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Delhi's Air Pollution and What Lies Beneath

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EXECUTIVE SUMMARY

Every year the air quality in Delhi NCR deteriorates to extremely hazardous levels precipitating an enormous public health crisis. The national capital gets enveloped by a toxic cloud of haze and smog, disrupting daily life, prompting closure of schools and offices, and causing widespread health problems such as reduced visibility, breathlessness, and eye irritation. With the onset of winter, the air quality index reaches more than 30 times the safe limit prescribed by the World Health Organisation due to dips in temperature and wind speed leading to accumulation and trapping of pollutants in the atmosphere.

While citizens from affluent backgrounds can afford to have air purifiers in their home, there is no respite for the poor and they continue to suffocate in Delhi's acrid air. The annual crisis has made clean air a luxury and policymakers have regularly failed to come up with a concrete solution to bring an end to this menace. Existing measures in place like the prominent Odd-Even Scheme for vehicles, banning of fireworks and restriction on construction activities have done little to mitigate the alarming rise in air pollution levels. This is because the root of the problem concerning Delhi's pollution during winter months lies in the agricultural fields in the north-western states of Punjab and Haryana.

Each year, starting from October, farmers in Punjab and Haryana set their fields on fire to get rid of the residue (straw and stubble) emerging after harvest of the paddy crop. This practice is known as Field Crop Residue Burning or Stubble Burning which is often considered by farmers as the quickest and most cost-effective land transformation technique in order to prepare it for sowing the next crop. It is reported that more than 23 million tonnes of stubble is burnt every year in northern India, the majority of which arises from cultivation of paddy. The fumes that emanate from the blazing stubble are highly noxious in nature and contain harmful gases such as carbon monoxide, sulphur oxide, methane along with particulate matter (PM2.5 and PM10) that travels hundreds of kilometres away to New Delhi in winter months severely polluting the environment and endangering human health along the way.

The government has followed a carrot and stick approach to deal with rampant burning of stubble in north-western states of India – banning the practice, fining and penalising those who violate it and on the other hand providing subsidies on machinery for proper disposal of agricultural wastes and even offering monetary compensation to farmers who do not burn stubble. But this approach has been largely ineffective and only widened the chasm between policy-makers and rural farmers who are entangled in a broken system that is fundamentally flawed.

The yearly episode of stubble burning and the resulting air pollution crisis in Delhi derives its origin from the populist policies of the government since many decades in the agricultural sector that have unabatedly incentivized production of rice which is a highly water-intensive crop in regions (i.e. Punjab and Haryana) that are not suitable for its growth. Not only has this artificial manipulation of natural order gravely threatened the environment but it has also led to serious economic losses for the entire country. The visible ramifications like atmospheric pollution are starting to surface since the last few years but there are also major invisible repercussions like rapid depletion in groundwater reserves and reduction in soil quality that are constantly worsening.

In this paper, we discuss some technical and policy-related aspects that have indirectly contributed towards the problem of stubble burning and highlights the need to address the policy design and foundational framework to achieve a viable and long-term solution for the air-pollution crisis.

INTRODUCTION

The second most populated country in the world and the largest democracy- India, is now also the nation with the most pollution linked deaths anywhere in the globe - a recognition which has catastrophic health consequences for each and every citizen. In 2017, more than 2.3 million people died prematurely in India due to pollution out of which air pollution was the leading killer causing a staggering 1.2 million deaths (based on a report by Global Alliance on Health and Pollution). One of the most alarming statistics comes from a Health Effects Institute study, which reported that more than 116,000 infants died within their first month in 2019 due to exposure to harmful particulate matter (PM) from both household and outdoor sources. The report also cited Air Pollution as the greatest health risk in India, which contributed to more than 1.67 million deaths caused by stroke, lung cancer, and various other chest diseases. According to a 2018 study conducted by the World Health Organisation based on annual average concentration of PM2.5 pollutant, 9 out of the 10 most polluted cities are in India. New Delhi is the most polluted capital city in the world. Using a conversion metric proposed by Berkeley Earth - a resident of Delhi, on an average, smokes about 10-15 cigarettes every day when they inhale the toxic air present in their surroundings. The irrevocable consequences of this on a child's lung is unimaginable and very distressing to even think of.

Delhi's Environmental Pollution Control Authority also known as EPCA declared a public health emergency on November 1, 2019 due to the alarming increase in the pollution levels which had even crossed the hazardous stage. To give a sense of how grave the situation was in early November, the air quality monitors in some places recorded PM10 levels at 999 microgram per metre cube which is not only way past the safe limit but also the maximum the scale can go to. The safe limit as recommended by WHO for PM10 is 50 micrograms per metre cube. The capital had transformed into a gas chamber and the Supreme Court of India even made statements like "Delhi has become worse than Narak (hell)" or "it's better to kill everyone with explosives".

Delhi worse than hell, people are living in gas chamber: SC

Centre Given 10 Days To Decide On Smog Towers

AmitAnand.Choudhary
@timesgroup.com

New Delhi: Noting that 45% of its garbage remained unattended and piled up on roads even as Delhi had virtually been converted into a gas chamber, the Supreme Court said on

FULL COVERAGE: P 5 & 7

Monday that the city was no longer liveable and had become worse than "narak" (hell) with people dying of various

'BETTER TO KILL PEOPLE AT ONE GO WITH EXPLOSIVES'

Is this not worse than internal war? Why are people in this gas chamber (Delhi)? ...you better finish them with explosives... It would be better to go rather than suffer from diseases like cancer

As on today, stubble burning is still adding 8% of pollution in the region. Why should we not impose fine on your state (Punjab) which will be recovered from officials right from top to bottom?

(Smog) towers are very successful in dealing with pollution. There is no question of testing it before making it operational. You sit together and prepare a plan on how many and where these towers should be set up

serving with time despite it passing a series of orders over the years. It accused the Centre and Delhi government of poli-

burst out, asking why the government should not kill people at one go by using explosives instead of letting them die

No politics over Delhi's quality of water: Court

The ongoing verbal battle between the Centre and Delhi government on quality of drinking water in the city came up in the Supreme Court, which said it would take suo motu cognisance of the matter while warning governments against playing politics over the issue, reports Amit Anand Choudhary

"You can do politics and fight but not on the issue of pollution," the bench said, adding that it will not "spare"

But this phenomenon of extreme deterioration of air quality and subsequent formation of gargantuan quantities of smog and haze is only witnessed in specific months i.e., from Mid -October to December. Often, the various factors contributing to ambient air pollution are accredited to rising vehicular emission, industrial and construction activity and dust. But one might wonder why such a massive spike in pollution transpires only during the months of October-November when these activities continue throughout the year.

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New Delhi/METRO MONDAY, NOVEMBER 04, 2019

ARUNACHAL NEEDS TIME ZONE OF ITS OWN: CM »p13 THERE'S NO NEED FOR SPLIT CAPTAINCY, SAYS BCCI CHIEF GANGULY »htsportp17

CAPITAL PUNISHMENT

AQI 494 Air quality touches worst level since 2016; PM2.5 peaks at 992, 16 times safe limit | **VISIBILITY 300M** Toxic smog makes eyes burn, throats itch; 22 flights cancelled at IGI | **BLAME GAME** Leaders debate causes even as Grap fails to arrest annual pollution crisis | **ODD-EVEN 3.0** Road rationing starts today; test for Metro, buses; CM makes carpool pitch

hindustantimes the air we breathe

Joydeep Thakur and Soumya Pillai

NEW DELHI: The national capital was on Sunday engulfed by a dense, noxious smog that reduced visibility, brought air quality to its worst level since 2016, and made residents rue the failure of both — leaders engaged in a blame game over the causes of pollution, and experts whose best-laid plans came to naught, plunging the city into prolonged public health emergency.

In the grips of a bad air crisis since Diwali, Delhi woke up on Sunday to the stench of smoke, burning eyes, sore throats, and shortness of breath — all symptoms of a larger malaise that increases morbidity, reduces immunity, and advances mortality. According to the Central Pollution Control Board (CPCB)'s 4pm bulletin, the average air quality index (AQI) for the preceding 24 hours sharply rose from 399 to 494, the worst level recorded since November 6, 2016, when it was 497. At 11pm, the AQI dropped marginally to 480.

Air quality is considered good when the AQI is below 50 and satisfactory under 100. The concentration of PM2.5 pollutants – one of the most harmful aerosols – peaked at 992µg/m3 in the Alipur monitoring station, over 16 times the level considered safe.

This was largely because of

> Bhopal gas tragedy occurred once and it has been dealt with, but this gas tragedy is occurring every year and is not properly dealt with.
>
> MUKESH KHARE, IIT-Delhi professor and EPCA member

secondary particles that led to a sharp PM2.5 spike. Experts said pollutants such as dust and finer particles accumulated up to a height of 50 metres on Sunday, turning the city into a gas chamber. Slow wind speeds failed to flush out the pollutants.

Angered residents and pollution experts questioned the effectiveness of the Graded Response Action Plan (Grap), a set of curbs meant to be automatically implemented when pollution levels cross certain thresholds. They said it appeared to have failed, as the plan was not pre-emptive and some additional measures, such as beefing up public transport infrastructure, should have been taken to make it successful.

Mukesh Khare, professor of environmental engineering at IIT-Delhi and a member of the Supreme Court-mandated Environment Pollution (Prevention and Control) Authority (Epca), said Grap needs to be re-evaluated and reassessed to make it more efficient.

"I have already aired this many times in Epca as well as on other platforms that the Grap measures need to be revisited. Bhopal gas tragedy occurred

India Gate, behind a smog screen, on Sunday morning. REUTERS

DANGER ZONE

992 Peak PM2.5 recorded at Alipur

This is **16.5 times** the safe limit

50M BLANKET

Conditions over the past few days have amplified the impact of pollution by creating a 50m layer of haze

- As temperature has gone down in the past week, a dense blanket-like layer of air heavy in pollutants has compressed over Delhi
- This is exacerbated by the moisture, to which pollutants get attached and get weighed down

ODD-EVEN TODAY

The 12-day-long scheme starts today

WHEN: Nov 4-15; **FROM:** 8am to 8pm

Will cover: All private four-wheelers except EVs, but exemptions apply

SMOG, NOT FOG

Fog is formed when water vapour in the air condenses to form tiny droplets of water that hang in the air, impairing visibility. When this fog merges with air pollution, it becomes smog. The past few days, the smoke from stubble burning has merged with the moisture in the air and cloaked Delhi in a toxic haze

Pollutants on a constant rise

The air quality over the past week in Delhi-NCR has consistently been hazardous

Peak wind speed is the highest speed of wind recorded at

Why lethal PM2.5 spiked twice as fast as other pollutants

Joydeep Thakur

NEW DELHI: Delhi's air quality turned more toxic on Sunday, primarily because of the formation of "secondary particles", which are much more potent in terms of toxicity than particulate matter that has already gone through the roof.

While "primary particles" like particulate matter are directly emitted by stubble burning and vehicles, "secondary particles" are formed due to reaction between primary particles in the presence of other factors such as sunlight and moisture. On Sunday, secondary particle pollution amplified pollution levels in the Capital.

"The ratio of PM2.5 and PM10 usually remains 50:50 in the air. On Sunday, however, the share of PM2.5 shot up to 75%. This is primarily because of the formation of secondary particles which are finer," said G Beig, who heads Safar, the Centre's pollution forecasting agency. From 5.30pm Saturday and 2.30pm Sunday, the 24-hour average concentration of PM2.5 in Delhi-NCR shot up from 259ug/m3 to 540ug/m3 – a rise of over 100%, compared to PM10 that saw a 50% hike. »P3

EVs get odd-even exemption in late decision by govt

NEW DELHI: On the directions of the Prime Minister's Office, the Delhi government on Sunday evening decided to exempt private electric vehicles from the third edition of the odd-even road rationing drive that kicks in on Monday as Delhi grapples

What the Beijing Grap gets right, and Delhi's doesn't

NEW DELHI: Delhi's deadly air pollution has exposed the lack of preparedness in NCR to implement the Graded Response Action Plan. It has also shown that Grap interventions should have kicked in earlier based on forecasts, similar to Beijing's

The principal reason that causes pollution levels to skyrocket starting from late October is that this period coincides with the kharif harvest season in the neighbouring states of Punjab and Haryana.

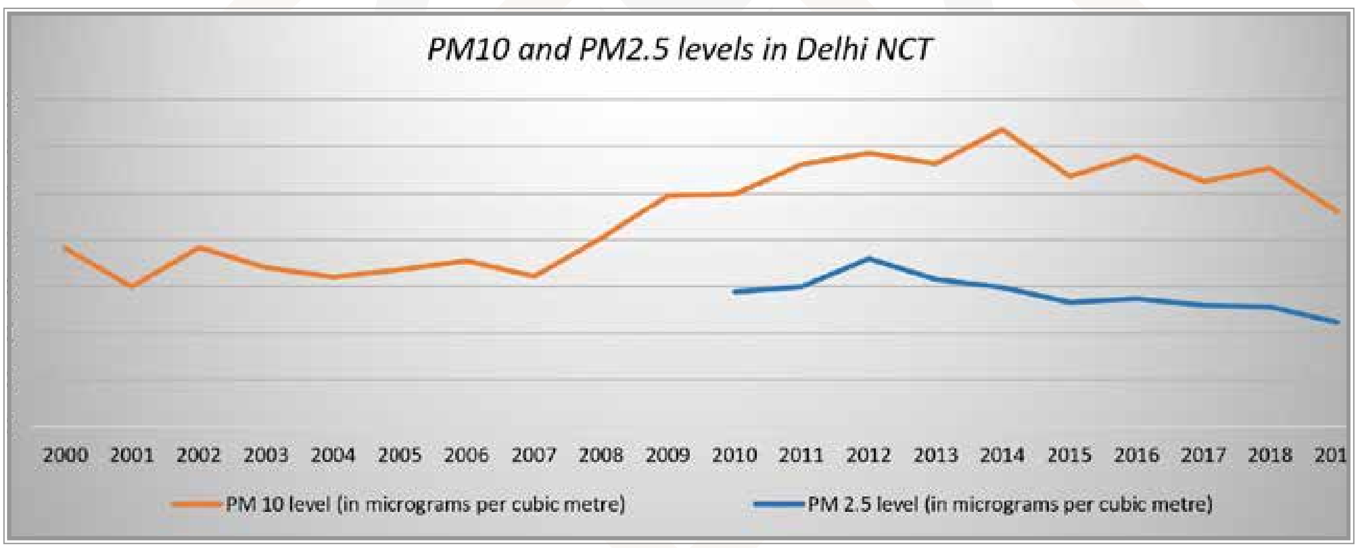
A large number of farmers in the two states set their fields on fire after harvesting paddy in order to eliminate crop residue and prepare the field for sowing the rabi crop i.e. wheat. The smoke that is emitted from the burning biomass contains extremely high levels of greenhouse gases like carbon monoxide, carbon dioxide, sulphur dioxide, black carbon as well as fine and coarse particulate matter like PM10 and PM2.5 (that can enter lower respiratory tracts of human beings and even the bloodstream). This deadly combination contained in the smoke makes its way towards the national capital and gets trapped in the atmosphere in winter months metamorphosing Delhi's air into a cesspool of toxic gases resulting in the formation of a thick blanket of haze and smog. Stubble Burning can refer to burning

of residue of different crops but as far as the annual Air Pollution episode in Delhi is concerned, it is due to the blazing paddy stubble in Punjab and Haryana. Punjab and Haryana are undisputedly the largest producer of food grains in India. Punjab which is uniquely popular for being the Granary of India comprises only 1.5% of India's total geographical area but contributes 35.5% and 25.5% of wheat and paddy respectively to the central pool. Punjab which is the third largest producer of rice in the country has an agro-based economy that was historically dependent on the growth of wheat and maize as principal crops only a few decades back. The climatic conditions in the region did not support a water-guzzler like rice due to less rainfall in the region compared to eastern and southern India. As the state didn't grow rice historically and therefore it was also not a major staple food item of the people in the state. A massive shift towards production of paddy was made in the last 3 to 4 decades with the advent of the Green Revolution. Now, almost three quarters of the total area under cultivation is dedicated to growing foodgrains (wheat and paddy) in rotation.

In this paper, we attempt to identify the root cause (indirect factors) of the spike in pollution due to stubble burning by examining the nature of rice cultivation and harvesting in Punjab and Haryana and how it has evolved in the past two decades. We also assess various factors of agriculture production such as minimum support price, power subsidy, access to Groundwater for irrigation that have caused a massive production shift in favour of paddy, a water-guzzler in a water-deficient state.

AIR POLLUTION

Fig 1 - Time trend of PM10 and PM2.5 levels in Delhi NCT



As per the National Ambient Air Quality Standards specified by the Central Pollution Control Board, the annual average concentration of PM10 and PM2.5 should not exceed 60 µg/m3 and 40 µg/m3 respectively. In New Delhi and neighbouring regions, the annual mean PM10 concentration has consistently been much above the safe limit for the time period 2000-2019. Annual PM10 levels shot up from 191 µg/m3 in 2000 to almost 250 µg/m3 in 2010 which is greater than 4 times the safety standard of 60 µg/m3 . Air quality further deteriorated in 2014 when PM10 concentration peaked at 318 µg/m3 which is considered hazardous to human beings. From 2014, PM10 concentration levels have declined but not significantly as they are still well over the prescribed norms of what is healthy air.

Fig 2 - PM 10 Pollution Level in Winter Months in Delhi NCT, 2014-2019

On the other hand, PM2.5 levels have also shown a decreasing trend as the annual mean concentration came down from 144 µg/m3 in 2010 to 112 µg/m3 in 2019 with the maximum being during 2012 at 180 µg/m3 . Even at 112 µg/m3 , PM2.5 concentration in air is 2.8 times the safety limit of 40 µg/m3 and is included in the unhealthy bracket which might cause breathing ailments to sensitive groups.

Even though a declining trend can be witnessed in PM 2.5 and PM10 levels in Delhi NCR from the year 2014 - the ground reports on some particular days reveal a starkly contrasting story. On November 3rd of 2019, Air Quality Index in several zones of Delhi reached the maximum measuring limit of 999, beyond which sensors are unable to record readings.

Fig 3a - Winter with Unhealthy or Hazardous PM 10 Levels (2014-2019)

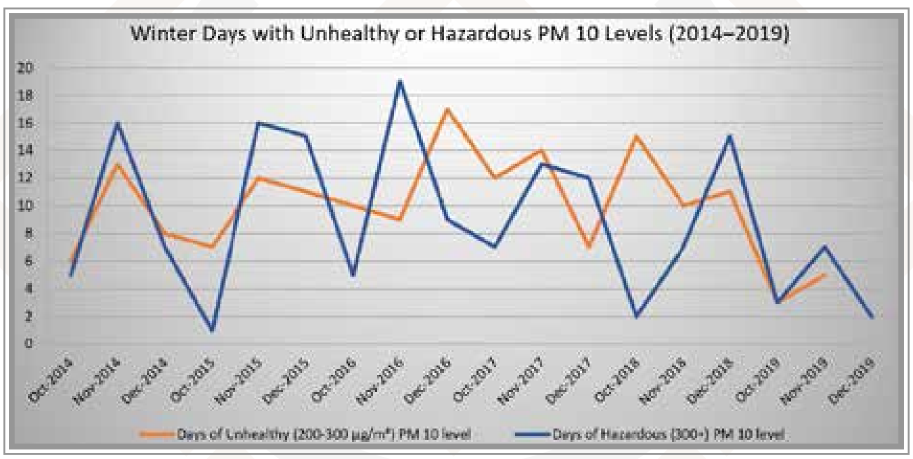
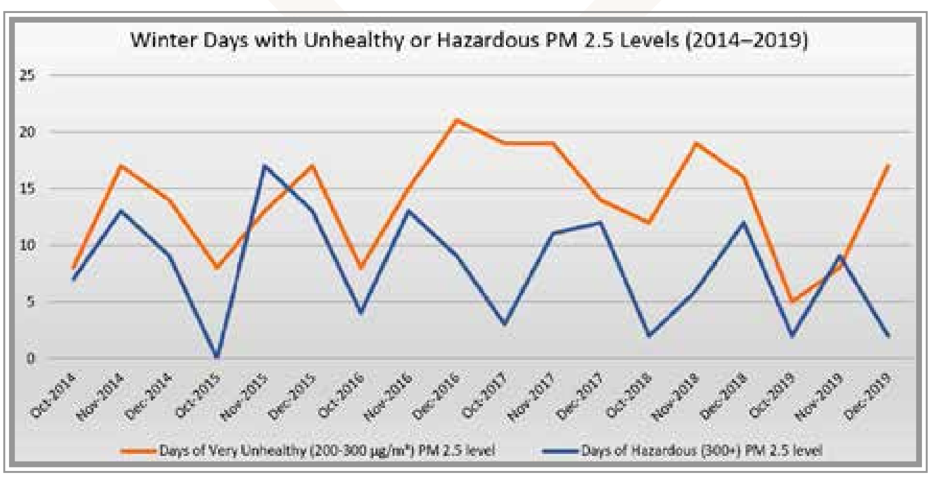


Fig 3b - Winter Days with Unheathly or Hazardous PM 2.5 Levels (2014-2019)



Source- aqicn.org, Central Pollution Control Board, Delhi Pollution Control Committee

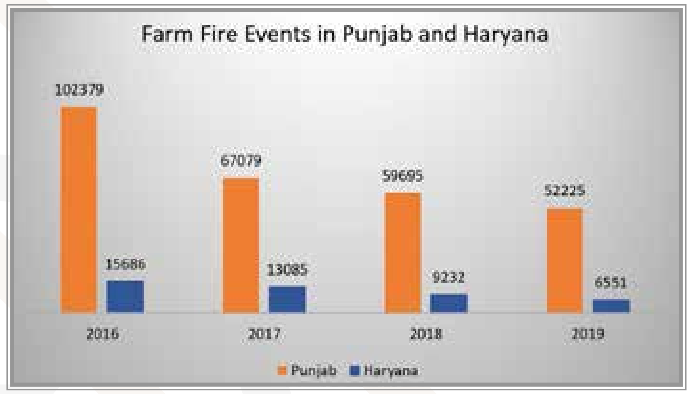
It is apparent from the above table[1] that there is a major spike in the concentration of particulate matter in ambient air every year during winter months. Owing to the dip in temperature coupled with change in direction and speed of wind, the temperature inversion layer (which determines the mixing and dispersion of pollutants from the atmosphere) is lowered. Due to this, the emitted pollutants from various sources get trapped and accumulate exponentially resulting in the formation of dense smog.

STUBBLE BURNING

In 2019[2] Haryana had 1.45 million hectares under rice cultivation. Out of this, 55% or approximately 0.795 million hectares was dedicated to cultivation of Basmati rice and remaining 0.655 million hectares (45%) for non-Basmati rice varieties. It is estimated that around 7.93 million metric tons of paddy stubble was generated in 2019 in the state of Haryana. Around 83% of this i.e. 6.59 million tonnes was utilised for different purposes while the remaining 1.34 million tonnes (17%) of paddy stubble was disposed of by burning. A high proportion of paddy straw not being burnt in Haryana is due to greater production of Basmati rice, which is typically harvested manually using labour. The problem of leftover paddy residue is minimised which results in a significantly lower amount of stubble. Moreover, Basmati stubble is highly valued as an animal fodder and is also incorporated in the soil itself.

In Punjab, the area under cultivation of rice was 3.1 million hectares in 2019 out of which only 16% was devoted to cultivation of Basmati variety of rice whereas 2.59 million hectares of farm land was used for growing non-Basmati rice. The minimum support price (MSP) regime does not include provision for procuring Basmati rice and its prices in the international market frequently fluctuate, discouraging farmers from taking the risk to shift from the common paddy crop with stable price structure and assured procurement to Basmati variety. Consequently, more than 20 million metric ton of paddy stubble was generated during 2019 out of which 9.96 million metric ton or 49.3% of the total stubble was burnt in fields[3]. As per a media report, Indian Council of Agricultural Research (ICAR) stated that about 23 million tonnes of paddy residue were burnt by farmers in 2019 in northern-India to clear the field for sowing of the wheat crop.

Fig 4 - Incidents of farm fire in Punjab and Haryana from 2016-2019



Source- Committee Report 2019, Ministry of Agriculture and Farmers Welfare, Govt of India

Farm fire or stubble burning events in the past five years were maximum during 2015-2016 at around 1.02 lakhs in Punjab. The same year - Haryana had more than 15,686 reported incidents of farm fires. Since then, there has been a constant decline in farm fire events in both states after implementation of various legal measures to outlaw the practice of stubble burning. Between 2016 and 2019, farm fire events in Punjab have undergone a reduction of almost 49% while in Haryana, there has been a 58.2% decline in stubble burning incidents.

Although strict measures and penalties have helped reduce instances of stubble burning to an extent, thousands of farmers still continue to set fire to crop residue by circumventing the ban. It was reported that a

1 The given figures are based on daily PM2.5 and PM10 data (24 hours average of hourly readings) in R.K. Puram which have been grouped according to a suitable range for October-December months from the year 2014-2019

2 Statistical Abstracts of Haryana 2019Farm fire or stubble burning events in the past five years were maximum during 2015-2016 at around 1.02 lakhs in Punjab. The same year - Haryana had more than 15,686 reported incidents of farm fires. Since then, there has been a constant decline in farm fire events in both states after implementation of various legal measures to outlaw the practice of stubble burning. Between 2016 and 2019, farm fire events in Punjab have undergone a reduction of almost 49% while in Haryana, there has been a 58.2% decline in stubble burning incidents.

3 Government of India. 2019. Report of the Committee. Ministry of Agriculture and Farmers Welfare. https://farmech.dac.gov.in/revised/1.1.2019/REPORT%20OF%20THE%20COMMITTEE-FINAL(CORRECTED).pdf

large number of farmers have started practising stubble burning at night to evade detection by local authorities. While farm fires are steadily declining, the pace at which it is taking place is not desirable and the enforcement of the stubble burning ban invites scrutiny as many violate it without facing repercussions. Pollution from farm fires significantly degraded Delhi's air quality in 2018-19 even when they were at their lowest point in the last five years. It is estimated that around 23 million tons of greenhouse gases (GHG) and particulate matter (PM) were released from burning of paddy stubble in three states- Punjab, Haryana and Uttar Pradesh in 2018[4]. As per the same report, Punjab contributed 83% to the total GHG emissions and PM while Haryana and Uttar Pradesh contributed 11% and 6% respectively.

In 2019, the total contribution of smoke emitted from burning of stubble in Punjab and Haryana to Delhi's air pollution was 44% on specific days according to the Ministry of Earth Science's Air Quality Monitor SAFAR[5].

BACKGROUND

PUNJAB

Geography:

Punjab is situated in the north-western part of the country sharing a border with the neighbouring country Pakistan on the west, Jammu and Kashmir and Himachal Pradesh on the north and north-east respectively and Haryana and Uttar Pradesh on the south. It is the 19th largest state by size and 16th largest in terms of population (Census 2011). Most of the state is occupied by fertile alluvial plains with an extremely vast natural resource base including 3 rivers- Sutlej, Beas and Ravi that flow through Punjab. Total geographical area of Punjab is 5.036 million hectares comprising just 1.5% of India's landmass out of which the net sown area is 4.023 million hectares or 2.87% of India's total net sown area (Statistical Abstracts 2019). The average altitude is 300 metres above sea level and average annual rainfall in the state is 598 mm.

Punjab belongs to Agro Climatic Zone VI also called "Trans Gangetic Plains Region" that is characterised by arid, semi-arid and sub-humid climate in different locations. There are 3 main Agro-climatic zones in this region that are classified on the basis of annual rainfall, texture and richness of soil and cropping pattern followed. These are[6] :

1. Sub-Mountainous Zones (8,938 squared km) with a belt of undulating topography spanning across the northeast part at the foot of the Siwalik range. Due to harsh weather conditions and infertile soil, productivity is low. Wheat-Maize cropping system is prevalent in this zone.
2. Central Zone (25,291 square km) has a well-developed irrigation canal system that is suitable for growing water intensive crops. The soil is rich in nutrients and highly fertile supporting a high yield of crops. Rice-Paddy cropping pattern is prevalent.
3. South-Western Zone (33,576 squared km[7]) mainly consists of semi-arid and desert-like landscapes. Expansion of the irrigation network has levelled off most of the former sand dunes in this zone. It has brackish underground water and is famous for growing wheat and mainly cotton in rotation.

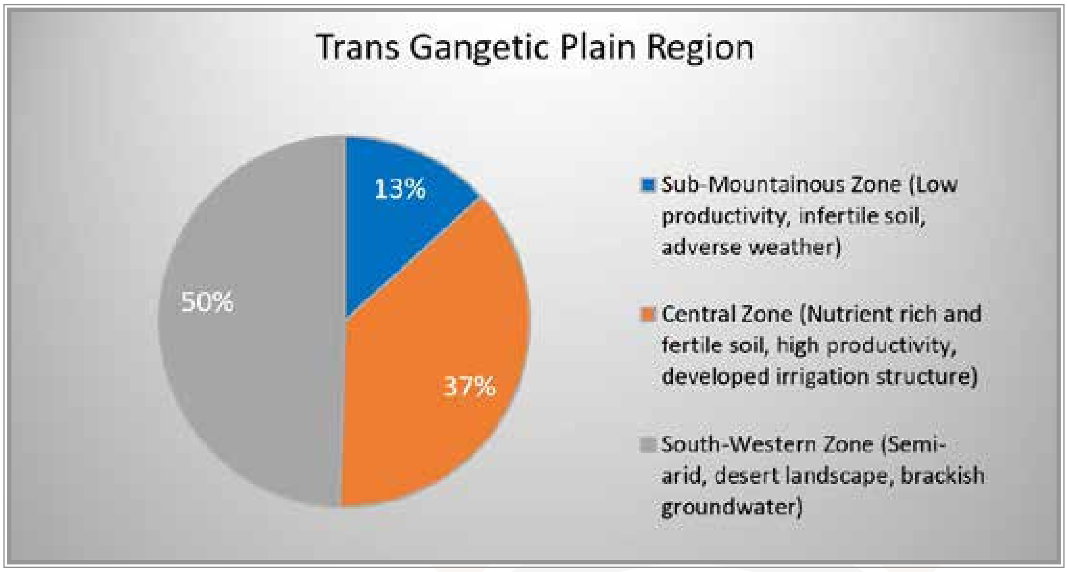
4 Government of India. 2019. Report of the Committee. Ministry of Agriculture and Farmers Welfare. https://farmech.dac.gov.in/revised/1.1.2019/REPORT%20OF%20THE%20COMMITTEE-FINAL(CORRECTED).pdf

5 2019, November 13. Delhi Pollution: Stable major contributor in 2019, says CPCB secy. Business Standard. https://www

6 Verma, S., & Singh, S. (n.d.). Long-term Strategies and Programmes for Mechanization of Agriculture in Agro Climatic Zone–VI: Trans-Gangetic Plains region (Rep.). Ludhiana, Punjab: Punjab Agricultural University.

7 Area calculated by adding area of individual districts falling in the zone

Fig 5 - Agro-climatic zones in Punjab



Source: Verma, S., & Singh, S. (n.d.)

Climate:

Punjab's climate is tropical, subtropical monsoon type and semi-arid often characterised by extremely hot summers and severe cold in winters. Monsoon season typically starts from early July and ends by mid-September. The state receives most of its rainfall from the monsoon current generated over the Bay of Bengal. Regions lying close to the Siwalik range receive heavy rainfall while the southern regions receive sparse rainfall and have higher day temperatures. Average annual rainfall in Punjab was 678 mm in 2019 which was higher than the national average (558 mm in 2019). The hot summer season begins from mid-April to June end, Monsoon season from July beginning to September end and chilly winters from early December to late February.

Political System:

Punjab follows a parliamentary system of representative democracy. The head of the government in the state is the Chief Minister who is indirectly elected and holds most of the power and executive authority. The formal head of state is the Governor, appointed by the President of India. The ruling government serves for a term of 5 years after which elections are held. The administrative organisation of Punjab consists of 5 divisions and 22 districts.

Economy:

The Gross Domestic Product of Punjab is INR 5.88 lakh crores (US $81 billion) and GDP per capita is Rs 1,54,313[8] (Ranked 16th in India). Punjab's economy has been historically dependent on agriculture and to date, agriculture and allied activities drive the state's economic growth as they contribute a little less than 30% to the Gross State Domestic Product. Punjab is an important part of India's agricultural sector and the state's contribution in the development of the nation's agriculture has become the cornerstone of our food security system. It is a state famous all over the world for

8 Statistical Abstracts of Punjab 2019

being one of the prime leaders of the Green Revolution era that transformed the growth potential of the world's second largest Agro-based economy.

Over the years, the state of Punjab has earned the reputation of being called the 'Breadbasket' or 'Foodbowl of India' as it is the largest contributor of food grains to the central pool. In 2019, it was the third largest producer of Rice (11% of All India Production) and second largest producer of Wheat (17.85% of All India Production) only after Uttar Pradesh. Punjab has the highest cropping intensity at 190, highest productivity in terms of yield per hectare of principal crops and the highest average farmer household income among all states in India. Factors like fertiliser consumption, number of tractors, percent share of irrigated area of net cropped area in Punjab are much greater than the national average. Development of rural infrastructure, power and water availability at negligible costs, subsidy support from government for various inputs, assured procurement and well-connected market facilities have played a major role in the quantum jump that Punjab has achieved in agricultural production over the years.

HARYANA

Geography:

The state of Haryana is located in northern India. It is surrounded by Himachal Pradesh on the north and Rajasthan on the South. Punjab and Uttarakhand border the state on the northwest and north-eastern side respectively. On the eastern border with Uttar Pradesh, river Yamuna flows. The National Capital Territory of Delhi extends into the state. Haryana's total geographical area is 4.42 million hectares, out of which the net sown area is 3.5 million hectares or 2.5% of India's total net sown area. Only 4% of the total area comes under forests (Statistical Abstracts 2019).

There are 3 main physiographic features in the state of Haryana:

1. Yamuna Ghaggar Plains - Flat alluvial plains occupying maximum area in the state. High soil fertility, adequate irrigation network and presence of a vast population make this region very suitable for agricultural activities. Major kharif crops that are raised here include rice, bajra, jowar, cotton, sugarcane and commonly grown rabi crops are wheat, barley, gram.

2. The highly dissected mountain range in the north-eastern part at the foot of the Himalayas is called Lower Shivaliks. Major crops grown in this region are wheat, maize and pulses.

3. Low risings, isolated remnants of the Aravali Range stretching from the South-West zone near Rajasthan to Delhi.

Climate:

Haryana has extremely hot summers and mild winters. The climatic conditions are mostly arid or semi-arid. Near the hilly regions in the northeast, the weather is more humid. The state's average rainfall in 2019 was 383 mm which was much lower than all-India average rainfall of 558 mm. Altitude spans 200-1200 m above sea level. Summers peak between May and June and December-January are the coldest. Monsoon season typically starts from July to end September with some rainfall between December and February. Rainfall greatly varies across regions with Shivalik Hills receiving the maximum amount of rain and Aravali Hills receiving the least.

Political System:

The system of governance in Haryana, like all other states, is according to the parliamentary system of representative democracy as established by the National Constitution (1950). The President appoints the head of state called Governor. The head of Government or Chief Minister is indirectly elected by people and is accountable to the state's legislative assembly (Vidhan Sabha). The Panchayati Raj system operates at village level. The Punjab and Haryana High Court in Chandigarh has complete jurisdiction over the entire state. Haryana has 22 districts and 6 administrative divisions.

Economy:

The Gross State Domestic Product was INR 7.34 lakh crores (101.1 billion dollars) during 2018-2019 of which the share of the service sector is the largest at 50.6%, share of manufacturing or industrial sector is at 32.8% and agricultural sector contributes 16.6% to the state's economy. The per capita income at current rates is INR 2,64,607 which is the fifth highest in India (Economic Survey 2019). In 2017-18, approx. 11.16% of the population lived below the poverty line. 80% of the geographical area of the state is under cultivation which makes Haryana an agricultural state. It contributes significantly to the production of foodgrains at the national level. The state is the largest producer of Basmati rice in the country and has the highest yield per hectare for rapeseed and mustard. Haryana has made rapid strides in the past decade to emerge as an industrial hub and the tertiary sector has become the key driver of economic growth. Gurugram, an important district in Haryana has received a significant amount of FDI as many Fortune 500 companies and industries (agriculture, automobile, IT, electronics) have established their offices and factories, giving a boost to the growth of the services and manufacturing sector in the city.

Governance Framework

The governance framework for air pollution management in Delhi is complex and fragmented, involving multiple tiers of government, overlapping jurisdictions, and sector-specific regulatory mandates, which contribute to coordination failures and inconsistent policy implementation.

At the national level, the Ministry of Environment, Forest and Climate Change (MoEFCC) sets overarching regulatory standards under the Air (Prevention and Control of Pollution) Act, 1981, and supervises the Central Pollution Control Board (CPCB). In Delhi, the Delhi Pollution Control Committee (DPCC), under the Government of NCT of Delhi (GNCTD), exercises regulatory oversight. This institutional arrangement creates ambiguity around compliance and enforcement due to conflicting instructions or differing interpretations of statutory powers.

Several major drivers of air pollution such as transport, land use, urban development, and municipal services fall under the jurisdiction of multiple bodies, including GNCTD departments, local bodies (NDMC and the MCDs), and centrally controlled agencies such as the Delhi Development Authority (DDA) and Delhi Police. This multiplicity of authority translates into lack of accountability, limited ability of city government to coordinate mitigation strategies, and leads to recurrent inter-agency conflicts. Stubble burning in Punjab and Haryana further contributes to Delhi's winter pollution. Effective mitigation requires coordinated action across state governments. However, such efforts often fail due to differing political priorities and weak mechanisms for joint planning and monitoring.

This regulatory vacuum and institutional incapacity within the executive branch has repeatedly compelled the Supreme Court of India and the National Green Tribunal (NGT) to intervene by issuing directives on stubble burning, construction activity, industrial emissions, and vehicular controls. These interventions, however, tend to be reactive and seasonal and are enforced weakly or inconsistently.

Overall, addressing Delhi's air pollution challenges demands a sustained governance strategy that assigns clear and comprehensive responsibility for long-term, systemic improvements across Delhi and its neighbouring regions.

RESEARCH QUESTION

One of the key contributors that chokes Delhi's air every winter happens to be the burning of the rice residual (stubble) locally known as 'Parali' by the farmers in the state of Punjab and Haryana. It is known that both the states have not been traditionally rice growing states. This paper is an attempt to examine **the changes in the factors of the agricultural ecosystem, which have made production of rice possible** in both the states. Therefore, this research focuses on analysing the institutional incentives that enabled the expansion of paddy cultivation in Punjab and Haryana, an agricultural shift that has intensified reliance on stubble burning.

The study aims to uncover how changes in agricultural policies, procurement systems, and support structures have contributed to rising pollution levels.

OBJECTIVE

The key objectives to undertake this study are:

1. To identify key factors with direct impact on agricultural production in the state of Punjab and Haryana.
2. To analyse changes in the factors that have enabled farmers to grow rice, a water intensive crop, in the state of Punjab and Haryana, regions characterized by low annual average rainfall.
3. To understand the role of public policy and institutions responsible for change in the agricultural ecosystem.
4. To find long term environmentally sustainable solutions to the issue of crop burning.

RESEARCH METHODOLOGY

The underlying objective of conducting this study is to explore the root causes behind the shift in cropping patterns in Punjab and Haryana that led to an increase in rice production. Therefore, the nature of the subject is diagnostic as it is intended to delineate the crucial factors that have resulted in this transition to water intensive rice production from non water intensive crops. The researchers have hypothesised a few factors contributing to growth in rice production which will be verified using published and genuine data from official and authentic sources. To test these hypotheses, we adopt a mixed-methods design that combines trend, descriptive, comparative, and document analysis, supported by triangulation.

To ascertain the cropping system followed in the state of Punjab and Haryana which is necessary to support our hypothesis that production of rice is favoured, we have analysed data about area under cultivation, production and yield of rice over the time period 2000-2019. This data has been strictly obtained from official government sources where records of such statistics are collected and maintained regularly. For this reason, we have primarily based our study on secondary sources of data using which we can interpret and evaluate the principal trends in agricultural production in Punjab and Haryana. It should be noted that the terms 'rice' and 'paddy' refer to the same crop and they have been used interchangeably hereon.

Data and statistics related to Area, Production and Yield of various crops for states of Punjab and Haryana were extracted from different editions of Statistical Abstracts of Punjab published by the Economic and Statistical Organisation, Government of Punjab and Statistical Abstract of Haryana published by Department of Economic and Statistical Analysis, Government of Haryana. Data pertaining to the agricultural ecosystem (irrigation, electricity, MSP, land holding) in each state was also obtained from Statistical Abstracts and Agriculture Statistics at a Glance published by the Ministry of Agriculture and Farmers Welfare, Government of India. Literature on power, fertiliser and other inputs' subsidies in the state of Punjab and Haryana was collected from the Department of Fertilisers, Economic Survey, Punjab State Electricity Board as well as various other independent research studies that have been appropriately mentioned in the manuscript.

RESEARCH HYPOTHESIS

Punjab and Haryana have traditionally not been rice growing states. Though, both the states have been among the largest producers and contributors of food grains to the central pool in India since early 1990s. The two states benefited immensely from the Green Revolution (post 1960s) that introduced modern agricultural practices and scientific technology to enhance farming methods and build self-reliance in food grain production. The policy of the state government to heavily subsidise power supply to the agricultural sector has enabled farmers to over-extract groundwater using electric tube wells for irrigation needs of the rice crop. Similarly, the availability of fertilisers, which are highly subsidized, and the usage of improved variety of seeds created conditions conducive to cultivation of the rice crop. Marketing facilities and assured procurement of rice at support prices by government agencies have incentivised farmers by making rice cultivation economically advantageous.

1. It is hypothesised that the following institutional and technical factors have contributed to the growth in area under cultivation of rice in the state of Punjab and Haryana:
2. Power subsidies that have made abundant electricity available to fulfil the extensive irrigation requirements of the paddy crop.
3. Use of fertiliser and wide availability of HYV seeds converting into high yield per hectare.
4. Comparatively higher price for paddy in market and/or through Minimum Support Price (MSP).
5. And therefore, the spike in winter pollution in Delhi is the consequence of the populist agriculture policy in Haryana and Punjab.

LIMITATIONS

1. This study was conducted during the COVID-19 pandemic and all research, synthesis of data, analysis and interpretation work was done remotely in a period of two months from Jan'21-March'21. The reference period for the data incorporated in this study was from the year 2000-2019. All analysis and conclusions were derived using facts, figures and statistics available within this time period.
2. All interpretations, estimations and conclusions were drawn using official data obtained from authorised government sources such as Statistical Abstracts and Agricultural Statistics at a Glance. Any error or inconsistency in the published data could affect the findings and interpretations.
3. Nature of the research is secondary wherein data was extracted from genuine and authorised sources available in the public domain like Department of Economics and Statistical Analysis (Haryana) and Economic and Statistical Organisation (Punjab).
4. The researchers frequently encountered issues related to statistical discrepancy on official government (state and central) websites. Often, some data seemed conflicting and didn't meet rational interpretation. There were other problems related to exact subsidy figures and specific data sets not being available in the public domain. For example - information on the amount of power subsidy, state-wise share in fertiliser subsidy, market price of paddy was not recorded systematically by official sources and lacked consistency in independent reports.

DATA ANALYSIS

This chapter provides an in-depth analysis of certain key factors of the agricultural ecosystem namely - power, irrigation, inputs and market/support price. The objective here is to evaluate and understand the historical trend and changes in these factors over the last few decades that have possibly contributed to an increase in rice cultivation in the state of Punjab and Haryana.

While efforts have been made to keep data sets consistent for both Punjab and Haryana, the time period may vary in some data sets due to differences in official record collection by authorised statistical agencies of individual states.

ACCESS TO ELECTRICITY

In this section- we look at distribution, access and availability of power in the agricultural sector post Green Revolution i.e. 1970-2019. Power or electric energy is an important resource for farmers as it is required to extract groundwater for irrigation through electric tubewells. Abundant, cheap and convenient access to power enables the farmer to pump out water from underground reservoirs at will to meet water requirements of their crops.

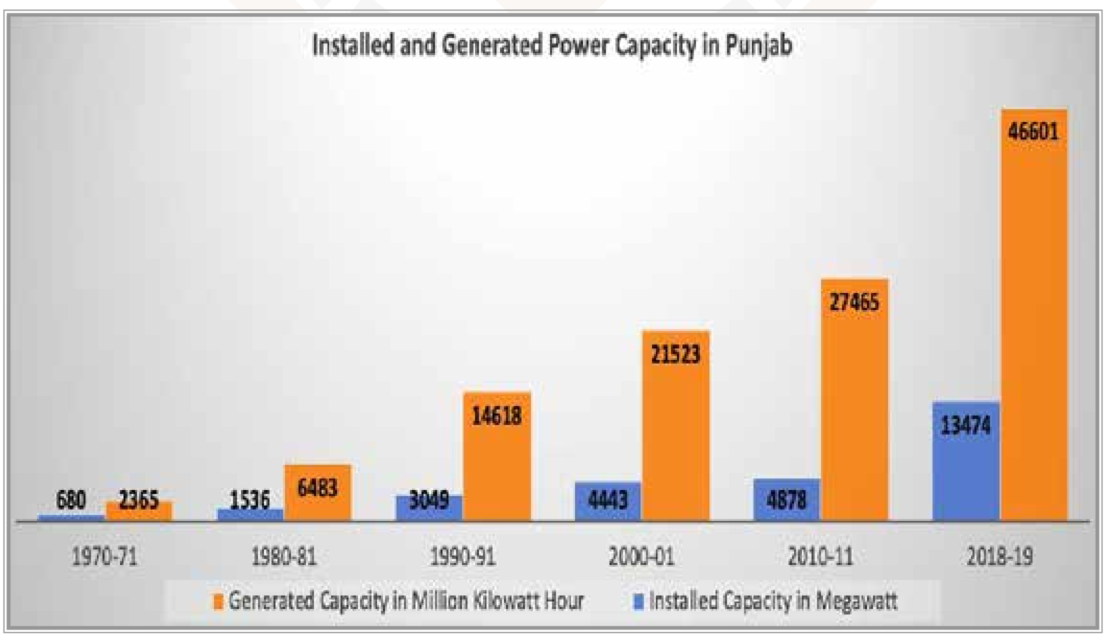
To understand the transformation of power as a resource in the agricultural sector in Punjab and Haryana, we carefully examine the following factors for each state -

1. Installed Capacity and Generated Capacity of Power
2. Agricultural consumption of electricity over the years
3. Growth in number of farmers consuming electricity
4. Average sale of power per farmer
5. Average revenue collected by the government per unit of power sold to the agricultural sector 6. Increase in number of electric tubewells

PUNJAB

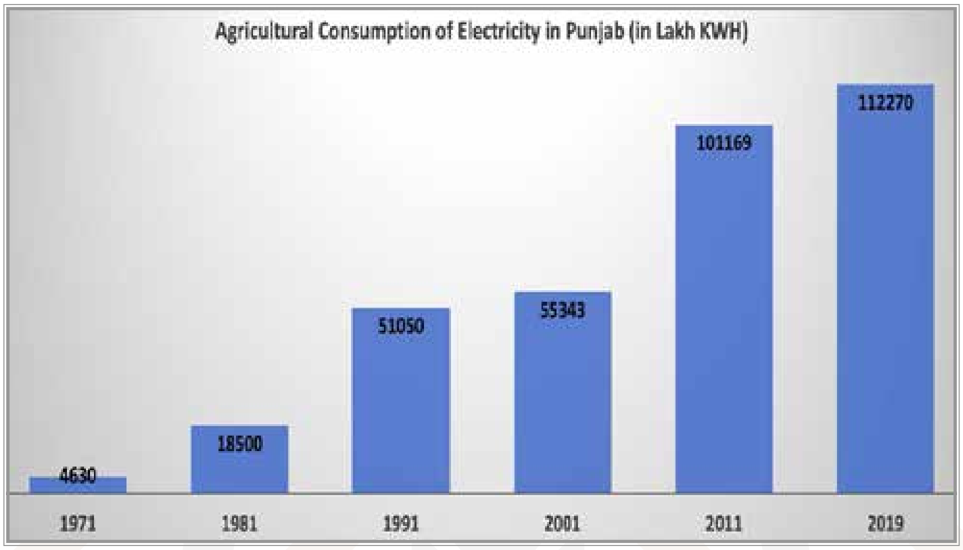
Installed power capacity in Punjab increased from 680 MW in 1970 to 4443 Megawatt (MW) in 2001 which is more than 6 times growth in installed capacity over three decades or a 6.46% compounded annual growth. From 2000-2011, the growth in capacity slowed down

Fig 6 - Installed and Generated Power Capacity in Punjab (1970-2018)



Source: Statistical Abstracts of Punjab, 2019 and increased by only 435 MW in the entire decade. After 2010, installed capacity increased manifold in just 5 years and amounted to 13,961 MW in 2017 which is a staggering addition of 9,083 MW in capacity. In 2019, capacity slightly decreased in absolute terms to 13,474 MW. The per annum growth rate of installed capacity from 2000-2019 is 6%. The generated capacity has been consistently increasing from 1970. It increased from 2364.5 million kilowatt hour (million kWh) in 1971 to more than 45,500 million kWh in 2019 indicating a growth of 6.45% per annum over the course of almost five decades.

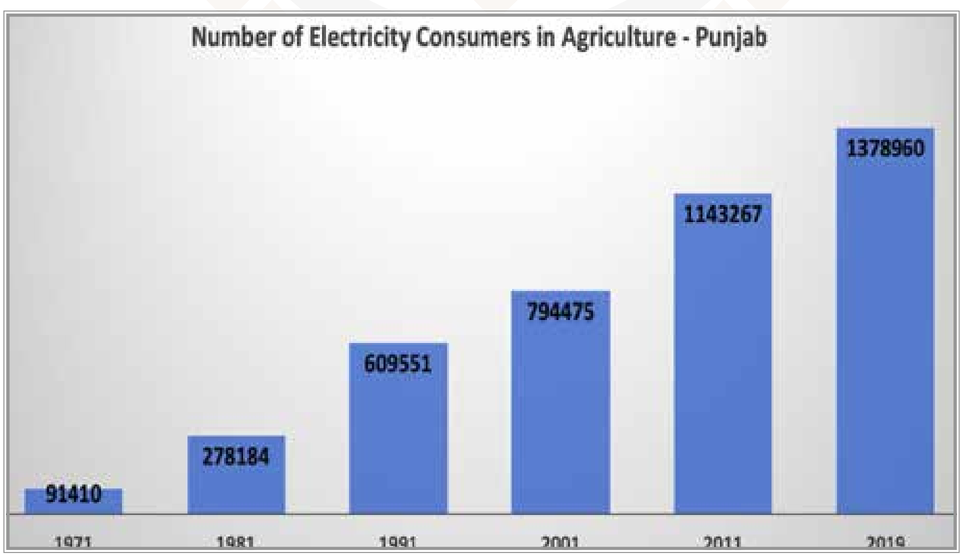
Fig 7 - Power Consumption in Agriculture in Punjab (1970-2019)



Source: Statistical Abstracts of Punjab, different issues

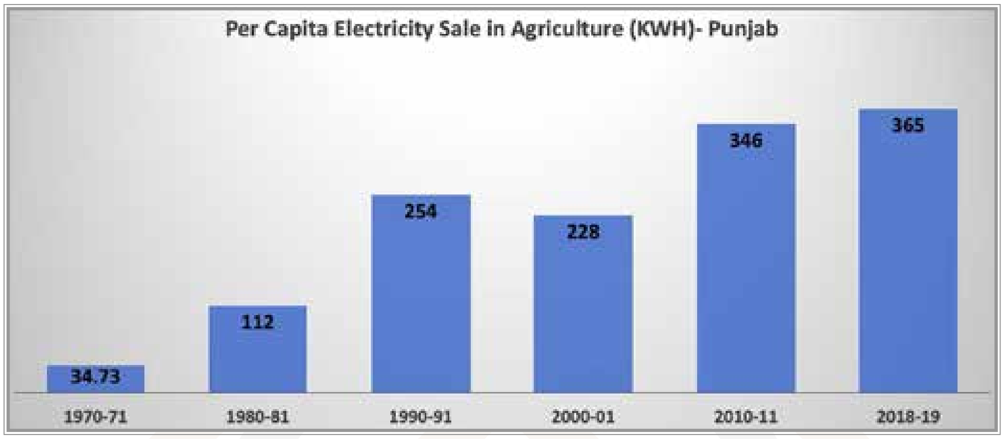
In Punjab, the power consumption in agriculture was 4630 lakh kwh in 1971. It increased to almost 12 times in only three decades i.e. 55,340 lakh kwh by 2001. Between 2000 and 2019, power consumption rose steadily at a rate of 3.8% per annum to reach 1,12,270 lakh kwh in 2019. Use of electricity by agricultural consumers reached its maximum level in 2018 at 1,24,840 lakh kwh following which it declined by 10% in the subsequent year. The total

Fig 8 - Power users in Agricultural Sector in Punjab (1981-2018)



Source: Statistical Abstracts of Punjab, various issues number of farmers consuming electricity increased from 2,78,184 in 1981 to 7,94,475 in 2001. In 2019, the total number of agricultural consumers of electricity was 13,78,960 which is a 73.5% increase from the 2001 number. In the 19-year period from 2000-2019, the compounded annual growth of farmers consuming electricity was a little less than 3% compared to the 5.4% per annum growth during 1980-2000. In 1977, it was declared that Punjab achieved 100% rural electrification and as per the 1991 census, all the inhabited villages had access to power[9].

Fig 9 - Electricity sale per capita in kilowatt hour in Punjab (1970-2019)

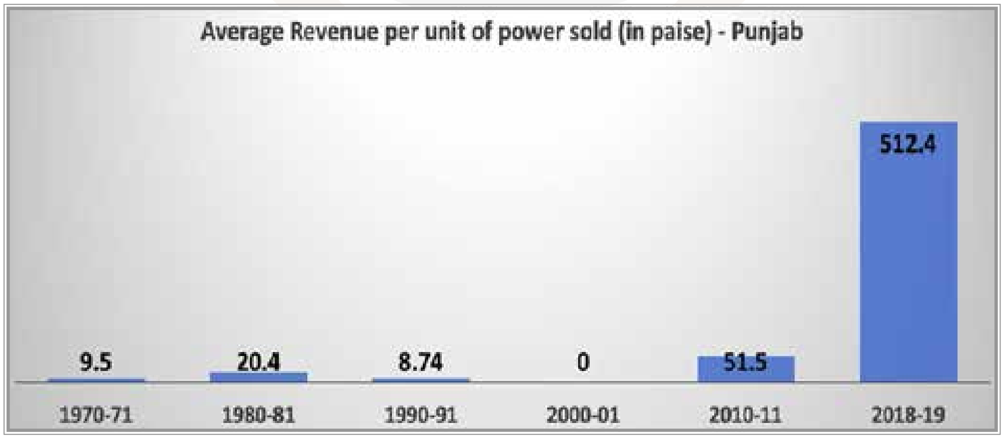


Source: Statistical Abstracts of Punjab, various issues

The per capita sale of electricity in the agricultural sector was just 34.73 KWH in 1971. In 3 decades, per capita consumption rose by 6.5 times to 228 KWH in 2001. After almost a decade in 2010, average electricity consumed by a farmer was 364 KWH, indicating a per annum growth of 5.34%. From 2011, it shows a stable increasing trend till 2018. In 2018, the per capita consumption of electricity peaked at 411 KWH after which it declined by 11% to 365 KWH in 2019.

In 2018, with an annual per capita consumption of electricity at 411 KWH in Punjab, it ranked second in India, following Telangana where per capita electric consumption was 532 KWH.

Fig 10 - Average Revenue per unit of power sold in Punjab (1971-2019)



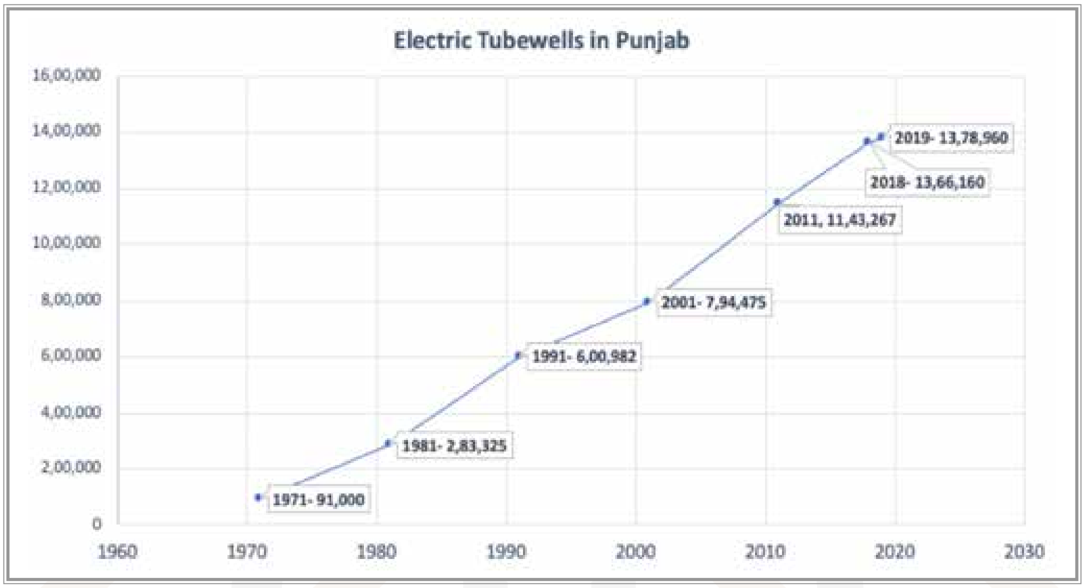
Source: Statistical Abstracts of Punjab, various issues

9 Status of Rural Electrification in Punjab. https://www.recindia.nic.in/download/PUNJAB.pdf

From 1998, the state government decided to extend electric energy to farmers at no cost.

Occasionally (in some years between 2002 and 2011), this policy was partially revoked and meagre amounts were recovered from farmers. But power continues to be heavily subsidised and supply is often unmetered. In 2019, the average revenue earned by the government per unit of electricity sold was 512.4 paise (little more than 5 rupees).

Fig 11 - Number of Electric Tubewells in Punjab (1971-2019)



Source: Statistical Abstracts of Punjab, various issues

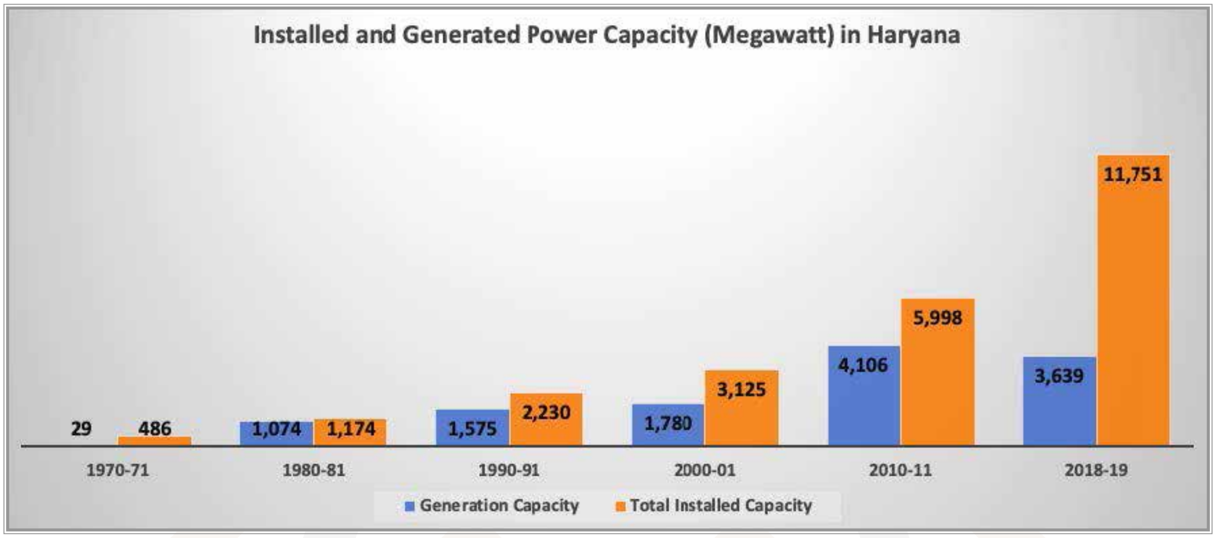
The total number of electric tubewells in the state of Punjab increased from 91,000 in 1971 to 13,78,960 in 2019 growing by more than 15 times over the course of 50 years. It should also be noted that more than 90% of the tubewells in Punjab are operated by electricity and only some use diesel as a fuel.

In the states of Punjab and Haryana, there is almost 100% rural electrification, as per the 2019 Statistical Abstracts, suggesting that the distribution and access to electricity is universal. Even in undeveloped or underdeveloped regions, power is readily available to the farmers' household for various purposes.

HARYANA

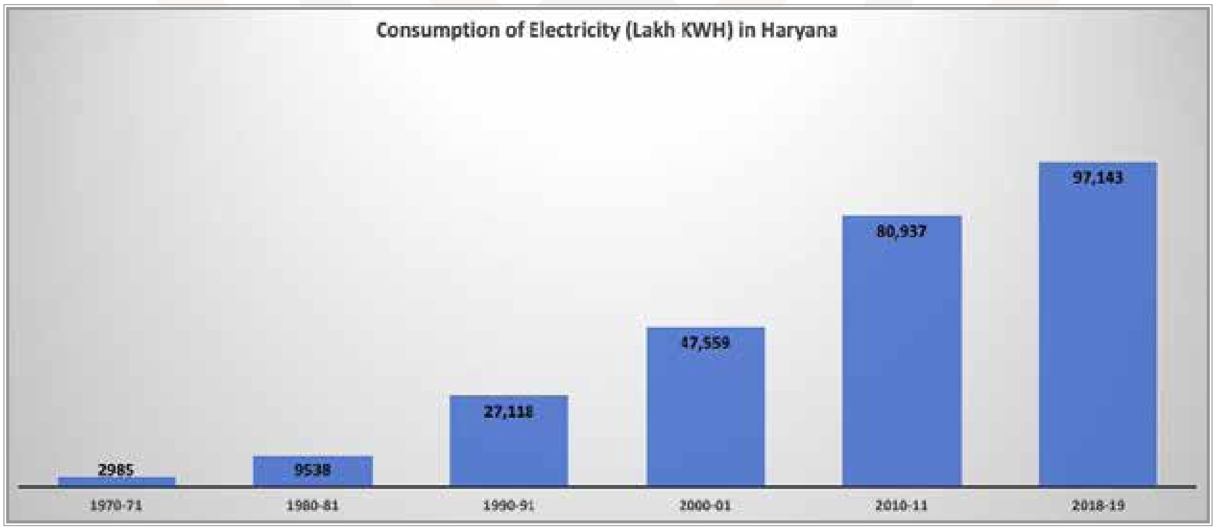
In 1971, electricity generation capacity in Haryana was only 29 MW. Additions to the installed capacity, from 486 MW in 1971 to 3,125 MW in 2001, raised the generation capacity to 1,780 MW in 2001. In 2019, out of the total installed capacity of 11,751 MW, generation capacity was 3,639 MW.

Fig 13 - Number of Electric Tubewells in Punjab (1971-2019)



Source: Statistical Abstracts of Haryana, 2019

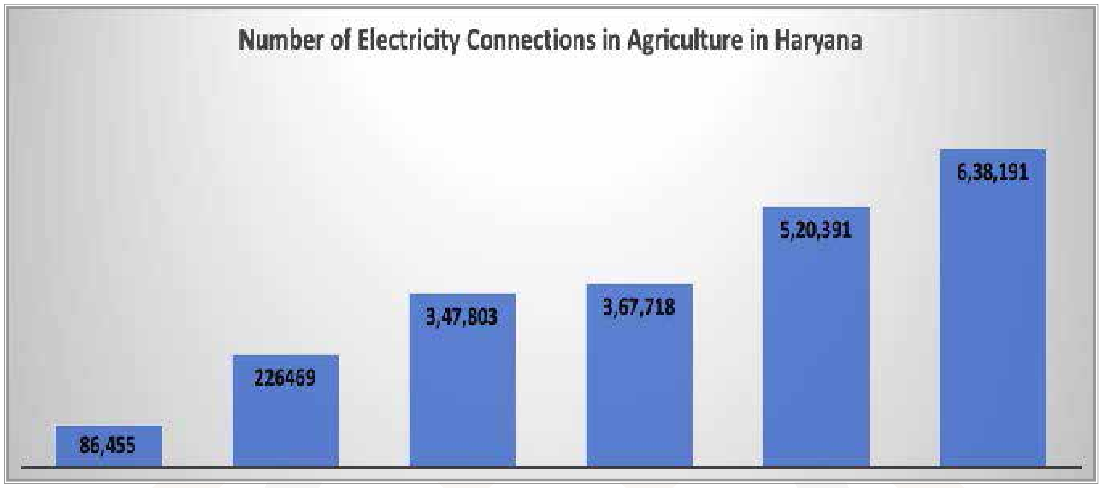
Fig 14 - Power Consumption in Agriculture in Haryana (1970-2019)



Source: Statistical Abstracts of Haryana, various issues

In the state of Haryana, the agricultural sector consumed 2985 lakh kwh of electricity in 1970. After 3 decades, electricity consumption became almost 16 times of the 1970 amount (CAGR of 9.7% between 1970 and 2000), totalling to 47,559 lakh KWh in 2001. It peaked at 1,00,673 lakh KWh in 2018 after which consumption of electricity declined slightly to reach 97,142 lakh KWh in 2019. From 2000-2019, power consumption by the farm sector grew by an average of 3.83% per year.

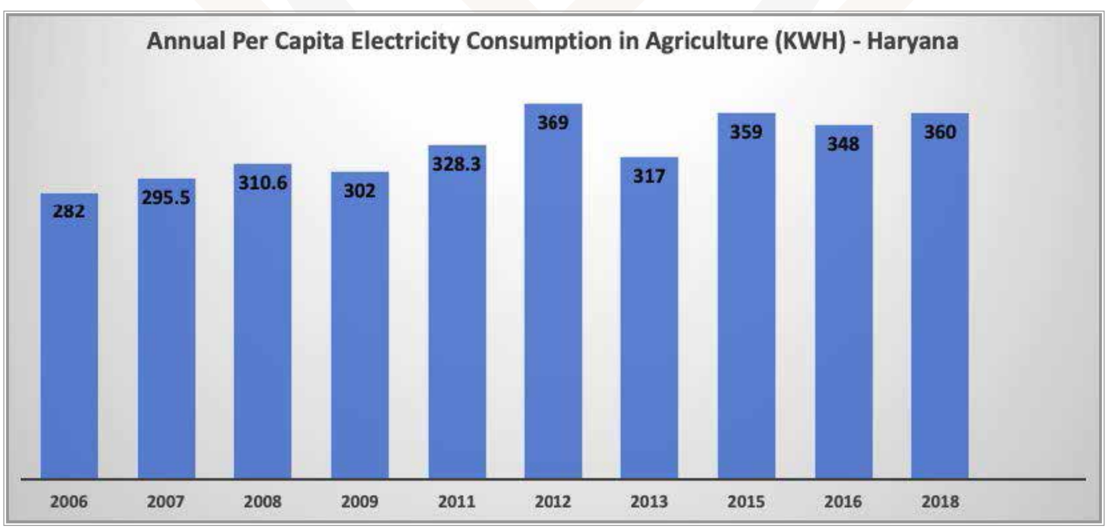
Fig 14 - Power users in Agricultural Sector in Haryana (1971-2019)



Source: Statistical Abstracts of Haryana, 2019

The number of electricity connections in the agricultural sector was just 86,455 in 1971. Power connections increased to 3,67,718 in 2001 and further to 6,38,191 in 2019. From 2000-2019, the number of electricity connections increased by 73.55%. According to NITI Aayog's annual report for the year 2016-17, the state of Haryana has achieved 100% rural electrification[10].

Fig 15 - Annual Per Capita Consumption of Electricity in Agriculture in Haryana[11]



Source: Agricultural Statistics at a Glance

10 Status of Rural Electrification in Haryana. http://www.garv.gov.in/assets/uploads/reports/statesnaps/Haryana.pdf

11 Per capita power consumption data for all sectors combined is available in Statistical Abstracts of Haryana and not for the agriculture sector in particular which doesn't fulfil our purpose. Therefore, we had to find that information from other sources and only the data for the above-mentioned years could be extracted.

Fig 16 - Power Distribution & Retail Supply Tariffs in Agriculture in Haryana[12]

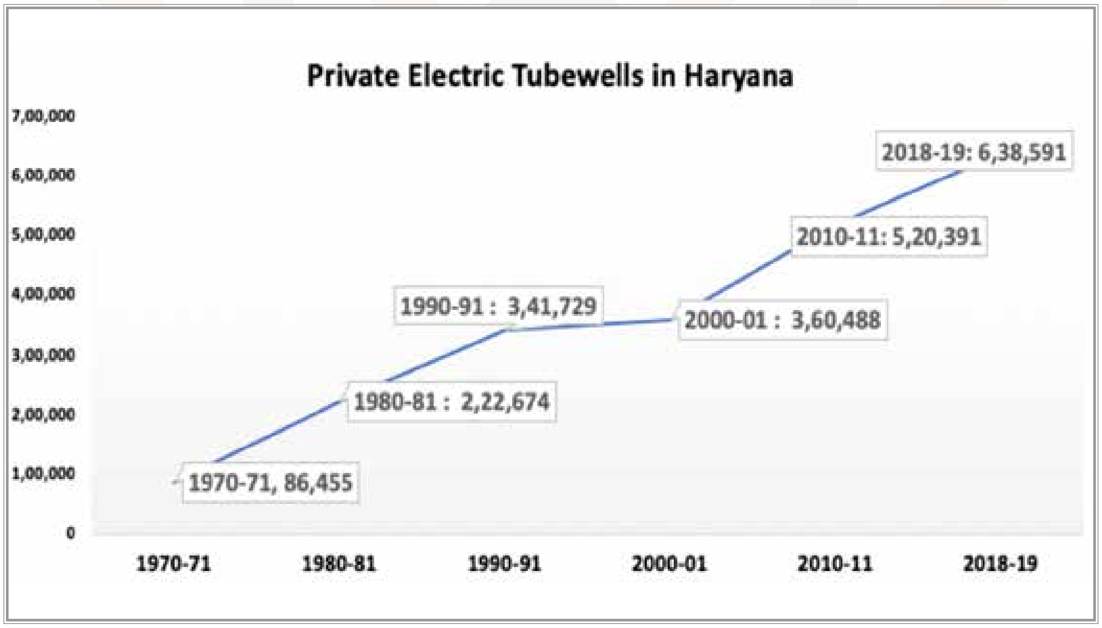
Energy Charges (Paise/kwh)		
Tariff Year	**Metered***	**Unmetered**
2012	25	nil
2013	25	nil
2014	25	nil
2015	10	nil
2016	10	nil
2017	10	nil
2018	10	nil
2019	10	nil

*metered supply for motor up to 15 BHP capacity
Source - Haryana Electricity Regulatory Commission

In Haryana, annual per capita power consumption increased from 282 kwh in 2006 to 360 kwh in 2018, peaking at 369kwh in 2012-13. In the 12-year period, per capita consumption of electricity by the state's farmers has grown by 27.65% or at a CAGR of 2.6%.

The electricity tariff rate charged to agricultural consumers in Haryana having an unmetered connection has been zero since 2012. For farmers with a metered supply of power (up to 15 BHP), energy charges have actually declined from 25 paise/kwh during 2012-2015 to 10 paise/kwh since 2015 till 2019.

Fig 17 - Number of agricultural private tubewells in Haryana (1971-2019)



Source: Statistical Abstracts of Haryana, various issues

12 The data set containing tariff rates for supply of electric energy to farmers is limited as it was not comprehensively available in the statistical records. Relevant information that is mentioned was found in annual reports of the Haryana state power commission but could only be gathered for the given time frame (2012-2019)

In 2001, the number of private tubewells receiving power supply was 3,60,488. Since then, it has consistently increased over the years and in 2019, the total private electric tubewells were 6,38,591 which is a 77% increase in 20 years. Between 1970 and 2019 in Haryana, the number of electricity operated tubewells has gone up from 86,455 to 6.38 lakhs which is almost a 7.5 times growth in five decades. In Haryana, 87.25% of the total tube wells are electric while the rest 12.75% are operated by diesel.

As per the Haryana Electricity Regulatory Commission (2018), the total power consumed by all private electric tube wells amounts to 857.1 crore KWh units or an average of 14,160 KWh per pump per annum. The government subsidy on power for the agricultural sector reduces the per unit cost to Rs 0.11 per KWh for the farmer against Rs. 7.34 per KWh supply cost incurred by the power distribution company.

IRRIGATION

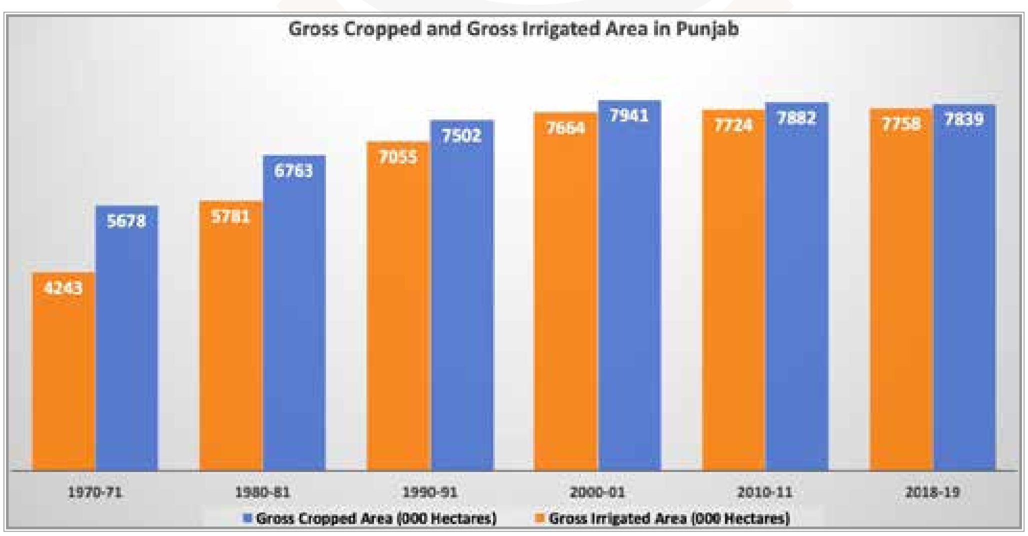
This section gives information on how the water requirements of different crops in Punjab and Haryana were met. It is important to assess the available irrigation sources in each state and the dependency of an average farmer on each source. Rice being a highly water intensive crop requires excess water for its proper growth and as we know, rainfall in Punjab and Haryana is quite erratic and inadequate to satisfy the extensive needs of rice crop. Moreover, there exists a critical link between power and irrigation as electric tubewells are operated using electricity for groundwater irrigation and as we have seen in the previous data sets (Fig 2.6 and Fig 3.6), use of electric tubewells has become dominant in both states.

Therefore, we evaluate the following factors to decipher how the increase in rice cultivation in our chosen time period (1970-2019) has been achieved -

1. Gross Cropped Area and Gross Irrigated Area (for all crops)
2. Total Area under Cultivation of Rice and Gross Irrigated Area for Rice
3. Net Irrigated Area by source along with share of Tubewells and Canals

PUNJAB

Fig 18 - Gross Cropped and Gross Irrigated Area in Punjab (1970-2019)



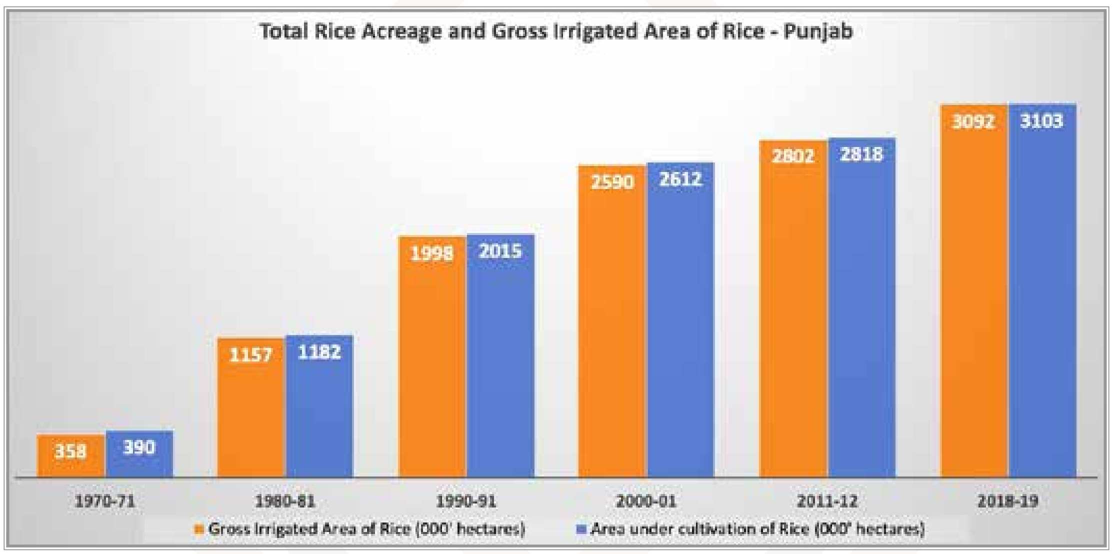
Source: Statistical Abstracts of Haryana, various issues

In 1971, the gross irrigated area was 4.24 million hectares out of a total 5.67 million hectares of gross cropped area in Punjab. Between 1970 and 2001, gross irrigated area increased by 80.66% to 7.66 million hectares in 2001, whereas gross cropped area increased by about 40% to 7.94 million hectares in 2001.

Since 2000, growth in gross irrigated area has slowed down. Between 2000-2019, gross irrigated area increased by only 1.22% to 7.76 million hectares (2019) while gross cropped area decreased by 1.28% to 7.84 million hectares in 2019.

Gross cropped area increased from 5.68 million hectares in 1971 to 7.84 million hectares in 2019 (38% growth) while gross irrigated area rose from 4.24 million hectares to 7.76 million hectares (83% growth) in the same time period. In terms of percentage, gross irrigated area to gross cropped area was 74.7% in 1971 which rose to 96.5% in 2001 and further to 98.9% in 2019.

Fig 19 - Total area and Gross Irrigated area of Rice in Punjab (1990-2019)



Source: Statistical Abstracts of Haryana, various issues

For rice crop in particular, area under cultivation increased from 0.39 million hectares in 1971 to 2.61 million hectares in 2001, growing by more than 6.5 times in about three decades. From 2001 to 2019, rice acreage increased to 3.1 million hectares which is an 18.8% increase in 20 years. Between 1970 and 2019, area under cultivation of rice soared from 0.39 million hectares to 3.1 million hectares representing 8 times increase in acreage over a period of 50 years.

Out of the total area under cultivation of rice crop, the gross irrigated area had increased from almost 0.36 million hectares in 1971 to 2.6 million hectares in 2001 (more than 7 times growth in 30 years). In 2019, gross irrigated area was 3.09 million hectares which is an increase of almost 20% from 2001. In the 50 years from 1970 to 2019, gross irrigated area of rice underwent an increase of more than 8.5 times - which is similar to the growth momentum shown by rice acreage in the same time interval.

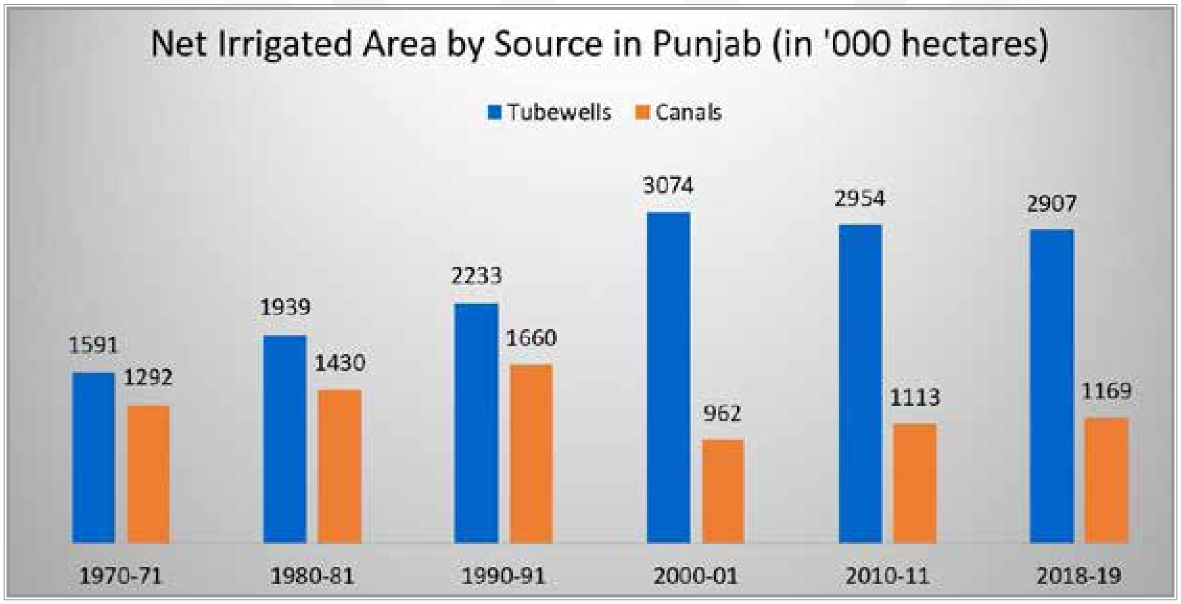
It is worth noting that the percent share of gross irrigated area to the total area under cultivation of rice in Punjab has consistently been above 99% since 1990-present. It was a little less than 92% in 1971 and then increased to almost 98% in 1981.

Fig 20 A - Net Irrigated Area in Punjab by source (1970-2019)

Energy Charges (Paise/kwh)				
Year	Net Area Irrigated (000 Ha)		Total*	Percent to net sown area
	Canals	Tubewells	000 Ha	
1970-71	1292	1591	2888	71
1980-81	1430	1939	3382	81
1990-91	1660	2233	3909	93
2000-01	962	3074	4038	95
2010-11	1113	2954	4070	97.9
2011-12	1113	2970	4086	98.8
2012-13	1133	2982	4115	99.2
2013-14	1160	2981	4141	99.9
2014-15	1175	2943	4118	99.9
2015-16	1201	2936	4137	99.9
2016-17	1152	2975	4127	99.9
2017-18	1176	2948	4124	99.9
2018-19	1169	2907	4076	98.9

*metered supply for motor up to 15 BHP capacity
Source - Haryana Electricity Regulatory Commission

Fig 20 B - Net Irrigated Area in Punjab by source (1970-2019)



Source: Statistical Abstracts of Punjab, 2019

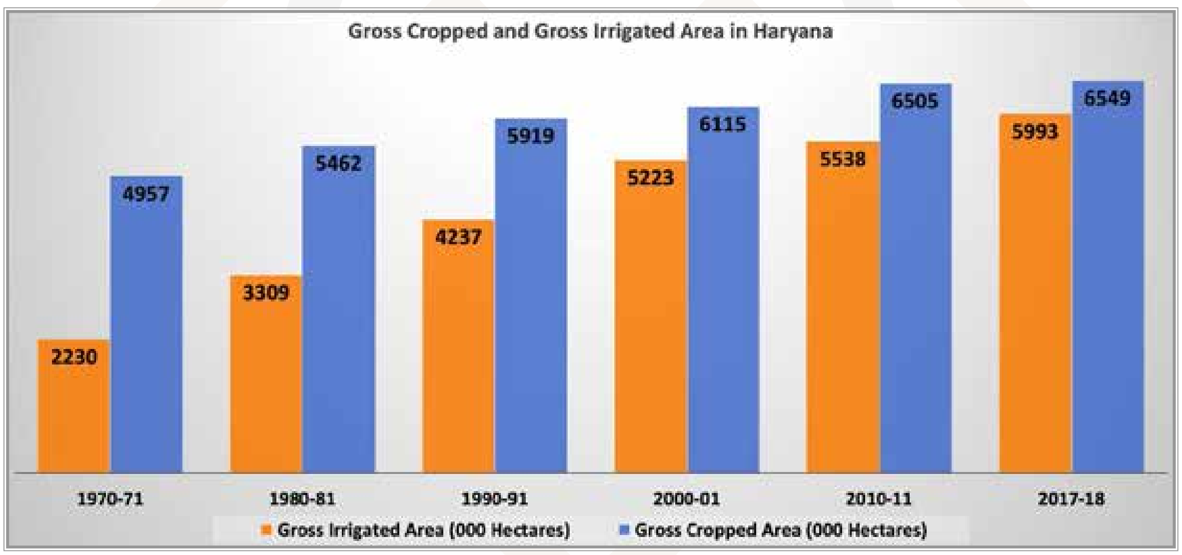
In Punjab, net area irrigated by government canals was 1.29 million hectares and that through private tubewells (electric and diesel) was 1.59 million hectares in 1971. Since then, canal irrigated area has been steadily declining while net area irrigated by private tubewells has soared. In 2001, the share of tubewells in net irrigated area in the state of Punjab increased to 3.074 million hectares from 1.59 million hectare while canal irrigated area declined to 0.96 million hectares from 1.29 million hectare. Between 1970-2000, the share of tubewells in net irrigated area went up from 55% to 76.2%. In the 50 years from 1970 to 2019, tubewell irrigated area has sharply risen by almost 83% from 1.59 million hectares to 2.9 million hectares while area irrigated by canals has reduced by about 9.5% from 1.29 million hectares to 1.17 million hectares.

Although since 2000, net area irrigated by tubewells has shown a slight decrease- it was maximum in 2001 (3.07 million ha) after which it decreased to 2.9 million hectares in 2019. In the same period, canal irrigated area rose from 0.962 million hectares to 1.17 million hectares showing an increase of 21.5% in almost two decades.

Most recently in 2019, the share of canals in net irrigated area was 28.68% indicating that water supply through private agricultural tubewells was meeting more than 70% of the irrigation needs of different crops in the state of Punjab.

HARYANA

Fig 21 - Gross Cropped and Gross Irrigated Area in Haryana

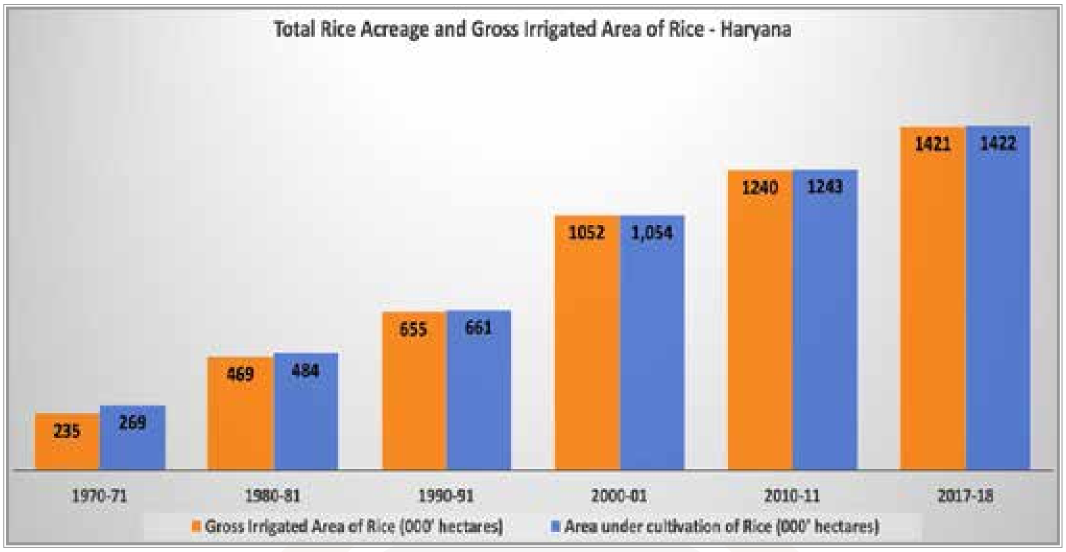


Source: Statistical Abstracts of Haryana, various issues

In 1971, the gross irrigated area was 2.23 million hectares out of the total 4.95 million hectares of gross cropped area in Punjab. Between 1970 and 2001, gross irrigated area increased by 134.2% to 5.22 million hectares whereas gross cropped area increased by only 23.3% to 6.11 million hectares. From 2000 onwards till 2018, gross irrigated area rose by 14.72% to 5.99 million hectares while gross cropped area rose by 7% to 6.55 million hectares.

In Punjab, gross irrigated area has grown by more than 2.5 times from 2.23 million hectares in 1971 to almost 6 million hectares in 2018 while gross cropped area showed a 32% expansion, rising from 4.96 million hectares in 1971 to 6.55 million hectares in 2018. Percent share of gross irrigated area to gross cropped area was 44.9% in 1971 which rose to 85.4% in 2001 and further to 91.5% in 2018

Fig 22 - Total area and Gross Irrigated area of Rice in Haryana (1970-2018)



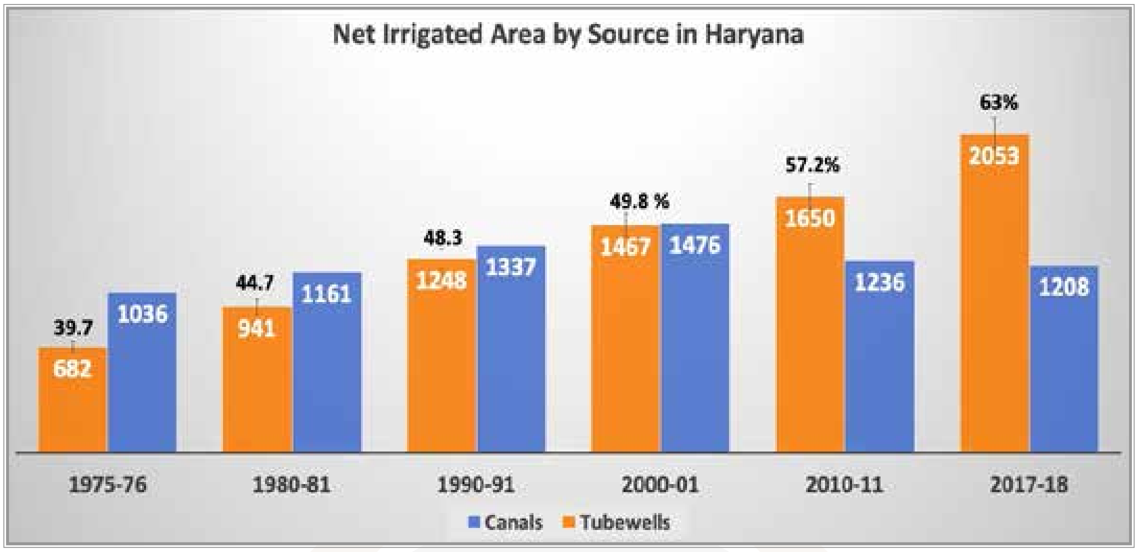
Source: Statistical Abstracts of Haryana, various issues

The area under cultivation of rice crop increased from 0.27 million hectares in 1971 to 1.054 million hectares in 2001 which is an increase of almost four times in three decades. From 2001 to 2018, rice acreage increased by almost 35% to reach 1.42 million hectares in 2018.

Out of the total area under cultivation of rice crop, gross irrigated area was only 0.235 million hectares, which was 87.4% of the total 269,000 ha area under rice cultivation in 1971. It grew proportionately with rice acreage to reach 1.05 million hectares in 2001 signifying 4.5 times increase in gross irrigated area in about 30 years. Between 2000 and 2018, gross irrigated area of rice rose by 35% to reach 1.42 million hectares in 2018 which is 99.9% of the total area under rice cultivation. Starting from 1970 till 2018, rice acreage has undergone an expansion of more than five times from 269,000 hectares to 1.422 million hectares. Gross irrigated area of rice has increased even more rapidly showing a six times growth from 235,000 hectares to 1.421 million hectares in the same time interval.

In Haryana, the percent share of gross irrigated area to total area under rice cultivation has been above 99% in all the years except 1981 and 2016. In 2018, gross irrigated area of rice was 1.421 million hectares and total rice area was 1.422 million hectares signifying a 99.9% share.

Fig 23A - Total area and Gross Irrigated area of Rice in Haryana (1970-2018)



Source: Statistical Abstracts of Haryana, various issues

Fig 23B - Net Irrigated area by Source in Haryana (1980-2018)

Energy Charges (Paise/kwh)				
Year	Net Area Irrigated (000 Ha)		Total*	Percent to net sown area
	Canals	Tubewells	000 Ha	
1975-76	1036	682	1754	48.4
1980-81	1161	941	2134	59.2
1990-91	1337	1248	2600	72.7
2000-01	1476	1467	2958	83.9
2010-11	1236	1650	2887	82.1
2011-12	1193	1879	3072	87.4
2013-14	1210	1721	2931	83.8
2014-15	1151	1818	2973	84.4
2015-16	1162	1850	3014	85.6
2016-17	1181	1996	3177	90.8
2017-18	1208	2053	3261	93
2017-18	1176	2948	4124	99.9
2018-19	1169	2907	4076	98.9

*Also includes other sources such as wells, rainfall, tanks

Source - Statistical Abstracts of Haryana, 2019

In Haryana, for all the crops combined, net irrigated area increased from 1.75 million hectares in 1976 to 2.96 million hectares in 2001 indicating a 69% rise in about 25 years. The share of net irrigated to net sown area climbed from almost 48% in 1976 to 84% in 2001. Between 2001 and 2018, net irrigated area further rose by 10.2% to reach 3.26 million hectares while its share in net sown area jumped from 84% to 93%. Overall, net irrigated area grew by 86% from 1.75 million hectares in 1976 to 3.26 million hectares in 2018 and its percentage share to net sown area expanded from 48.4% to 93% in the same 45-year period.

In 1976, area irrigated by canals was 1.036 million hectares and tubewell irrigated area was 0.68 million hectares. Between 1976-2001, net area irrigated by tubewells grew by 115% to reach 1.467 million hectares in 2001 while canal irrigated area increased to 1.476 million hectares in 2001 which is a 42.4% rise.

After 2001, the net area irrigated by private agricultural tubewells soared rapidly and overtook canal irrigated area, suggesting an increase in the dependence on tubewells. From 2001-2018, tubewell irrigated area increased by almost 40% to about 2 million hectares (2018), whereas net area irrigated by government canals actually declined by a little more than 18% during this time period to reach 1.2 million hectares in 2018. In 2018, the share of tubewells in net irrigated area was almost 63% whereas in 1976, it was only 38.8%. Parallelly, dependence on canals has reduced from 60% in 1976 to 37% in 2018.

Punjab and Haryana - Preservation of Subsoil Water Act, 2009

The Preservation of Subsoil Water Act, 2009 was enacted first in Punjab and then in Haryana in response to the rapidly depleting groundwater levels. The law had a major impact on the timeline of the paddy crop as it prohibited establishment of paddy nurseries before 10th May and transplanting of paddy seedlings before 10th June.

"Any farmer, who contravenes the provisions of this Act, shall be liable of penalty of ten thousand rupees for every month or part thereof, per hectare of the land till the period, such contravention continues"

The law gives authorised officials legal power to destroy the nursery of sown or transplanted paddy of those farmers who have violated the law by carrying out their operations before the notified date.

The primary motive was to push back the schedule of rice transplanting and bring it nearer to the monsoon season so dependence on rainfall for irrigation requirements of the paddy crop is augmented and groundwater is conserved. Moreover, a lot of water was expected to be saved as the rate of evapotranspiration is relatively less in the monsoon season compared to the hot summer months in which rice was grown earlier.

Implementation of this law significantly shortened the time window available to the farmers between harvesting of rice and preparing the field for sowing of the rabi crop i.e., wheat. Therefore, the farmers got a very limited time frame in which they had to harvest paddy, clear the residue and sow the next crop. A number of farmers resorted to stubble burning in order to expedite the process or else they risked harming the yield of wheat which could have an adverse impact on their earnings. The delayed timing of stubble burning due to the law directly coincided with the start of Winter season in Northern India which severely exacerbated air pollution.

AGRICULTURAL INPUTS

To suitably and profitably cultivate crops, farmers require various kinds of inputs to ensure systematic growth and high yield (thereby high production) apart from fulfilling the basic irrigation requirements. Use of chemical fertilisers and improved variety of seeds has been a critical factor in influencing the cropping pattern as well as production of foodgrains on a large scale in Punjab and Haryana. The availability of fertilisers coupled with the extent to which they are used in an average farm plays an important role in helping us understand how the massive leap in rice production and yield was achieved starting from the Green Revolution era.

We look at the historical trend in the following statistics to gain a deeper insight into the contribution of inputs in agricultural production in the state of Punjab and Haryana -

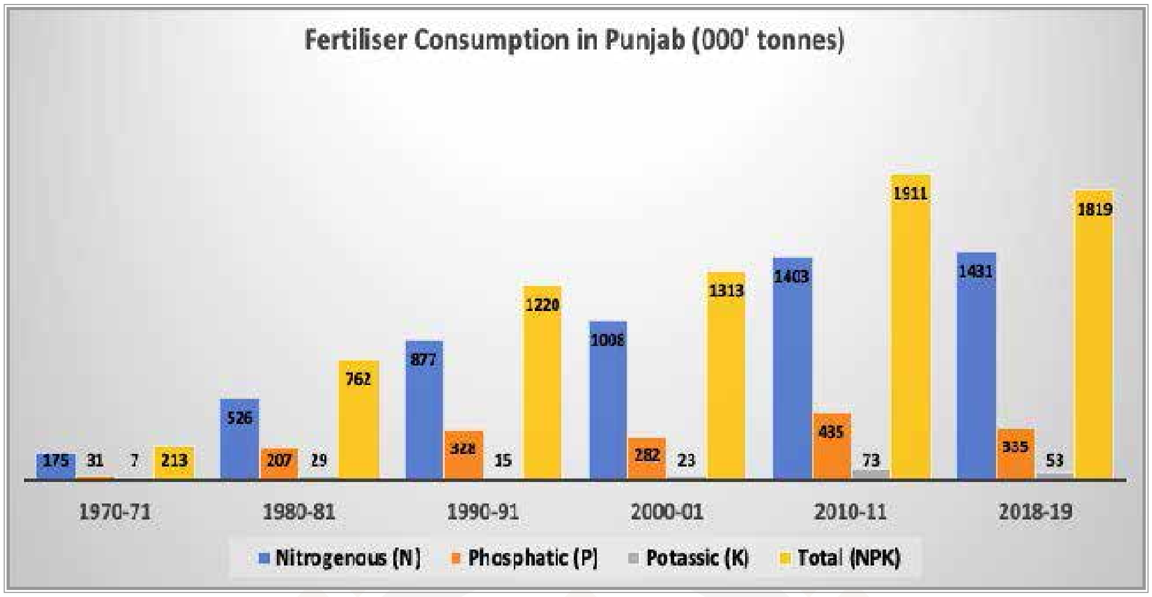
1. Consumption of Chemical Fertilisers (most commonly used - Nitrogen, Phosphorus and Potassium based)
2. Application of Fertilisers per hectare (in kilogram) in major rice producing states
3. Rice Production data (Area, Production, Yield)

Fig 24 A - Consumption of Chemical Fertilisers in Punjab

Fertiliser Consumption in Punjab (Nutrient tonnes)				
Year	Nitrogenous (N)	Phosphorus (P)	Potassium (K)	Total (NPK)
1970-71	175000	31000	7000	213000
1980-81	526000	207000	29000	762000
1990-91	877000	328000	15000	1220000
2000-01	1008000	282000	23000	1313000
2010-11	1403000	435000	73000	1911000
2014-15	1321000	326000	30000	1677000
2015-16	1447000	418000	78000	1943000
2016-17	1458000	411000	48000	1917000
2017-18	1498000	359000	51000	1908000
2018-19	1431000	335000	53000	1819000

Source - Statistical Abstracts of Punjab, 2019

Fig 24B- Consumption of Chemical Fertilisers in Punjab



Source: Statistical Abstracts of Punjab, 2019

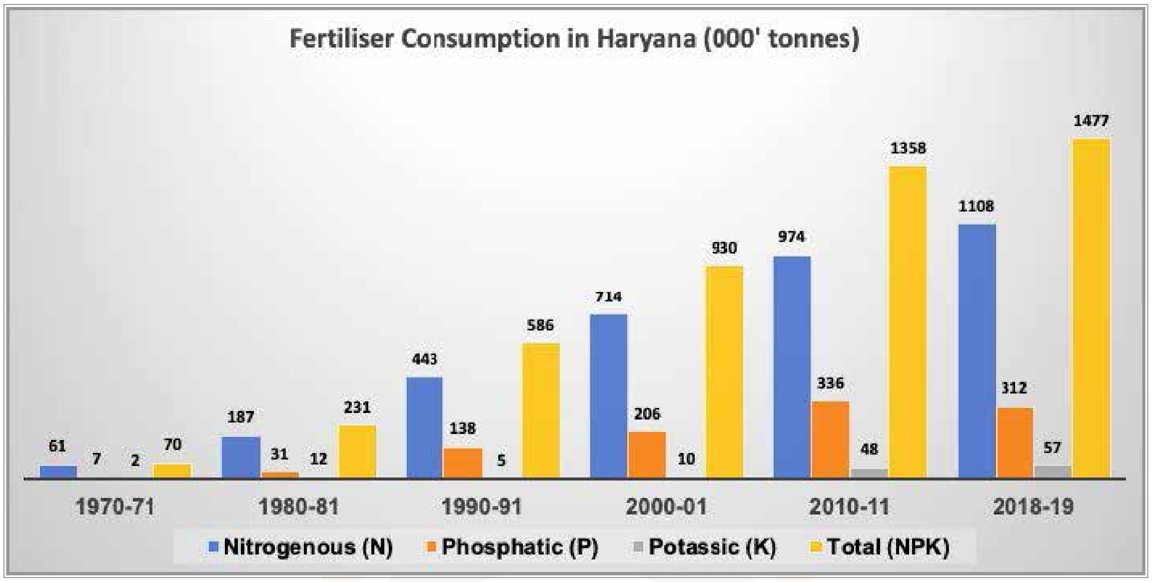
Figure 24 B depicts the annual consumption of most commonly used chemical fertilisers (Nitrogenous, Phosphorus, Potassium) in Punjab for the last five decades. It is observed that the total consumption rose from 2.1 lakh nutrient tonnes in 1971 to 13.1 lakh nutrient tonnes in 2001 with a compounded annual growth rate of 6.25% for the 30-year period. From 2000 onwards, total NPK consumption further rises to reach 19.1 lakh nutrient tonnes in 2010 after which it starts fluctuating. Consumption of NPK fertilisers reaches its peak at 19.4 lakh tonnes in 2016 but then gradually reduces in the subsequent years. In 2019, total annual consumption of fertilisers was 18.2 lakh nutrient tonnes which is a 6.2% slump from peak consumption in 2016. Between 1970 and 2019, annual chemical fertiliser consumption showed a growth of more than 8 times or a CAGR of 4.4%.

Fig 25 A - Consumption of Chemical Fertilisers in Haryana

Fertiliser Consumption in Punjab (Nutrient tonnes)				
Year	**Nitrogenous (N)**	**Phosphorus (P)**	**Potassium (K)**	**Total (NPK)**
1970-71	60972	6860	2228	70060
1980-81	187385	31340	12098	230823
1990-91	443245	138005	5042	586292
2000-01	714308	206319	9668	930295
2010-11	974045	335950	47627	1357622
2011-12	1020892	369624	37531	1428048
2014-15	1013267	254437	36199	1303903
2015-16	1037101	290591	19699	1347391
2016-17	1007232	290555	41522	1339279
2017-18	1049270	280270	46211	1375751
2018-19	1107798	311608	57273	1476679

Source - Statistical Abstracts of Haryana, 2019

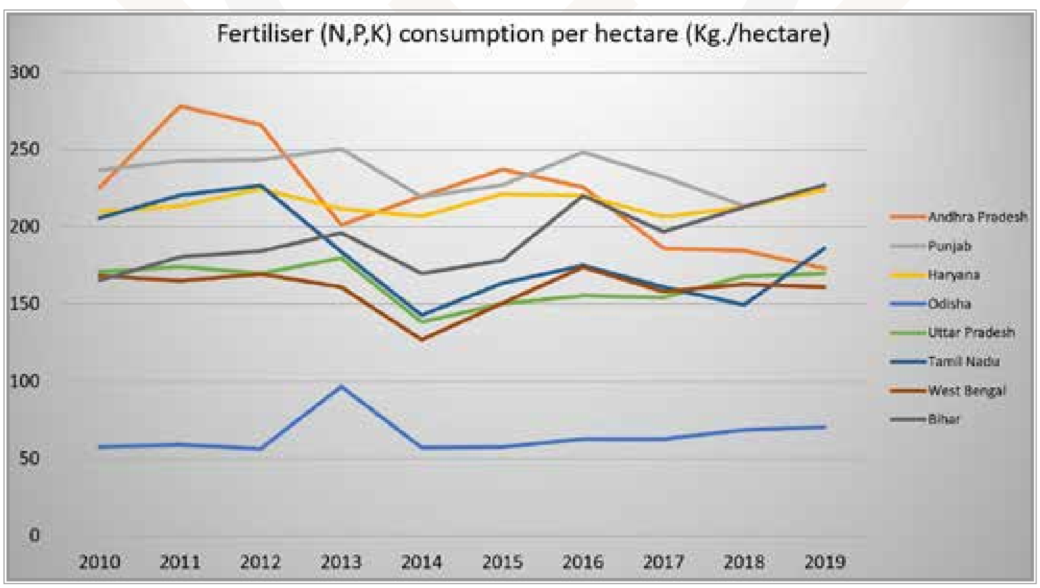
Fig 25B- Consumption of Chemical Fertilisers in Haryana*



*Values have been rounded off to the nearest thousand in the graph. See table for exact number
Source - Statistical Abstracts of Haryana, various issues

In 1971, fertiliser consumption was only 70 thousand nutrient tonnes in Haryana. Over the next four decades, it rose rapidly to 930 thousand tonnes in 2011, growing at a compound annual rate of 9%. After rising further to 14.28 lakhs tonnes in 2012, consumption declined and remained in the 13-lakh tonne range for following six years. Total NPK consumption again rose in 2019 to reach 14.76 lakh tonnes which is the highest for the decade. Thus, in the 50 years from 1970-2019, NPK fertiliser annual consumption rose by more than 21 times with a 6.3% CAGR.

Fig 26- Chemical Fertiliser Consumption in kilogram per hectare in major rice producing states (2010-2019)

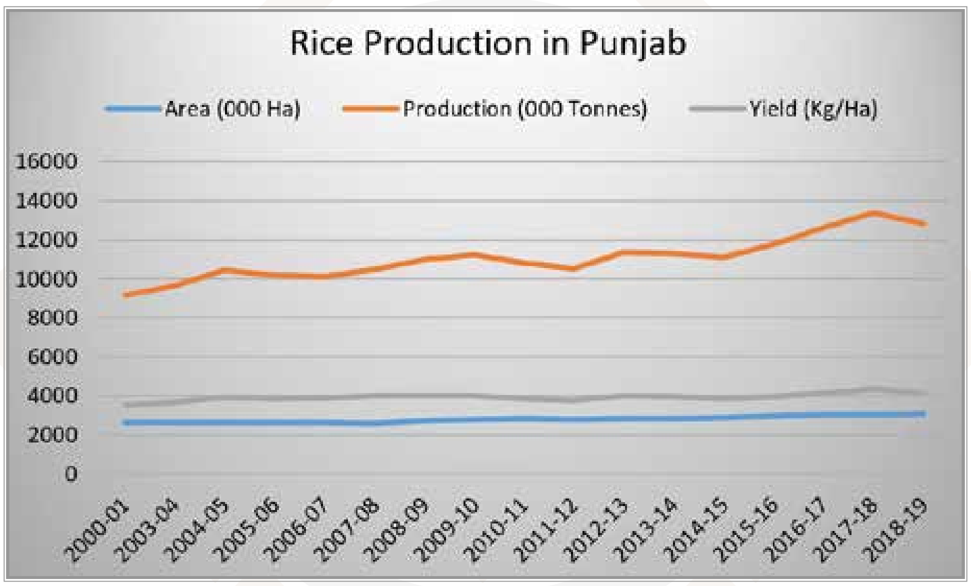


Source -Agricultural Statistics at a Glance, various issues

In 2019, the fertiliser consumption per hectare was almost equivalent in Punjab and Haryana at 224.5 kg/ha of NPK fertilisers used per hectare of sown area. Bihar had the highest consumption of chemical fertilisers per hectare in the country at 227.3 kg/ha in 2019 which is only slightly more than Punjab and Haryana. It is observed that from 2010-2020, Punjab and Haryana are in the top 3 states using the maximum amount of fertiliser per hectare along with Andhra Pradesh which has had the highest application of fertilisers per hectare in 2011,12,14,15. Although after 2015, Andhra Pradesh has shown a rapid decline in the above ratio and fertiliser consumption per hectare has come down to 173 kg/hectare. Consumption of fertilisers per hectare is the maximum in Punjab in 2013 after which it has gradually decreased whereas in Haryana, it is mostly stable with minor fluctuations.

As per Economic Survey of Punjab, ratio of area sown using high yielding variety of seeds to total gross area sown under rice crop is 100% since 2000 meaning all cultivation is essentially carried out using improved variety of seeds. Although in Haryana, the average area under high yielding variety of paddy seeds was around 62% of the gross sown area in 2001 and it rose to 75% in 2006.

Fig 27- Rice production data from Punjab

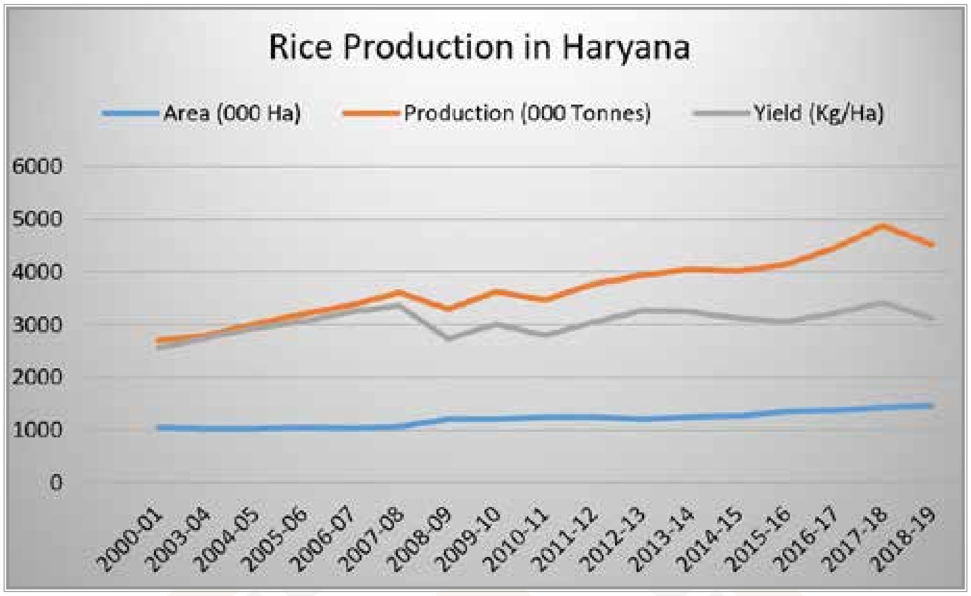


Source -Statistical Abstracts of Punjab, various issues

Fig 27 A and B depicts the three main parameters of rice production in the state of Punjab over the two decades from 2000-2019.

Rice production between 2000 and 2019 increased from 91.57 lakh tonnes to 1.28 crore tonnes which is a growth rate of 1.27% per annum. The increase in production was due to both increase in area and productivity of rice. Rice acreage in Punjab increased from 2.6 million hectares in 2001 to 3.1 million hectares in 2019 while yield rose from 3506 kg/ha to 4136/ha in the same time period. It can be observed that production quantity peaks at 1.34 crore tonnes in 2018 after which it suffers a decline of about 555000 tonnes in the subsequent year. Productivity at 4366 kg/hectare is also the maximum in 2018 while area under cultivation of rice is highest in 2019 at 3.1 million hectares.

Fig 28- Rice production data from Haryana



Source -Statistical Abstracts of Haryana, various issues

Between 2000 and 2019 in Haryana, rice production steadily increased to reach its maximum quantity at 48.8 lakh tonnes in 2018 and then declined to 45.2 lakh tonnes in 2019. The compounded annual growth of rice production from 2000-2019 is 2.76%

Area under cultivation of rice also undergoes an increase from 1.054 million hectares in 2001 to 1.45 million hectares in 2019 indicating a 37.5% increase in rice acreage in the state of Haryana. Yield has gradually increased from about 2557 kg/ha in 2001 to 3422 kg/ha in 2018 after which there is a minor decline to 3121 kg/ha in 2019.

MINIMUM SUPPORT PRICE AND MARKET PRICE OF RICE

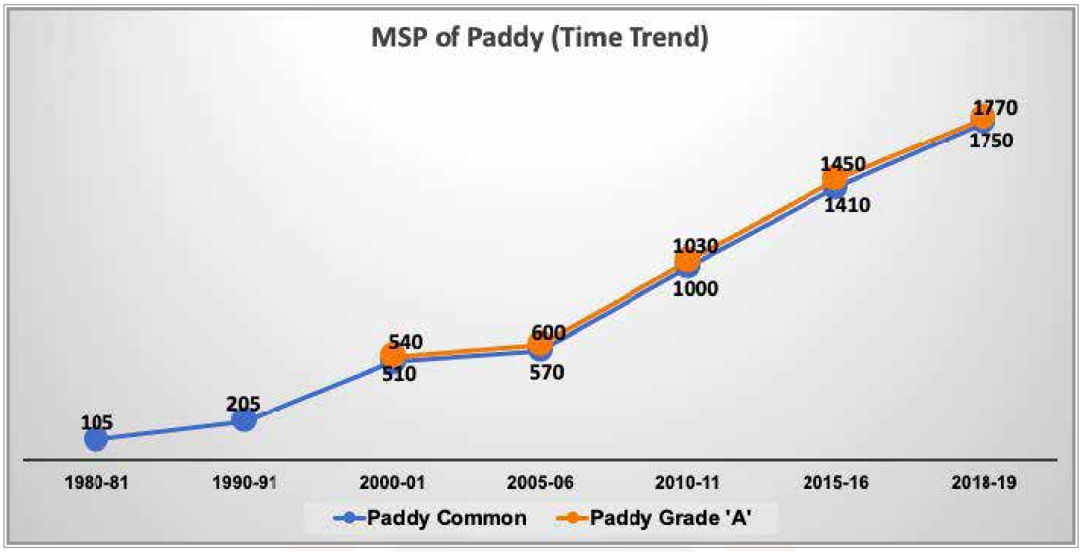
In the final section of data analysis, we try to analyse why cultivation of the rice crop has been preferred by a large number of farmers in the state of Punjab and Haryana. After production has been completed, the price at which the crop gets sold in the market determines the farmer's income. Stability of price, demand for the crop and growth in price level majorly influence the decision making process of farmers about which crop to continue to grow.

Therefore, it is essential to examine the trend in minimum support price (MSP) for paddy which the government offers when it procures the crop. It is equally important to look at the quantity of crop being procured at the assured price by the government every season. We look at the following-

1. MSP of Paddy for the last 20 years

2. Procurement rate of paddy for the last 20 years

Fig 29- Minimum Support Price of Rice as per crop year

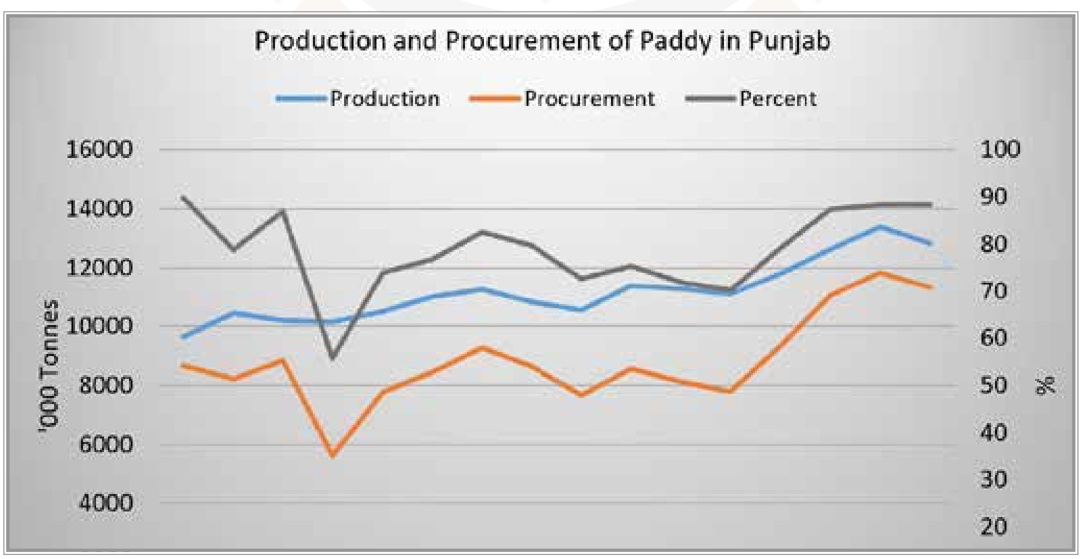


*MSP is fixed by a central agency and therefore is similar for all states apart from state-specific bonus if any
Source- Reserve Bank of India

Between 1980 and 2001, MSP for common paddy shot up from Rs 105 to Rs 510 growing by almost five times in only two decades. Support Price of common paddy further surged to Rs 1750 in 2019 while that for Grade A Paddy went up from Rs 540 in 2001 to Rs 1770 in 2019. For common paddy, MSP has shown only a slight increase in certain years but large jumps during others. Till 2007, the price of common paddy increased by only Rs 10 or 20 per annum but in 2008, it rose by Rs 165 and in the next year, it further rose by Rs 155. Likewise, from 2017-18 - there was a Rs 90 increase but in the very next year, MSP shot up by Rs 200.

From 1980 to 2019, MSP for common paddy has increased from Rs 105 to Rs 1750 which is close to a 17 times growth over 30 years or a compounded annual growth rate of 9.83% during this period. For grade A paddy, MSP has risen from Rs 540 in 2001 to Rs 1770 in 2019 signifying a CAGR of 6.12% over a period of 20 years.

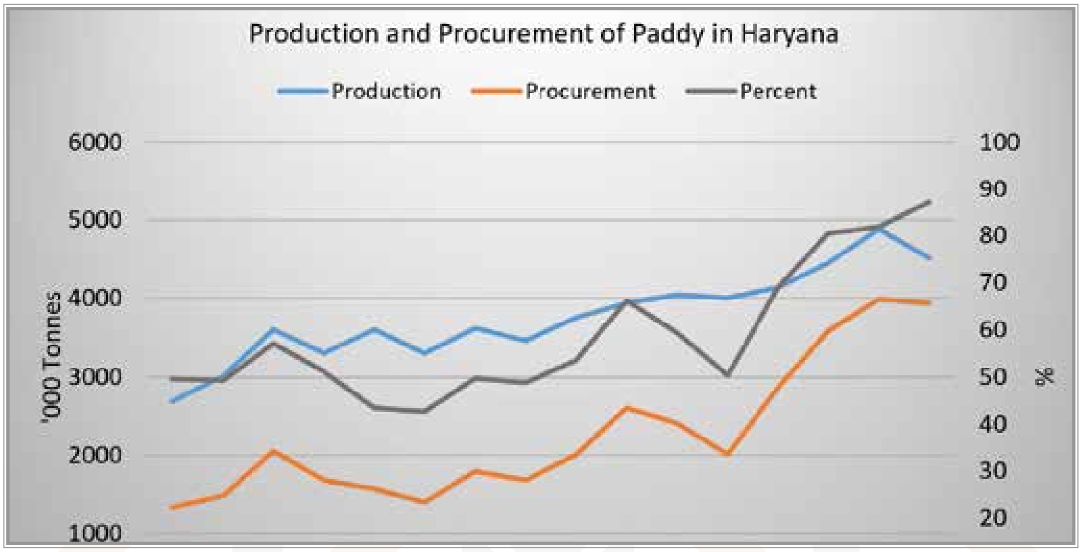
Fig 30- Production and Procurement of Paddy in Punjab



Source: Food Corporation of India

Procurement of rice in Punjab has risen from 8.66 million tonnes in 2004 to 11.33 million tonnes in 2019 registering an increase of 30.7% within 15 years. Procurement as percent of the total quantity of rice produced in the state has been relatively high in comparison to other crops but has shown some major fluctuations in certain years. In 2019, procurement of rice at MSP as percent of total rice production in Punjab was 88.4% and has mostly been above 70% in the above-mentioned time period (2004-2019) except in 2007 when it was only 55.7%.

Fig 31- Production and Procurement of Paddy in Punjab



Source: Food Corporation of India

Procurement of rice in the state of Haryana has shown a considerable rise in terms of quantity going up from just 1.3 million hectares in 2004 to 3.9 million hectares in 2019 which is a three times growth in 15 years. Procurement in 2004 was a little less than half of the rice produced in the state but it has shown an increasing trend over the years. In 2019, 87.2% of the rice produced was procured at the minimum support price. It can be seen that percent share of procurement of rice at support price to the total rice produced in the state of Haryana has rapidly climbed up from 49.5% in 2004 to 87.2% in 2019

SUMMARY OF FINDINGS

1. Installed power capacity in Punjab has increased from 680 MW in 1970 to 13,391 MW, representing about 20 times growth in five decades. Consequently, power generation capacity also rose proportionately from 2365 MW to 45,504 MW, registering an increase of more than 19 times in the same period. Between 1970 and 2019 in Haryana, installed power increased from 486 MW to 11,971 MW (25 times) while generation capacity shot up from 29 MW to 3,639 MW, becoming more than 125 times in the same time interval.

2. Due to extensive investment and advancement in power infrastructure, 100% rural electrification has been achieved in Punjab and Haryana, providing almost universal access to power. As a result, the number of electricity connections in Punjab in the agriculture sector increased from just 91,000 in 1971 to almost 13.79 lakhs in 2019 while in Haryana, power connection to farmers has gone up from 86,000 in 1971 to 6.38 lakh in 2019. Sale of electricity to agricultural consumers in Punjab rapidly surged from 4630 lakh kwh to 1,12,000 lakh kwh between 1970 and 2019 whereas in Haryana, power consumption by state farmers soared from 2985 lakh kwh to 97,143 lakh kwh in the same period.

3. Per capita consumption of electricity by farmers in Punjab has shot up from 34.7 kwh in 1970 to 365 kwh in 2019 becoming more than 10 times in five decades. As depicted in Fig 2.5 B, the average revenue collected by the state power corporation per unit of electricity sold to agricultural consumers was null in 2001, 2017, 2018 and in some years, Punjab government has charged farmers a minimal rate (2014-2019) for power supply which is insufficient to meet even the basic operational and maintenance costs.

4. In the state of Haryana, annual per capita consumption of electricity in the agriculture sector increased from 282 kWh in 2006 to 360 kWh in 2018 as shown in Fig 3.5. Energy tariff rate to farmers in Haryana through retail and distribution channels has shown a stable but declining trend. Power tariff for metered connections has gone down from 25 paise/kwh (2012-2015) to 10 paise/kwh (2015-2019) while there are evidently no charges for farmers with an unmetered connection.

5. Area under rice cultivation in Punjab rose from 2.6 million ha in 2000 to 3.1 million ha in 2019 while in Haryana, rice acreage increased from 1.054 million ha to 1.45 million ha in the aforementioned time period. According to various sources, rice requires about 4500-6000 litres of water per kg of produce and therefore is one of the most water intensive crops. In Punjab and Haryana, gross irrigated area of rice as a percent of the total sown area under rice crop has been higher than 99% since 1990-present suggesting there is virtually no reliance on rainfall as far as rice cultivation is concerned and water needed for irrigation is either extracted from underground reservoirs through pump sets or from government canals.

6. Crop area irrigated by canals has rapidly declined in both states over the years as shown in Fig 4.1 and 4.6 B. In Punjab, the share of tubewells in irrigation of crops has risen from 41.3% in 1980 to 71.3% in 2019 while in Haryana- the share of tubewells increased from almost 45% in 1980 to 63% in 2019. In Punjab, the number of electricity operated tubewells soared almost five times from around 2.83 lakhs in 1980 to 13.79 lakhs in 2019 whereas in Haryana, it has increased by almost three times in the same time period from 2.22 lakhs to 6.38 lakhs. An overwhelming majority of private tubewells owned by farmers in Punjab and Haryana are energised by electric power (90% in Punjab and 87.25% in Haryana) while the rest are operated by diesel.

7. As previously mentioned, rice acreage in both states has undergone a considerable increase. In 2019, area under cultivation of rice in Punjab was 75% of the net sown area while in Haryana- rice area was in terms of percent was significantly less than Punjab at 40.5% of the net sown area. The yield of rice crop has gone up from 3506 kg/ha in 2000 to 4132 kg/ha in 2019 in Punjab, registering a growth of about 18% in two decades. In Haryana, yield has increased by 22% between 2000 and 2019 i.e. from 2557 kg/ha to 3121 kg/ha. It is notable that rice yield in both states is among the highest in India. Production of rice in Punjab has

shot up from 91.57 lakhs tonnes in 2000 to 1.28 crore tonnes in 2019 rising by about 40%. In Haryana, rice production has surged from almost 27 lakh tonnes in 2000 to 45.16 lakh tonnes in 2019 showing a rise of 67%

8. This tremendous growth in production statistics for rice crop in Punjab and Haryana has also been possible due to widespread availability of chemical fertilisers and greater use of improved variety of seeds. In Punjab, area under HYV seeds as a percent of gross sown area of rice crop has been 100% since year 2000. Consumption of chemical fertilisers in Punjab has soared from 12.2 lakh nutrient tonnes in 1991 to 18.2 lakh nutrient tonnes in 2019 registering a growth of almost 50% in three decades. In Haryana, consumption of chemical fertilisers has risen from 5.86 lakh nutrient tonnes to 14.76 lakh nutrient tonnes in the same time period showing 2.5 times increase. In 2019, consumption of fertilisers per hectare was almost similar in Punjab and Haryana which in terms of quantity usage in India ranked only behind Bihar where it was slightly higher. Punjab and Haryana have regularly featured in the top 3 states having the highest fertiliser consumption per hectare since 2010 as observed in Fig 26.

9. Minimum Support Price of Paddy has shown a drastic increase in the past 20 years. Between 2000 and 2019, MSP registered a 6.70% compounded annual growth rate (CAGR), rising from Rs 510 in 2001 to Rs 1750 in 2019 for common paddy. For Grade A paddy, procurement prices have soared from Rs 540 to Rs 1770 in the same period. Procurement of paddy by government agencies, FCI, independent traders etc. has been considerably high in Punjab. In 2019, 11.33 million tonnes of paddy or 88.4% of the total produce was procured at MSP while in Haryana, 3.94 million tonnes of paddy were procured which amounted to 87.2% of the total output of paddy in 2019. In Haryana, the procurement rate has significantly shot up keeping in view that less than 50% of the rice used to be procured at support price just a decade and half ago. The sudden, irregular and substantial hikes in MSP of rice during particular years hint towards political factors and considerations rather than being a result of economic forces.

CONCLUSION

Delhi's severe air pollution crisis cannot be understood without examining the agricultural dynamics of neighbouring Punjab and Haryana, where the annual practice of stubble burning forms a critical link between agricultural policy and Delhi's winter pollution. Farmers resort to burning residue to quickly and cheaply prepare their fields for the next sowing cycle. This practice is rooted in the adverse alignment of agro-ecological realities with cropping patterns shaped by agricultural policy incentives.

Paddy is one such crop that generates a very large quantity of stubble and is grown extensively in Punjab and Haryana in rotation with wheat. In the last few decades, there has been a major shift in favour of rice cultivation in both states-often at the expense of other traditional crops more suited to the local agro-climatic conditions and this expansion has come at great costs to the environment through overexploitation and inefficient utilisation of natural scarce resources. This shift was enabled by government policies that minimised the risks associated with paddy cultivation. High minimum support price, effective procurement mechanism, subsidy on seeds, fertilisers and electricity provided farmers with a safety net comprising input support, assured procurement, and stable income. These incentives made paddy the preferred and most secure crop choice in both Punjab and Haryana.

Technological reforms further entrenched this cropping pattern. Punjab and Haryana are among the few states which invested heavily in modern agricultural technology in the past few decades and the effects of the reforms made back then are still very much pervasive, contributing to the overall growth of the farm sector. Introduction of seeds with improved genetics enabled productive growth of crops, increased application of chemical fertilisers and pesticides improved yield and minimized risk of crop failure, continuous expansion of irrigation infrastructure (canals and tubewells) enabled cultivation of water demanding crops in areas with critical water shortage, use of tractors and other equipment coupled with reliable electricity supply mechanised the conventional farming methods which improved overall efficiency.

However, in a bid to achieve food security and empower farmers across the nation, there were several unintended ecological and environmental consequences that are now starting to surface. The annual air pollution crisis which turns the national capital into a cesspool of harmful gases and toxic pollutants is partly triggered by burning of paddy residue in the state of Punjab and Haryana. As previously mentioned, 1.34 million tonnes of stubble in Haryana and almost 10 million tonnes of stubble in Punjab were disposed of by burning in 2019. At the onset of winter every year, the air quality plummets to alarming levels causing significant discomfort and numerous health problems to Delhi residents.

Cultivation of paddy is also extremely water-intensive and as it is apparent from the statistics, reliance on groundwater to meet the irrigation requirements of paddy crop has become the standard norm in Punjab and Haryana. Large scale availability of power at heavily subsidised rates has allowed farmers to inordinately extract groundwater by operating electric tubewells. This has made rice cultivation convenient even in water deficient zones. Such unprecedented pressure on natural freshwater resources has resulted in rapid depletion of the water table coupled with other problems like soil salinity, loss of nutrients, water logging and poor yield of crops. These are symptoms of long-term ecological stress that rarely feature in Delhi's pollution discourse but form part of the deeper systemic problem.

Equally significant is the sheer volume of crop residue generated by mechanised harvesting. In Punjab and Haryana, rice is primarily grown as a commercial crop and hardly for self-consumption. The average size of agricultural land holding in Punjab was 3.62 hectares in 2016 which is more than three times the all-India average of 1.08 hectares.

In Haryana, average land holding size was twice the national average [13]. Due to very large operational holdings and prevalence of commercial varieties, there is greater mechanisation in the fields leading to creation of stubble and straw. Although, in Haryana, the problem of stubble burning is not as much aggravated as it is in Punjab because Basmati variety is dominant (occupying 62% of the total paddy acreage [14]) in Haryana and it is usually manually harvested using conventional farming methods which do not leave residue behind.

A comparison with other major rice-producing states underscores how different structures yield different environmental outcomes. In other major rice producing states, various other measures to effectively manage stubble are present. For example, in West Bengal which is the largest rice producing state in India - of the stubble that is generated during harvesting - a large portion is utilised for economic gains like feeding livestock, selling to industries as raw material, as fuel and even for mushroom cultivation. However, a similar environment that is conducive to sustainable management of paddy residue seems to be missing in Punjab and Haryana and incineration is generally perceived as the quickest and cheapest option.

13 Agricultural Census 2015-16

14 Basmati Crop Survey Report 2019, https://apeda.gov.in/apedawebsite/Announcements/Basmati_Crop_survey_Report_1_Season_2019.pdf

RECOMMENDATIONS

Short Term Solutions

These methods are commonly recommended as alternative ways to manage paddy stubble. While they can be effective, one has to keep in mind that they are only band-aid solutions and can just temporarily put off the crisis.

Stubble Management Systems currently existing:

1. Pressing and burying the stubble under the soil which further acts as a natural manure and increases the nutrient value in the soil (Straw Chopper, Rotavator, Zero Till Seed Drill)

2. Sowing the next crop directly amongst the intact standing stubble by spreading the straw uniformly in the field (Mulcher, Super SMS, Happy Seeder)

3. Make bundles out of the left-over straw called bales and putting it to other uses (Baler)

The third option is sometimes preferred because farmers can expediently sell bales to bio-thermal industries for power generation as they are a renewable source of energy. Bales can also be used as a domestic fuel in households or for feeding the cattle (although, this is not practised extensively due to the high silica content present in rice residue). These practices can become an extra revenue source for the farmer. But, extraction and collection of paddy straw is an arduous task and requires expensive machinery that most farmers find uneconomical. Currently, the state government subsidises these machines by financing 50-80% of the upfront costs or buys them and then rents them out to farmer co-operatives.

Medium Term Solutions

In the medium term - more concrete, practical and feasible solutions should be adopted that have the ability to be adopted by thousands of farmers regardless of their economic status.

1. Crop Diversification: It is imperative at this stage to make sustained efforts to end the dominance of the paddy-wheat cropping system in Punjab and Haryana. Area under non-basmati paddy variety should be significantly brought down and alternate crop varieties (like maize, cotton, groundnut, pulses) should be promoted at the state level. Although, it is of paramount importance to take note that farmers will make a decisive shift towards other crops only if they are equally competitive with paddy in terms of the risk, yield, support price and marketing infrastructure.

The government can incentivise farmers to divert paddy area to other crops by offering direct cash transfers, input subsidies on seeds, raising the MSP of other crops and making their procurement mechanism more effective so that the risk factor is minimised.

2. Restructuring of subsidies - Power subsidy policy of the government to the agricultural sector needs correction on priority basis to protect the environment as well as the power industry itself. Unrestrained access to electricity leads to over-consumption of precious groundwater resources as farmers engage in flood irrigation which is wasteful in nature.

In many zones, electricity supply to farmers is unmetered at the consumer end. This is a big hurdle in calculating accurate electricity consumption and subsidy amount at an individual level. Proper metering is essential to bring more transparency in the system and ensure responsible use of power and water. Additionally, the government can provide capital subsidies on the purchase of drip-irrigation and micro-irrigation equipment which have proven to be highly effective and water-efficient.

Subsidies on fertilisers and improved genetic variety of seeds should be gradually phased out as excessive use of chemicals is destroying the fertility of soil, lowering crop yield and leading to domination of particular cropping patterns. The MSP system needs a thorough review as it appears to be biased towards foodgrains.

All factors of the agricultural ecosystem namely power, irrigation, subsidies, and MSP are complexly interlinked in a manner that is inherently problematic. The issues surrounding them can only be addressed by holistic overhaul of the entire mechanism

Long Term Solution

In the long term, policy focus should shift to restoring the natural order in India's agricultural ecosystem and eventually do away with the legacy of input subsidies and other artificial incentives of the government that have done more harm than good - to the environment as well as to the nation's development. The farmer should have complete freedom to produce what he wants and sell the produce to whomever he wants without being influenced by the state or any other force. Appeasement politics coupled with manipulation of market mechanisms has had drastic implications by neglecting long term concerns in favour of populist policies. An average farmer has become largely dependent on government machinery in the form of subsidy support for every stage in the production process and this extreme dependence has adversely affected their income, rural and agricultural growth and the environment.

Ultimately, we envisage a future where organic farming becomes the norm and use of chemical fertilisers, pesticides and genetically modified seeds is replaced with healthy and sustainable practises that restore the natural fertility of soil, raise productivity, protect the environment and give the farmers greater decision making power over the entire process with minimum intervention from the government. All the factors of agricultural production - seeds, fertilisers, farm machinery, irrigation equipment, market prices should be left to the free market and be de-regulated so that they can play out as per their natural tendencies. When this is accomplished, the cropping pattern in individual states will automatically comply with the availability and accessibility to existing resources and therefore- rice will only be cultivated in regions that are conducive to its growth keeping in view the economic and environmental feasibility. Consequently, as there will be a major shift away from rice cultivation in Punjab and Haryana, the problem of stubble and the resulting air pollution will significantly dissipate.

BIBLIOGRAPHY

Thacker, Hency. 26 December 2019. "India Ranked First in Pollution-Related Premature Deaths in 2017". The CSR Journal. Accessed on 8 March 2021 at https://docs.google.com/document/d/15aI2zF7iynBMKKgagxkuK0vzTnu-Za5eC745__EAPgP-8/edit#

Shagun. 21 October 2020. "Air pollution killed 116,000 Indian kids within a month of birth in 2019". Down to Earth. Accessed on 8 March 2021 at https://www.downtoearth.org.in/news/air/air-pollution-killed-116-000-indian-kids-within-a-month-of-birth-in-2019-73893

Musaddique, Shafi. 3 May 2018. "Here are the world's 10 most polluted cities – 9 are in India". CNBC. Accessed on 8 March 2021 at https://www.cnbc.com/2018/05/03/here-are-the-worlds-10-most-polluted-cities--9-are-in-india.html

Muller, Richard and Elizabeth Muller. 17 December 2015. "Air Pollution and Cigarette Equivalence". Berkeley Earth. Accessed on 8 March 2021 at http://berkeleyearth.org/air-pollution-and-cigarette-equivalence/

Economic Survey of India 2015-16. Government of India

Economic Survey of India 2017-18. Government of India

Government of India. 2015. Economic Survey of India 2015-16. Department of Economic

Affairs, Ministry of Finance.

Government of India. 2017. Economic Survey of India 2016-17. Department of Economic

Affairs, Ministry of Finance.

Government of India. 2018. Economic Survey of India 2017-18. Department of Economic

Affairs, Ministry of Finance.

Government of India. 2019. Economic Survey of India 2018-19. Department of Economic

Affairs, Ministry of Finance.

Government of India. 2020. Economic Survey of India 2019-20. Department of Economic

Affairs, Ministry of Finance.

Government of India. 2020. Economic Survey of Delhi 2019-20. Planning Department, Government of NCT of Delhi

Government of India. 2009. National Ambient Air Quality Standards. Central Pollution Control Board

Joshi, Mallica. 24 October 2020. "Explained: Why does air pollution rise in October every year?". The Indian Express. Accessed on 11 March 2021 at https://indianexpress.com/article/explained/explained-why-does-air-pollution-rise-in-october-each-year-6759030/

Economic and Statistical Organisation. 2000-2020. Statistical Abstract of Punjab. Department of Planning, Government of Punjab

Department of Economic and Statistical Analysis. 2000-2020. Statistical Abstract of Haryana. Government of Punjab

Singh, S.K. December 2017. ICAR Reporter. Indian Council of Agricultural Research. Accessed on 11 March 2020 at https://icar.org.in/sites/default/files/IR-October-December-2017.pdf

Government of India. 2019. Report of the Committee. Ministry of Agriculture and Farmers Welfare. Available at https://farmech.dac.gov.in/revised/1.1.2019/REPORT%20OF%20THE%20COMMITTEE-FINAL(CORRECTED).pdf

Singh, Jasdev, D.K. Grover and Tejinder K. Dhaliwal. 2012. "State Agricultural Profile – Punjab". Department of Economics and Sociology, Punjab Agricultural University. Available at http://www.aercpau.com/assets/docs/Punjab%20Profile.pdf

Bhupal, D.S. 2012. "Agricultural Profile of Haryana". Agricultural Economics Research Centre, Delhi University. Available at http://du.ac.in/du/uploads/Academics/centres_institutes/Agricultural_Eco/15.2012-Agricultural%20Profile%20of%20Haryana%20by%20DSB.pdf

Government of India. Various Issues. Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare.

Government of Haryana. 2019. Electricity Charges. Haryana Electricity Regulatory Commission.

Government of India. 2020. "Study of System of Fertilizer Subsidy." Ministry of Chemicals and Fertilisers. Available at http://164.100.47.193/lsscommittee/Chemicals%20&%20Fertilizers/17_Chemicals_And_Fertilizers_5.pdf

Government of India. 2000-2020. State wise Procurement of Rice Data. Food Corporation of India.

Government of Punjab. 2009. The Punjab Preservation of Subsoil Water Act. Department of Agriculture and Farmers Welfare. Available at https://agri.punjab.gov.in/sites/default/files/Pb_preservation_of_Subsoil_Act%2C2009.pdf

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