprising of Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. One of the main catalyst for this was the cooperative movement. In 1950-51, only two (one each in Maharashtra and Andhra Pradesh) out of 139 factories belonged to the cooperative sector and the remaining was in private sector. Though the Cooperative Society Act was in place since 1904, it was the passing of the Industrial Policy Resolution on April 6th, 1948, followed by the Industrial Act, 1956, which led to the growth of Indian sugar industry in an organized manner. The act emphasized that the principle of cooperation had an important role in the country's economic development particularly for industries based on agriculture produce such as sugarcane. Under this policy, the Government of India started giving preference to licensing of new sugar factories in the cooperative sector. This policy was reemphasized in all the subsequent Industrial Policy Resolutions made by the Government till the de-licensing of the sugar industry in 1998. This preferential licensing policy was mainly responsible for the rapid development of the sugar factories especially in the cooperative sector of Maharashtra.

Another crucial development was the adoption of social land reforms policy by the Government of India. Ceiling was imposed on land holdings - both irrigated and dry land. This made private sugar factories with captive large sugarcane plantations unworkable. Even

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34 http://www.coopsugar.org/history.php

35 http://dfpd.nic.in/writereaddata/images/pdf/sugar/Mahajan1.pdf
(Mahajan Committee Report - Report of High Powered Committee on Sugar Industry (Volume 1), Ministry of Food and Consumer Affairs (Department of Sugar and Edible Oils), Government of India – April 1998)

the sugarcane estates developed by private sugar factories in Maharashtra were taken over by the State Government and brought under the control and management of State Farming Corporation, a State Government undertaking. The private entrepreneurs lost interest in the sugar industry.

The evolution of the cooperative sugar industry in Maharashtra set a trend for all the cooperatives in India. The establishment of sugar factories in areas which did not have any irrigation facilities and which were almost barren like Pravara, Sanjivani and Sangamner, not only achieved success as agro industrial units concerned with the production of sugar, but also in terms of the distribution of socio-economic benefits to all their members spread over the entire sugarcane region in the country.

Annexure 3: Economics of drip irrigation in Maharashtra: Methodology and results

2.1 Methodology

The method of "Farm Investment Analysis" (Gittinger, 1982) was used to work out the benefit-cost ratio, net present worth and the pay-back period associated with the drip technology adoption.

1. Net Present worth (NPW) (in Rupees)

The NPW is a measure of the profitability of the adopted technology. A positive NPW value indicates that it is profitable to adopt the technology.

NPW = Present Value of Benefit – Present Value of Cost

Present Value of benefit = $\sum B_i/(1+r)^n$

Present Value of cost = $\sum C_i/(1+r)^n$

where, B_i = Benefit realised per annum; C_i = Cost incurred per annum; r = Discount rate (discount rate considered at 7%, 10% and 12%); n = 1,2….N (N=7 years; life of drip system)

2. Benefit- Cost Ratio (BCR)

If the ratio of benefit to cost is greater than 1, the technology is considered feasible for adoption.

BC Ratio = NPV benefit/ NPV cost = $[\sum B_i/(1+r)^n$ / $[\sum C_i/(1+r)^n$]

3. Pay Back period (PBP) (years)

It is the time period required to recoup the funds invested in a technology

PBP = Initial Investment/Annual payback

The discount rate considered in case the source of capital for the farmer is from own funds, is 7 per cent (considering the opportunity cost foregone by investing the in a long tern deposit at the rate of interest of 7%) and in case the source of capital for the farmer is from borrowed funds, the discount rate considered is 12 per cent (12% taken as the interest charged for micro irrigation loans). The cost of cultivation has not been considered while calculating the cost-benefit ratio. The investment cost of drip system installation and the associated incremental income from the crop after installation of drip system has been considered for the analysis. Further, the benefits have been assumed to be constant over the life of the drip system.

Cost and benefit parameters in drip irrigation in Sugarcane in Maharashtra

Parameters		**Source**
Life of drip set (years)	*5, **7, ***10	As given by (Narayanamoorthy, 2004) ** JISL *** (NMMI, 2014)
Cost of drip - fertigation set and installation (Rs./ha)	151906	Jain Irrigation Systems Limited
	85400	The cost of drip set installation for calculation of financial assistance. *Source*: (NMSA, 2014)
Maintenance charge (Rs./year)	5000	For sand filter cleaning (Rs. 300 labour charge for cleaning twice per month) and acid treatment (Rs. 400 – twice a year) and other miscellaneous charges Rs. 1000 per year
Depreciation per year (Rs./year)	18230	Assuming *straight line method* for calculating depreciation
Yield (t/ha) (Average for Maharashtra)	89	Average yield of sugarcane in Maharashtra in 2014-15 (Department of Agriculture, GoM)
Incremental Yield (ton/ha) (due to drip system)	26.7	33% (~30%) increase in yield due to drip irrigation in sugarcane; Source: (JISL)
	17.80	20% increase ; Source: (Narayanamoorthy, 2004)
	35.6	40% increase in yield; Source: (NMMI, 2014)
Yield (ton/ha) (Average for Maharashtra, 2014-15)	118	Average yield + Incremental yield through adoption of drip = 89+29.37 = 118.37 ~ 118
	107	Total yield = 89+17.80 = 106.8 ~ 107
	125	Total yield = 89 + 35.6 = 124.6 ~ 125
Price (FRP 2014-15) (Rs./ton)	2615	For 2014-15 The FRP for sugarcane at 9.5 % recovery rate = Rs. 220. For Maharashtra , recovery rate = 11.29% Source: (CACP, 2015-16) FRP for MH = (FRP + (MH state recovery rate-Basic recovery rate)* (2.32/0.1) Rs. 2.32 is the additional price given for each 0.1% increased recovery rate Basic recovery rate = 9.5% 220+((11.29-9.5)*(2.32/0.1)) =Rs. 261.5/quintal= Rs.2615/t
Total incremental returns (Rs/ha)	69821	Returns from drip irrigation at 30% incremental yield, i.e from 26.7 t/ha incremental yield =Rs. 2615*26.7= Rs. 69821
	46547	Returns from drip irrigation at 20% incremental yield = Rs. 2615*17.80 = Rs. 46547
	93094	Returns from drip irrigation at 20% incremental yield = Rs. 2615*35.60 = Rs. 93094

Farm Investment Analysis

Item	Farm Investment analysis
Period analysed	Useful life of investment
Treatment of capital	Initial investment, residual value
Time value of money [36]	Discounted (using 7% , 10% and 12%)
Interest on loan (at 12%[37])	Taken as cash outflow based on repayment schedule for 7 years with initial year moratorium. (5 years and 10 years also considered for sensitivity analysis)[38]

Source: (Gittinger, 1982)

2.2 Sensitivity analysis

Sensitivity analysis for changes in discount rates, incremental yield, life of drip irrigation system and initial cost of drip system was carried out in the calculation of BCR, NPW and pay-back period

Parameters considered for sensitivity analysis

Parameters considered			
Useful life of drip irrigation system	5 years	7 years	10 years
Incremental yield due to Drip irrigation method (DIM)	20%	30%	40%
Discount rates	7%	10%	12%
Subsidy status	Without subsidy	With 45% subsidy	With 60% subsidy
Initial investment cost (Rs.)	151906	85400	

The adoption of drip irrigation system was found to be a feasible technological intervention for the farmers even in the absence of subsidy in most cases (results of different cases of sensitivity analysis given below). The only exception to this was noted in the case 6 where the useful life of drip was 5 years or less with an incremental yield of 20 per cent and the initial investment amounted to Rs. 151906 with the farmer taking a loan in the absence of subsidy. In this case, the BCR was found to be less than one and NPW was negative.

36 ** For domestic deposits (5 years and upto 10 years period) less than Rs. 1 crore, the rate of interest given is 6.50 (general) 7.00 (senior citizen) in State bank of Hyderabad

37 For irrigation loans the rate of interest charged is ~12% (11.95%) (State Bank of India)

38 In case the source of capital for the farmer is from own fund, discount rate considered is 7% and in case the source of capital for the farmer is from borrowed fund, discount rate considered is 12%

Results

Case 1: BCR and NPW calculated

(Useful life of drip system = 10 years and Initial cost = Rs.85400)

Parameters	@ 20% yield increase*			@ 30% yield increase^			@ 40% yield increase***		
Discount rate	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**
BCR									
Without Subsidy	2.52	2.3	2.16	3.77	3.43	3.23	5.01	4.57	4.31
With 45% Subsidy	3.69	3.41	3.24	5.51	5.09	4.84	7.33	6.78	6.44
With 60% subsidy	5.6	5.04	4.72	8.36	7.53	7.05	11.13	10.03	9.39
NPW (Rs.)									
Without Subsidy	185255	153018	134686	336887	287050	258694	488519	421083	382701
With 45% Subsidy	223685	191448	173116	375317	325480	297124	526949	459513	421131
With 60% subsidy	252135	217203	197381	403767	351236	321388	555399	485269	445395

Source: Author's calculation

*(NMMI, 2014); ** (NMSA, 2014) (For lateral spacing 1.2m to 2m); *** (Narayanamoorthy, 2004); ^ (JISL)

Case 2: BCR and NPW calculated

(Useful life of drip system = 7 years and Initial cost = Rs.85400)

Parameters	@ 20% yield increase***			@ 30% yield increase*			@ 40% yield increase^		
Discount rate	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**
BCR									
Without Subsidy	2.04	1.9	1.81	3.03	2.81	2.68	4.01	3.72	3.55
With 45% Subsidy	3.1	2.9	2.78	4.59	4.3	4.12	6.07	5.7	5.47
With 60% subsidy	3.74	3.53	3.39	5.57	5.22	5.03	7.33	6.92	6.66
NPW (Rs.)									
Without Subsidy	117990	99511	88589	228924	200873	184276	339858	302235	279963
With 45% Subsidy	156420	137941	127019	267354	239303	222706	378288	340665	318393
With 60% subsidy	169230	150751	139829	280164	252113	235516	391098	353475	331203

Source: Author's calculation

*(JISL); ** (NMSA, 2014)(For lateral spacing 1.2m to 2m); *** (Narayanamoorthy, 2004); ^ (NMMI, 2014)

Case 3: BCR and NPW calculated

(Useful life of drip system = 5 years and Initial cost = Rs.85400**)

Parameters	**@ 20% yield increase***			**@ 30% yield increase^**			**@ 40% yield increase*****		
Discount rate	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**
BCR									
Without Subsidy	1.62	1.53	1.47	2.36	2.23	2.15	3.11	2.93	2.82
With 45% Subsidy	2.54	2.41	2.33	3.71	3.52	3.4	4.87	4.63	4.47
With 60% subsidy	3.14	2.98	2.89	4.57	4.36	4.22	6.01	5.73	5.55
NPW (Rs.)									
Without Subsidy	65912	55381	48983	144744	129155	119673	223576	202929	190362
With 45% Subsidy	104342	93811	87413	183174	167585	158103	262006	241359	228792
With 60% subsidy	117152	106621	100223	195984	180395	170913	274816	254169	241602

Source: Author's calculation

*(Narayanamoorthy, 2004); ** (NMSA, 2014); *** (NMMI, 2014); ^(JISL)

Case 4: BCR and NPW calculated

(Useful life of drip system = 10 years and Initial cost = Rs.151906)

Parameters	**@ 20% yield increase*****			**@ 30% yield increase****			**@ 40% yield increase***		
Discount rate	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**
BCR									
Without Subsidy	1.67	1.5	1.41	2.49	2.24	2.1	3.31	2.98	2.79
With 45% Subsidy	2.07	1.87	1.75	3.08	2.79	2.62	4.09	3.71	3.48
With 60% subsidy	2.55	2.27	2.11	3.80	3.38	3.15	5.05	4.50	4.18
NPW (Rs.)									
Without Subsidy	124402	91581	72940	276034	225613	196947	427667	359646	320954
With 45% Subsidy	159832	127011	108370	311464	261043	232377	463097	395076	356384
With 60% subsidy	188282	152766	132634	339915	286799	256641	491547	420832	380648

Source: Author's calculation

*(NMMI, 2014); ** (JISL); *** (Narayanamoorthy, 2004)

Case 5: BCR and NPW calculated

(Useful life of drip system = 7 years and Initial cost = Rs.151906)

Parameters	**@ 20% yield increase****			**@ 30% yield increase***			**@ 40% yield increase*****		
Discount rate	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**	**7%**	**10%**	**12%**
BCR									
Without Subsidy	1.35	1.24	1.18	1.98	1.82	1.73	2.61	2.4	2.28
With 45% Subsidy	1.72	1.59	1.51	2.79	2.58	2.45	3.33	3.08	2.93
With 60% subsidy	1.90	1.76	1.67	2.79	2.58	2.45	3.67	3.40	3.24
NPW (Rs.)									
Without Subsidy	61571	42008	30471	172505	143370	126158	283439	244732	221845
With 45% Subsidy	100001	80438	68901	210935	181800	164588	321869	283162	260275
With 60% subsidy	112811	93248	81711	223745	194610	177398	334679	295972	273085

Source: Author's calculation

*(JISL); ** (Narayanamoorthy, 2004); *** (NMMI, 2014)

Case 6: BCR and NPW calculated

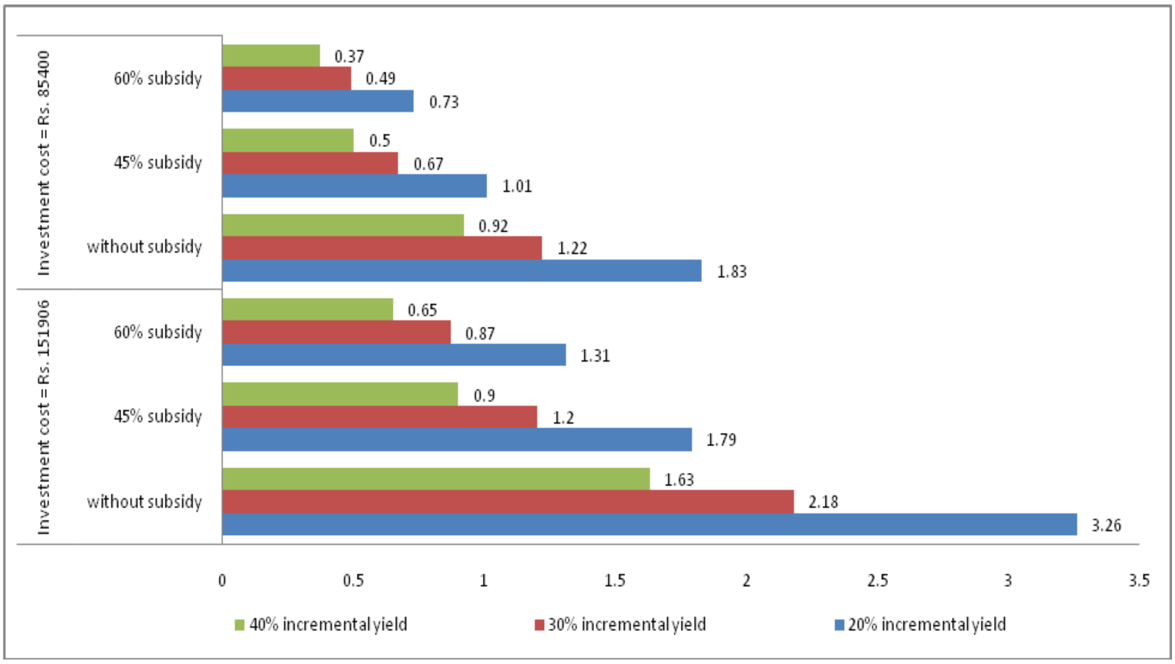
(Useful life of drip system = 5 years and Initial cost = Rs.151906)

Parameters	@ 20% yield increase			@ 30% yield increase			@ 40% yield increase		
Discount rate	7%	10%	12%	7%	10%	12%	7%	10%	12%
BCR									
Without Subsidy	1.08	1.01	**0.97**	1.54	1.45	1.39	2.01	1.88	1.81
With 45% Subsidy	1.75	1.65	1.58	2.51	2.36	2.27	3.26	3.08	2.96
With 60% subsidy	2.24	2.11	2.03	3.21	3.03	2.92	4.18	3.95	3.81
NPW (Rs.)									
Without Subsidy	13013	1372	**-5687**	91846	75146	65003	170678	148919	135693
With 45% Subsidy	78371	66729	59671	157203	140503	130361	236036	214277	201051
With 60% subsidy	101157	89515	82457	179989	163289	153147	258821	237063	223836

Source: Author's calculation

The pay-back period (PBP) was also found to be less than the useful life of the drip equipment. The PBP in the case of 40 percent incremental yield was found to be less than one except in the case where there was no subsidy and the initial investment was Rs. 151906 (Figure 20). Even in the case where the incremental yield was only 20 per cent, with no subsidy for the initial investment cost of Rs. 151906, the pay-back period was found to be 3.26 years. Thus the pay-back period did not exceed beyond 3.26 years in any case indicating that the investment cost could be recovered within this maximum period even in the absence of subsidy.

Pay-back period for the investment made on drip irrigation technology in sugarcane crop



Source: Author's calculation

Annexure 4: Opportunity cost (or returns foregone) due to flood irrigation in sugarcane

The benefit of drip irrigation is not only restricted to water saving and water use efficiency. It also generates additional benefits by bringing more land under irrigation using the water saved. Thus the water saved from the adoption of drip irrigation in sugarcane can be used for irrigating other crops. The opportunity cost incurred by the farmers in using conventional flood irrigation method in sugarcane, was used to capture the benefits foregone by them by not adopting sustainable water saving technology like drip irrigation system.

3.1 Methodology

Opportunity cost (or returns foregone) due to flood irrigation in sugarcane was analyzed by evaluating the returns obtained from the additional land under different crops that is brought under irrigation using the water saved from adopting drip irrigation in one hectare of sugarcane crop.

Efficiency of flood irrigation method (FIM)= 65% ; Efficiency of drip irrigation method (DIM) = 90% (Appendix 2)

Water saved = [(**Irrigation water applied in flood irrigation method)* 0.55]**

Taking the average value of water saving from drip irrigation technology in sugarcane as given in the study conducted by (Narayanamoorthy, 2004) and (JISL) , we assume 55% water saving in sugarcane using drip irrigation technology over flood irrigation method.

The rainfall parameter is not deducted from the total water requirement in the calculation. It is assumed that in the absence of rainfall (Effective rainfall = 0), Irrigation water requirement = Crop water requirement. Crop water requirement is calculated using the Evapo-Transpiration (ET) method.

The excess land brought under irrigation from the water saved was calculated considering the water requirement of different crops per hectare and the water saved from drip irrigation in sugarcane.

Excess land brought under irrigation

= [Quantity of water saved per hectare of sugarcane (cubic metres)] ÷ [water requirement for surface or drip irrigation for crop (cubic metres/ha)]

Opportunity cost of irrigation water

= {Excess land irrigated (ha)}*{Irrigated yield (qntl/ha)}*{Unit price of crop (Rs./qntl)}

3.2 Results

On an average the water saved through adoption of drip irrigation system in one hectare of sugarcane cropped area is 10.3 thousand cubic metre (55%) over flood irrigation method. The excess land that can be brought under irrigation for other crops through the water saved from drip technology adoption in one hectare area of sugarcane crop is given in the table below. These values hold good if the crops are irrigated using conventional method. However on adopting micro irrigation technology in irrigating these crops, the irrigation coverage can be doubled than the conventional practice. For instance, the water saved through drip technology in 1 ha of sugarcane area can bring an additional 2.29 ha area under conventional irrigation and double this area, if drip irrigation is adopted in cotton.

Water saving in sugarcane (Lakh litres/ha) through drip irrigation technology

Sugarcane crop	Irrigation water applied (cubic metres/ha)		Water saving (55% over FIM) (cubic metre/ha)
	Flood Irrigation Method (FIM) (65% efficiency)	Drip Irrigation Method DIM (90% efficiency)	DIM over FIM
Pre season	20630	9283	11347
Adsali	24380	7221	13409
Suru	16880	7596	9284
Ratoon	16880	7596	9284
Average	18750	8438	10312

Source: Author's calculation

The opportunity cost or returns foregone from alternate crops by using flood irrigation method in one hectare of sugarcane was found to range from Rs.47008 to Rs. 232535. If drip irrigation is adopted in sugarcane it is possible to generate additional returns through water saving (as shown in table given below). For instance, the water saved through drip technology in 1 ha of sugarcane area can bring an additional 2.29 ha area under conventional irrigation which can produce output worth up to Rs. 1.95 lakhs (based on FHP and yield data of 2014-15). Thus, this helps farmers to realize increased income. Thus the additional benefit from the increased yield of sugarcane crop through drip irrigation and additional returns from irrigated cotton crop will help augment farmers' incomes as well as promote sustainability of agriculture.

Opportunity cost (or returns foregone) due to flood irrigation method in sugarcane

Crops	Irrigation water requirement (conventional irrigation method) (cu.m/ha)	Yield (irrigated yield) (kg/ha)	Farm Harvest Price (FHP) (Rs./kg)	Excess land brought under irrigation using water saved from 1 ha of drip irrigated sugarcane plot (ha)	Production (kg) from additional irrigated land	Opportunity cost (returns foregone from alternate crops by using flood irrigation method in sugarcane)(Rs.)
Soyabean	2250	1498	33.87	4.58	6866	232535
Arhar	2250	1079	46.34	4.58	4945	229159
Cotton (kapas)*	4500	1488 - 2251	37.8	2.29	3140 - 5158	128892- 194983
Groundnut	2250	1394	29.87	4.58	6389	190835
Paddy	3750	3724	16.49	2.75	10241	168866
Jowar**	2250	1148	27	4.58	5261	142058
Gram	2250	1010	27.58	4.58	4629	127666
Wheat	3000	1824	16.44	3.44	6270	103074
Sunflower	2250	358	28.65	4.58	1641	47008

Source: Author's calculation based on the data collected from sources mentioned below

Note: Farm Harvest Price (FHP) prevails to 2014-15 (DES, 2014-15)

Price of cotton prevailing at Khargaon, MP considered as the data on cotton price for Maharashtra is not given in Farm Harvest Price of Principal crop in India 2014-15 report. Hence the cotton price in district in Madhya Pradesh nearest to the cotton growing districts in Maharashtra is considered.

(DES, 2014-15). Cotton yield expressed in terms of Lint is converted to Kappas yield using the conversion factor 1.25

Similarly rice yield was converted into paddy yield using the conversion factor 1.44

Sugarcane price prevails to price calculated for Maharashtra based on the FRP (Fair and Remunerative prices) of 2014-15 (CACP, 2015-16)

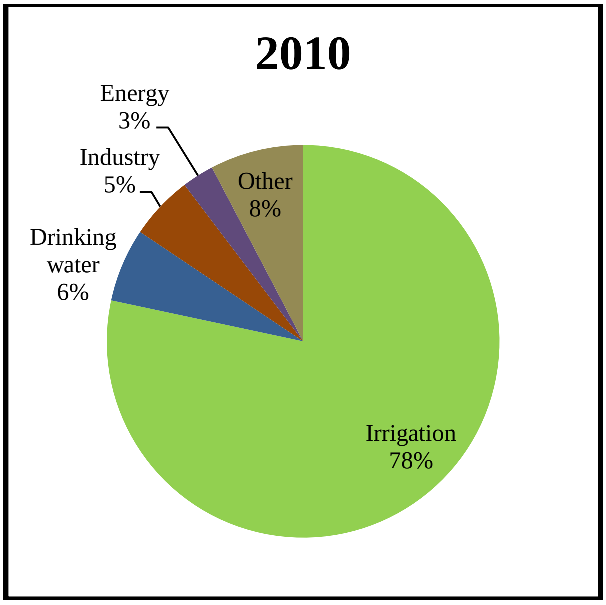
*The upper limit of range of irrigated yield of cotton corresponds to that of Gujarat. In Gujarat with 56% irrigation coverage the incremental yield due to irrigation is 2.33 times that of unirrigated yield, which has been taken to show the upper limit of excess economic value output that can be produced by bringing additional cotton area under irrigation

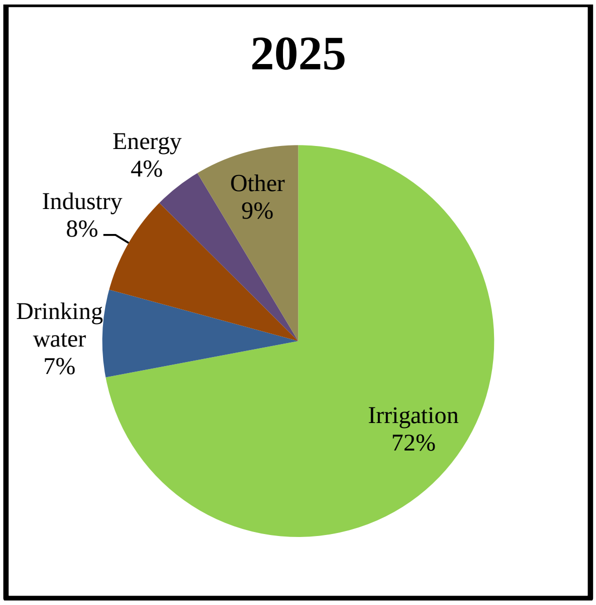
** Since by-product forms a major portion (40%) in the jowar crop output, a 34.4% [value of main product = 65.6% and by-product = 34.4%, (DES, GoI)] increase over the FHP (which gives the value of only main product, FHP = Rs. 14.14/ kg) is taken as the total value of jowar output.

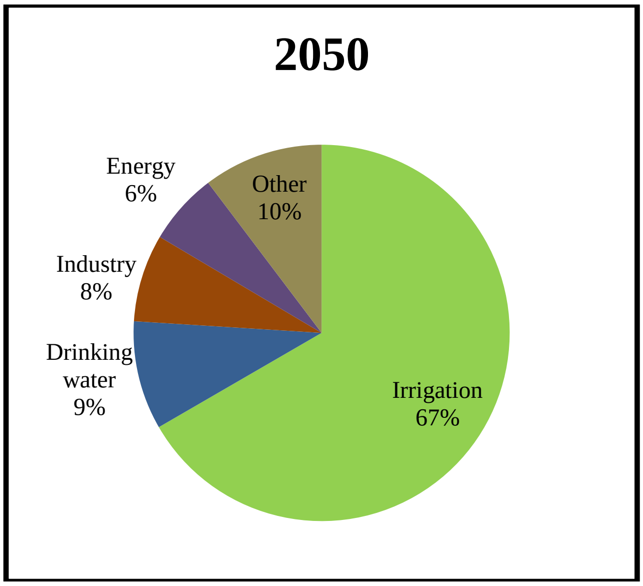
Irrigated yield as reported in Crop estimation survey on principal crops (2010-11) (NSSO, 2010-11). Irrigated yield of sugarcane taken as the average yield of sugarcane in 2014-15 as 100% area under sugarcane in Maharashtra is irrigated (Department of Agriculture, GoM)

Appendices

Appendix 1: Share of different sectors in water use in India during 2010 and projected for 2025 and 2050







Source: (CWC, 2015)

Note: Values as projected in NCIWRD report 2000"

Appendix 2: Efficiency of different systems of irrigation

Irrigation methods	Efficiency (%)
Conveyance	
Through unlined canal surface water	55-60
Through lined canal surface water	70-75
Application for both surface and groundwater	
Flood irrigation	65
Furrow irrigation	80
Sprinkler	85
Drip	**90**
Overall Efficiency for surface irrigation	**30-65**
Overall Efficiency for ground water irrigation	**65-75**

Source: (CWC, 2014)

Appendix 3: Punjab – District Map

Appendix 4: Percentage irrigation cover under rice across major rice growing states (TE 2013-14)

States	Irrigated area ('000 ha)	Area cultivated ('000 ha)	Irrigation ratio
West Bengal	2563	5464	47
Uttar Pradesh	4927	5946	83
Punjab	2827	2838	100
Andhra Pradesh	3334	3436	97
Tamil Nadu	1591	1708	93
Bihar	2031	3267	62
Chattisgarh	1386	3970	35
Assam	227	2512	9
Orissa	1358	4069	33
Madhya Pradesh	463	1789	26
Others	4996	8644	58
GCA	25703	43642	59

Source: LUS, DES[39]

Appendix 5: Incremental yield of rice due to irrigation and associated irrigation water productivity with respect to the incremental yield (2013-14)

States	Weighted average of Incremental yield (kg/ha) *	Water productivity of rice (kg/lakh litre)	Irrigation ratio (%)
Assam	481.83	8.76	11
Bihar	1300.69	19.71	63
Tamil Nadu	104.34	0.95	93
West Bengal	826.65	11.56	47

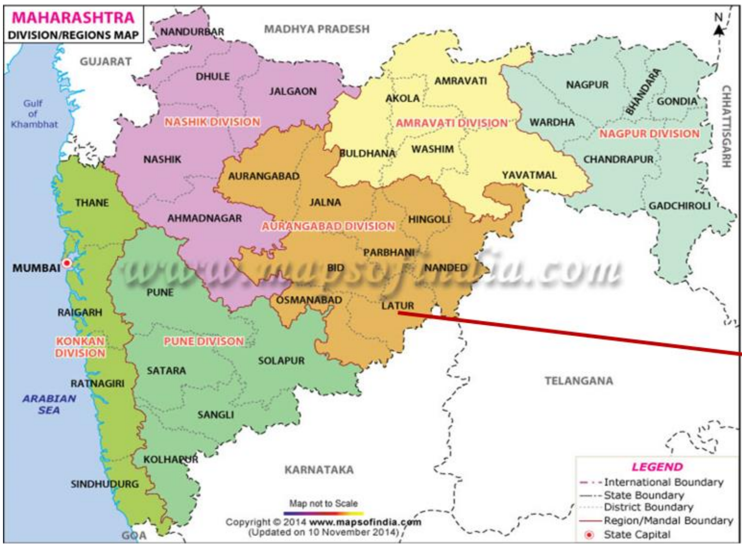
Source: Yield data calculated from NSSO. (2013-14); Irrigation ratio: DES. (2016)

Note: *Proportion of area under different rice cultivating seasons was taken as weights to calculate the weighted average of incremental yield across seasons across states.

** For UP with irrigation ratio of 83.4per cent, the data on irrigated and unirrigated yield was not available in the data source ***NSSO. (2013-14)***

39 http://eands.dacnet.nic.in/LUS_1999_2004.htm

Appendix 6: Maharashtra – District map and regions



Jaldoot express supplying drinking water to Latur in April, 2016

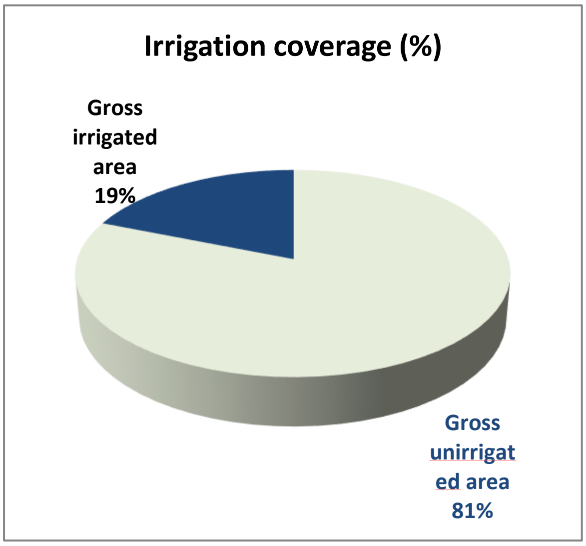
More thand 6 crore litres transported from Miraj to Latur
(Source: PIB, Ministry of railways)

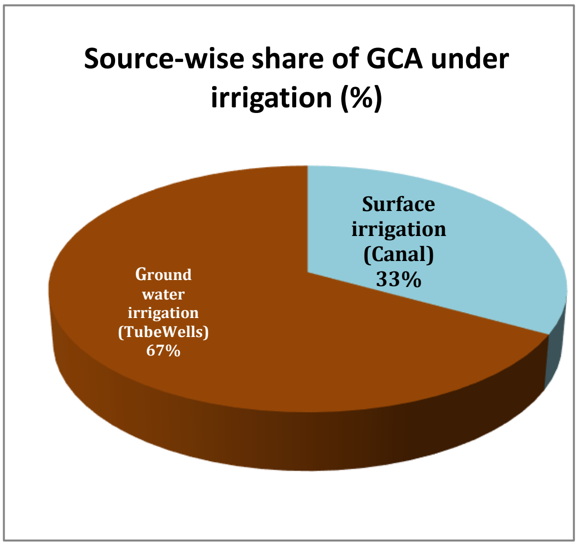
Divisions	Regions
Aurangabad division	Marathwada region
Amravati division	Vidharbha region
Nagpur division	
Pune division	Western Maharashtra region
Nashik division	
Konkan division	Konkan region

Regions of Maharashtra

Regions	Population	Districts covered	Percent population to total MH
Marathwada	1.87 crore	Aurangabad, Jalna, Bid, Latur, Osmanabad, Nanded, Parbhani, Hingoli	16.64%
Vidharbha	2.30 crore	Buldhana, Akola, Washim, Amaravati, Yavatmal, Wardha, Nagpur, Bhandara, Gondia, Gadchiroli, Chandrapur	20.46%
Rest of Maharashtra (Khandesh , Paschim Maharashtra and Konkan)			
Khandesh	1.40 crore	Nashik, Dhule, Nadurbar and Jalgaon	12.46%
Paschim Maharashtra	2.80 crore	Pune, Solapur, ahmednagar, Satara. Sangli, Kolhapur	24.91%
Konkan	2.87crore	Mumbai, thane, Raigad, Ratnagiri, Sindhudurg, Palghar*	25.53%

Appendix 7: Irrigation status of Maharashtra (TE 2013-14)





GCA of Maharashtra: 22.5 million hectares

Irrigated area: 4.3 million hectares

Unirrigated area: 18.2 million hectares

Source: (LUS, DES)

Appendix 8: Cane pricing across the major states (2014-15)

States	Cane Pricing followed	Sugarcane price (Rs./quintal)	Recovery rate (2014-15)
Uttar Pradesh	Rs.290 per quintal (Early Varieties)* Rs.280 per quintal (Normal Varieties)* Rs.275 per quintal (Rejected Varieties)* * : UP - Mill will pay Rs.240 per quintal as first installment to the farmers & II installment of Rs. 40/- per quintal will be paid within three months from the closure of the crushing season.	282	9.6
Tamil Nadu	Rs.265 per quintal linked to 9.5% with increase of Rs.2.21 for every 0.1% point increase in recovery above 9.5%. (includes Rs.10 per quintal transport)	265	9.0
Maharashtra	Sugar mills in the State paying FRP based on their recovery % of last season ranging from Rs.220 to Rs.370 per quintal including Rs.50 per quintal transport & harvesting charges	261.5	11.3
Karnataka	State Govt. initially fixed cane price mill-wise, ranging from Rs.220 per quintal upto 9.5% recovery to Rs.291 per quintal at 12.56 % recovery	248.5	10.8
Bihar	Rs.270 per quintal (Un-recommended varieties)^ Rs.260 per quintal (Central Varieties)^ s.250 per quintal (Early Varieties)^ ^ : Bihar - Includes Rs.5 per quintal as bonus to be paid by State Govt.	260	9.2
Andhra Pradesh	The sugar factories are paying over & above ranging from Rs.226 to Rs.256 per quintal. FRP & purchase tax incentive of Rs.6 per quintal (purchase tax to be remitted by the sugar factories to the Government is being passed on to the cane suppliers).	241	9.4

Source: ((CACP, 2016-17) (ISMA, 2014-15))

Appendix 9: Subsidy pattern for drip irrigation system in PMKSY

	Category of Beneficiaries	Subsidy given (% of drip system cost)	Central Government Share	State Government Share
DPAP and DDP areas	Small & Marginal Farmers	60%	36%	24%
	Other than Small & Marginal Farmers	45%	27%	18%
Other than DPAP and DDP areas	Small & Marginal Farmers	45%	27%	18%
	Other than Small & Marginal Farmers	35%	21%	14%

Note: National Mission on Sustainable Agriculture (NMSA) cost norm for calculation of financial assistance for sugarcane crop = Rs. 85400 per ha; Central: State share = 60:40

Source: (PMKSY, 2015-16)

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