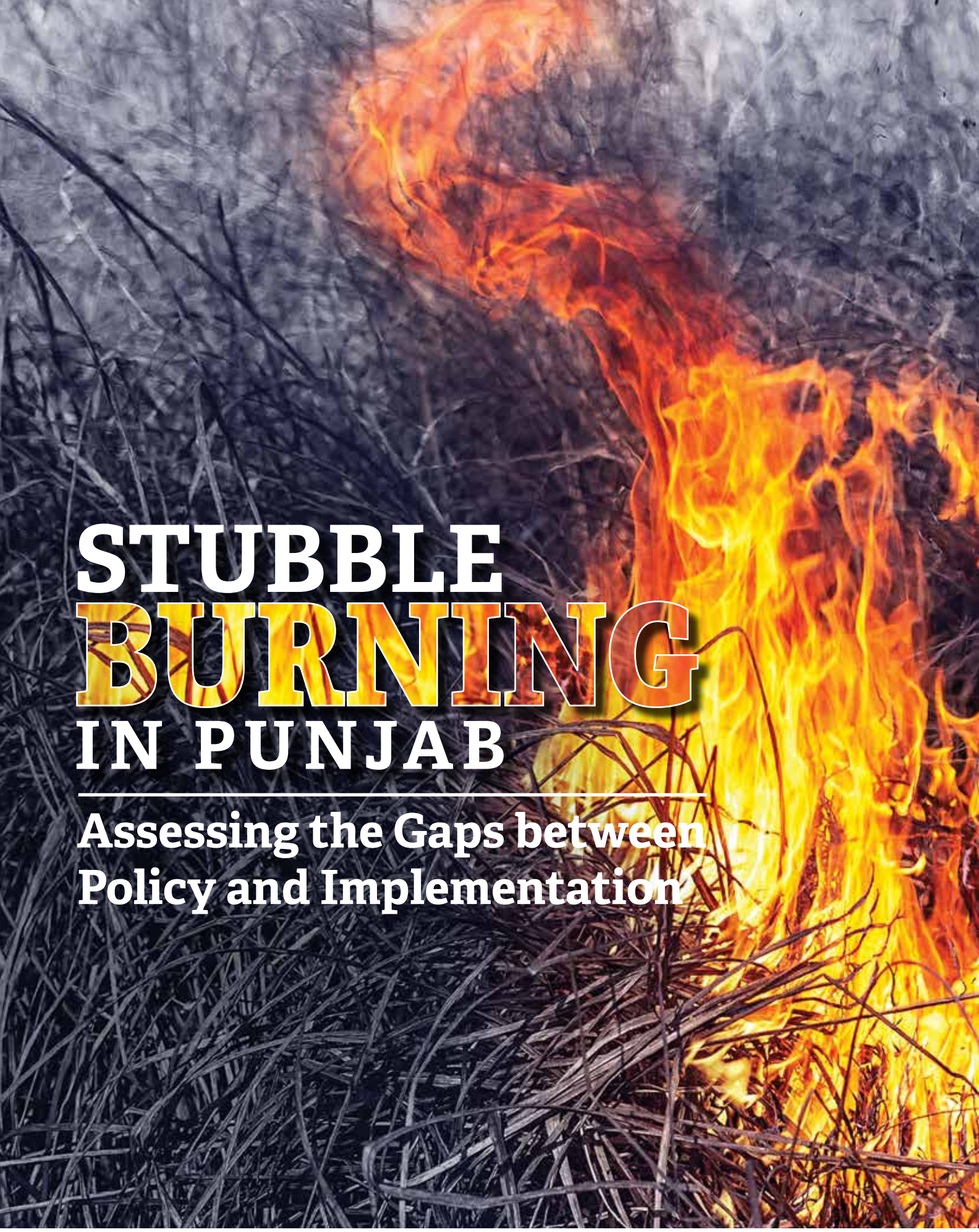


STUBBLE BURNING IN PUNJAB

Assessing the Gaps between Policy and Implementation

Centre for Chronic Disease Control

WHO Collaborating Centre for Surveillance, Capacity building and Translational Research in Cardio-Metabolic Diseases

HEALTH & ENVIRONMENT LEADERSHIP PLATFORM H.E.L.P

STUBBLE BURNING
IN PUNJAB

Assessing the Gaps between Policy and Implementation

Centre for Chronic Disease Control
WHO Collaborating Centre for Surveillance, Capacity building and Translational Research in Cardio-Metabolic Diseases

HEALTH & ENVIRONMENT LEADERSHIP PLATFORM
H.E.L.P

Acknowledgement

This report was developed by the Centre for Chronic Disease Control (CCDC) under the supervision of Dr. Poornima Prabhakaran, Additional Professor & Deputy Director, Centre for Environmental Health (CEH), Public Health Foundation of India (PHFI) and Senior Research Scientist, (CCDC). The core writing team that drafted this report was led by Sanya Prakash (Research Fellow), Shriram Manogaran, (Senior Research Associate & Program Coordinator Technical), and Masroor Azam (Research Fellow).

This research is based on a review of policies and programmes implemented in Punjab over the previous decade to address the issue of stubble burning. We are grateful to all our colleagues at Public Health Foundation of India, Centre for Environmental Health and Centre for Chronic Disease Control who helped in reviewing the outcomes and the final report.

About the Organisation

About Centre for Chronic Disease Control

Centre for Chronic Disease Control (CCDC) is a New Delhi based not-for profit organization, established in December 2000. The mission of CCDC is primarily intended to address the growing challenge of chronic diseases, in varied settings of the developing countries through:

- Knowledge generation, which can inform policies and empower programmes for the prevention and control of chronic diseases
- Knowledge translation intended to operationalize research results by bridging the critical gaps between relevant research and effective implementation, through analytic work, capacity building, advocacy and development of educational resources for enhancing the empowerment of people and professionals.

CCDC has been recognized as a Scientific and Industrial Research Organization (SIRO) by Department of Scientific & Industrial Research (DSIR), Ministry of Science and Technology, Government of India. It also holds registration under Foreign Contribution (Regulation) Act, 1976. CCDC undertakes clinical research with special emphasis on chronic non-communicable diseases (NCD). Within the spectrum of chronic diseases, our main focus areas are: cardiology, diabetes and metabolic disease, vascular diseases, cancers and mental health. In addition, basic science research in diet/nutrition and cardiac biochemistry are also carried out. The research work at CCDC has produced major insights into the epidemiology, developmental origin, and biomarkers of CVD and diabetes in India; practice patterns on Acute Coronary Syndrome; translation research in CVDs; and development of low-cost combination drugs for primary and secondary prevention of CVDs in South Asia. CCDC holds recognition as a 'Centre of Excellence in Clinical Research' from the Clinical Development Service Agency (CDSA), Department of Biotechnology, Government of India. It is also a WHO Collaborating Centre for Surveillance, Capacity building and Translational Research in Cardio-Metabolic Diseases.

Authors of the Report

Sanya Prakash
Research Fellow, CCDC

Shriram Manogaran
Senior Research Associate &
Program Coordinator (Technical), CCDC

Masroor Azam
Research Fellow, CCDC

List of Abbreviations

APFs	–	Agricultural Pumpset Feeders
CDP	–	Crop Diversification Programme
CEA	–	Central Electricity Authority
CO	–	Carbon Monoxide
CO_2	–	Carbon dioxide
COPD	–	Chronic Pulmonary Obstructive Disorder
CRM	–	Crop Residue Management
CHC	–	Custom Hiring Centres
GHG	–	Greenhouse gases
GoI	–	Government of India
IARI	–	Indian Agriculture Research Institute
IGP	–	Indo-Gangetic Plains
IPCC	–	Intergovernmental Panel on Climate Change
MoU	–	Memorandum of Understanding
MNRE	–	Ministry of New and Renewable Energy
MSP	–	Minimum Support Price
MSW	–	Municipal Solid Waste
Mt	–	Million tons
NAAQS	–	National Ambient Air Quality Standards
NCAP	–	National Clean Air Programme
NCR	–	National Capital Region
NGT	–	National Green Tribunal
NH_3	–	Ammonia
NMHC	–	Non-methane hydrocarbon
NOX	–	Nitrogen oxide
NPMCR	–	National policy for management of crop residue
NREGA	–	National Rural Employment Guarantee Act
PAH's	–	Polycyclic aromatic hydrocarbons
PCDFs	–	Polychlorinated dibenzofurans
PEDA	–	Punjab Energy Development Agency
PM	–	Particulate matter
PSPCL	–	Punjab State Power Corporation Limited
SOX	–	Sulphur oxide
SMS	–	Straw Management System
SVOCs	–	Semi volatile organic compounds
TPP	–	Thermal Power plant
UP	–	Uttar Pradesh
USEPA	–	United States Environmental Protection Agency
VOCs	–	Volatile organic compounds
WHO	–	World Health Organization
µg	–	Micro-gram

Table of Content

List of Tables

List of Figures

Executive Summary

The burning of paddy fields after the harvest, or stubble burning just prior to winter, has often been labelled as the main culprit behind the poor air quality in north India. With only 10-15 days left between the rice-harvesting season and the wheat-sowing time, farmers often resort to burning, to quickly eliminate the paddy stubble. Every year, Punjab alone produces 20 million tonnes of paddy residue, out of which 80-90% gets burnt on ground. Despite years of work by the government agencies to curb stubble burning, Punjab witnessed an unfortunate increase of 44.5 per cent incidents in 2020 (Business Standard, 2021).

In an effort to understand the complexity of the issue, this study sought to explore the gaps which are hindering the implementation of the existing policies. The study reviewed the policies and programmes introduced in the last decade (2009-2019) by the government to control this menace. After examining the policies, it was found that there are various factors which may have directly or indirectly influenced the problem of stubble burning.

- Ground water exploitation
- Absence of Multiple Cropping system
- Market Dynamics supporting the rice and wheat cultivation and problems for the small farmers
- Lack of facilities for straw management
- Experimentation with in-situ machineries
- Labour shortage
- Over-reliance on Agricultural Subsidies

While recognizing these barriers that are affecting effective implementation of existing regulations, we propose various recommendations that may assist in addressing the problem:

- Establishing review process to monitor and evaluate the policies proposed for sustainable agriculture interventions in Punjab
- Strengthening Financial deliveries & infrastructure to relieve the additional burden put on subsidy-driven agriculture systems
- Improving the Minimum Support Price dynamics and encourage deficiency payments to promote diversification
- Facilitating sustainable management practices for crop residue which includes crop diversification and composting

- Promoting more research opportunities to identify and adapt to depleting labour, irrigation and soil conditions
- Enhancing participatory approach including farming communities, empowering farmers outreach and education
- Placing more emphasis on the impacts of stubble burning on public health
- Strengthening multi-sectoral thinking and action

It is high time that the state should start looking at the root causes of the problem rather than providing the surface level assessment and solutions to address those factors alone. A multi-pronged approach is required that takes into account all the issues and barriers to meet the desired goal of zero stubble burning.

CHAPTER - 1

Introduction

The Indian agricultural sector plays a vital role in the overall economic growth of the country (Mahadevan, 2003). The agricultural waste is not regulated as a municipal solid waste (MSW). The MSW is regulated and managed by local municipalities who maintain data of waste generated and disposed. Agricultural waste is largely managed by the owners of the agricultural land which primarily falls in the private sector, with little involvement by municipal waste management (Bhuvaneshwari et al., 2019).

The Indian agricultural sector plays a vital role in the overall economic growth of the country.

The demand for food has been on the rise around the world which has led to increase in food production and agricultural activity (Elferink & Schierhorn, 2016). This increase in agricultural activity has led to overall increase in waste generation and consequent environmental pollution (Nagendran, 2011).

According to the Indian Ministry of New and Renewable Energy (MNRE), 500 Million tons (Mt) of crop residue is generated per year (MOA, 2014). Table 1 compares the agricultural waste generated by selected Asian countries in Mt/year (MOA, 2014; Jeff et al., 2017). The volume of entire production of agricultural waste burnt in India is much larger than other Asian countries.

Table 1: Agricultural waste generation in India compared to other nations in the same region

Country	Agricultural Waste Generated (million tons/year)
India	500
Bangladesh	72
Indonesia	55
Myanmar	19

(Source: MOA, 2014; Jeff et al., 2017)

There are various agro-based solutions for handling waste from the agricultural industry. But the cost of collection, processing, transportation and management of agricultural waste is higher than revenue which has not helped private stakeholders to partake in this process (Ross, 2018). Economic reasons are one of the important factors in not attaining sustainable use of agricultural waste management (Bhuvaneshwari et al., 2019).

The discussion of agricultural waste management is vital for two reasons. First, the amount of crop residue and other end products of agriculture being managed unsustainably has created adverse environmental impacts that are often transboundary in nature (Zhang et

al., 2017; De Leeuw, 2002). Second, agriculturally crop residue helps in enriching the soil that could benefit the farming community (Bhuvaneshwari et al., 2019; Lal, 1997).

1.1. Stubble Burning

Crop residue or Stubble are by-products from harvesting left on the cultivated land. Traditionally crop residues were used as animal feed, fodder, as biomass for cooking, packaging and composting (Yadav et al., 2017). India produces large volumes of cereal crop such as rice, wheat and pulses for domestic consumption as well as for export (MOA, 2014; Jain et al., 2014). Out of the waste generated post harvesting, the surplus residue is burnt on the field and the remains are left behind (MOA, 2014).

Crop residue or Stubble are by-products from harvesting left on the cultivated land. Traditionally crop residues were used as animal feed, fodder, as biomass for cooking, packaging and composting.

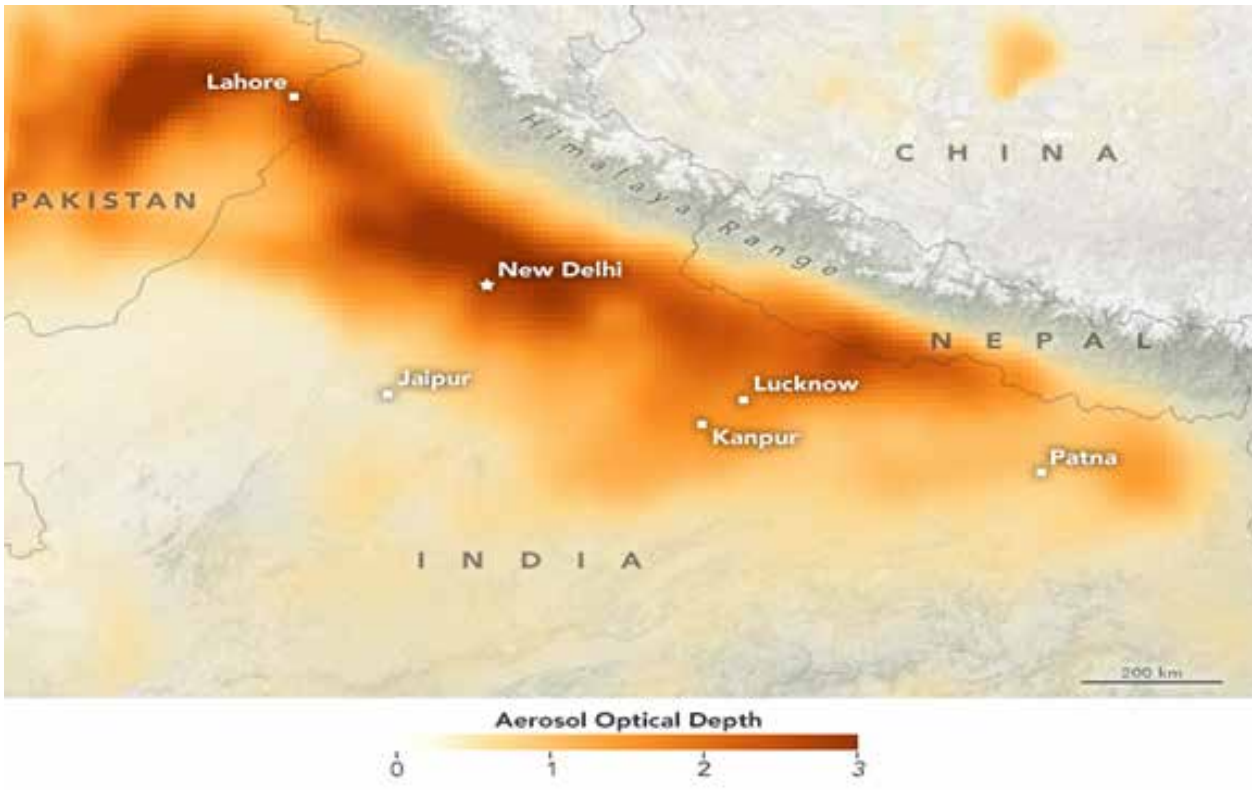
According to Jain et al., 2014 and the Intergovernmental Panel on Climate Change (IPCC), the crop residue burnt ranges from 8-80% for paddy crops waste across all states in India. Jitendra et al., (2017) reported that 80% of the crop residue burning takes place during the post-harvest period of April-May and November-December. The reason behind this is attributed to change in cropping patterns (MOA, 2014) and economic incentives. Some farmers also resort to a cycle of cultivating the same three crops with a short period in between crops resulting in unsustainable management of crop residue (Bhuvaneshwari et al., 2019); major contribution is from rice, wheat, sugarcane and oilseeds contributing 43%, 21%, 19% and 5% respectively.

1.2 Stubble Burning in North Western states and its impacts

Stubble burning has gained a lot of traction due to its transboundary pollution and depletion in air quality in the National Capital Region (NCR), Delhi and the whole of Indo-Gangetic plain. The practice of crop residue burning is highly prevalent in the states of Punjab, Haryana and Uttar Pradesh (UP) in the north of India (Bhuvaneshwari et al., 2019). The emission from stubble burning from the north-western states of Punjab, Haryana and UP spreads in all directions through long-range transport mechanisms depending upon the meteorological conditions (Sarkar et al., 2018). Metereologically, the pattern of winds post-monsoon is northerly to north-westerly. This pushes the smoke from stubble burning to the entire IGP region resulting in hazardous air quality and impacts on visibility (Chauhan, & Singh, 2017; Allen, 2017). Due to a high pressure situation, low temperature and divergence prevailing at this time of the year, the smoke and particulate matter engulfs the entire IGP and impacts central India as well (Sarkar et al., 2018). With the onset of cooler weather in November, the smoke from stubble burning, and other fossil combustion activities, mixed with dust, traffic and industrial pollution, forms a thick haze. The lack of high wind pressure worsens this problem for several days (Sarkar et al., 2018; Allen and Volland, 2017; Draxler and Rolph, 2003). It is to be noted that stubble burning is not the only reason for post-monsoon bad air quality in the northern region and across IGP. Meteorological conditions such as ambient

temperature, relative humidity, wind speed, wind direction and ambient air pressure also play vital roles (Ravindra et al., 2019). This growing hazardous air pollution burden is disproportionately shouldered by many in the northern and central states of India. Figure 1 is a satellite picture showing heavy particulate matter clouding the states of Delhi and others in the Indo-Gangetic plain post stubble burning incidents.

Figure 1: Aerosol Optical Depth in Delhi and IGP post stubble burning incidents

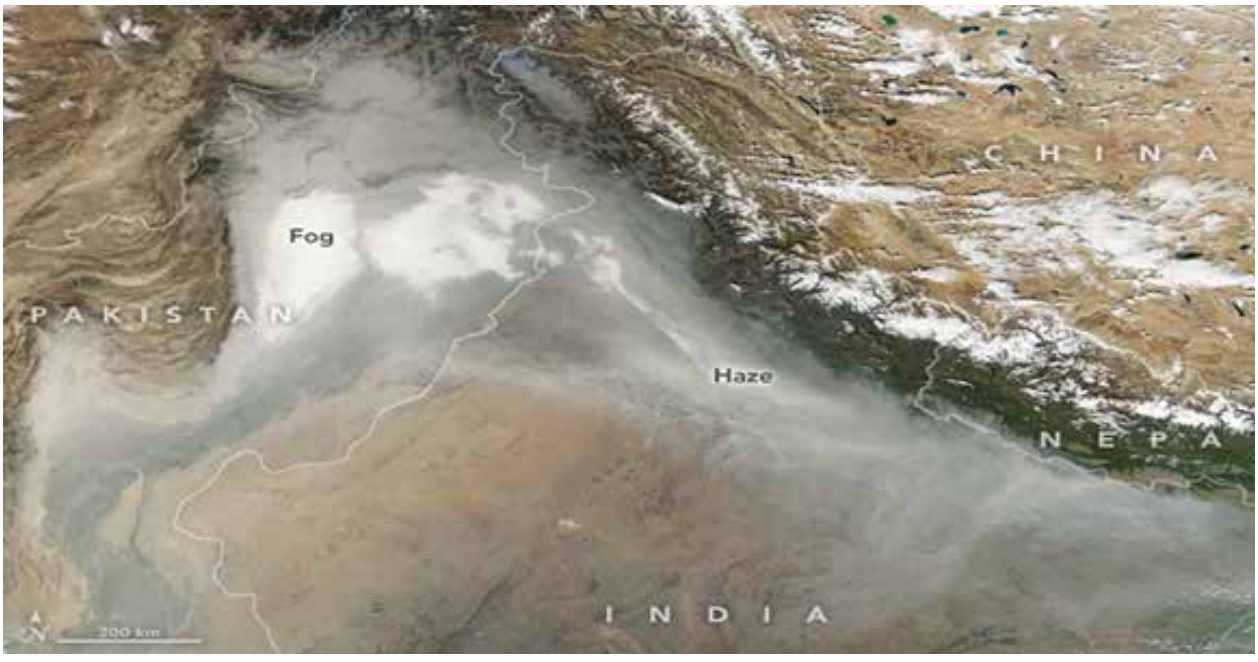


(Source: NASA images)

1.3 Stubble burning and its environmental consequences

Burning of crop residue results in various environmental consequences. The adverse impact of crop residue burning includes emission of greenhouse gases (GHG), loss in soil fertility and harmful ambient air quality levels which leads to increased levels of particulate matter (PM) and smog that can cause immediate health hazards (Gupta et al., 2004). Crop residue burning significantly increases the quantity of air pollutants such as CO_2, CO, NH_3, NOX, SOX, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs) and PM (Mittal et al., 2009; Zhang et al., 2011). It also results in release of black carbon and high PM concentration that contributes to dire climate change impacts in the longer run (Streets et al., 2003; Gadde et al., 2009; Jiang et al., 2019; Washenfelder et al., 2015). Figure 2 shows the thick smog engulfing the Indo-Gangetic plain post the stubble burning event in the states of Punjab and Haryana.

Figure 2: NASA Earth Observatory image of fog and haze distribution over the Northern States (NOV 7,2017)



Source: NASA Imagery

1.4. Health Impacts Due to Stubble Burning

Pollutants released from stubble burning have toxicological properties and are potentially carcinogenic. These pollutants also impact farm animals and livestock, with the implications being greater for milk producing animals.

The air quality in northern India during post monsoon season (October to November) is adversely affected by crop burning when the prevailing meteorological conditions favours the accumulation and long range transport of pollutants. Gadde et al. (2009) states that open burning of crop stubble leads to release of harmful chemicals like polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated dibenzofurans (PCDFs) referred to as dioxins. These pollutants have toxicological properties and are potentially carcinogenic. Stubble burning also impacts farm animals and livestock, with the implications being greater for milk producing animals.

The pollutants from stubble burning get caught in the winter inversion and stay over IGP for days, sometimes weeks. This causes severe adverse health impacts especially on the vulnerable population (children, pregnant women, elderly and anyone with pre-existing respiratory, pulmonary and cardiovascular diseases). Inhaling of these fine particles for an extended period of time can trigger asthma and also worsen chronic obstructive pulmonary disorder (COPD). According to Singh et al. (2008), more than 60 % of the population in Punjab lives in the rice growing areas and is exposed to air pollution due to burning of rice stubbles. As per the same study, medical records of the civil hospital of Jira, in the rice-wheat belt showed a 10 % increase in the number of patients within 20–25 days of the burning period every season. Most of the farmers exposed to stubble smoke complained

about eye irritation and lung infections and had spent a considerable amount of money on medical expenses (Kumar et al., 2015). According to a study conducted by the Bengaluru-based Institute for Social and Economic Change, individuals in rural Punjab spend around Rs 7.6 crore per year on treatment for ailments caused by stubble burning (Yadav, 2019). Extended studies have not been done yet to learn the immediate impacts of this stubble burning pollution in the IGP (Singh et al., 2008).

1.5 Scope of this study

India has a huge task ahead, as we face a dual challenge of curbing growing air pollution levels across the country as well as health impacts from poor air quality which is starting to affect many Indian states (Health Effects Institute, 2020). At present, stubble burning is blamed by many or perceived as one of the biggest reasons for hazardous air pollution levels in Delhi and in IGP. The practice of crop residue burning is prohibited by many state governments and the Supreme Court of India in 2019 (Khanna, 2020). The National Green Tribunal (NGT) also imposed fines in 2015 ranging between 2,500 INR to 15,000 INR on farmers to discourage them from burning paddy fields. Besides the fine, NGT has notified the state governments of Delhi, Rajasthan, Punjab, Haryana and Uttar Pradesh to update on the steps taken to check the harmful practice. But these ruling and fines have had a very little impact on the ground, with the practice still being widely followed for many reasons. The state and central governments have passed many policies in the last decade to aid farmers to move away from stubble burning. This presents us with an opportunity to investigate these policies and its effectiveness in one of the states – Punjab in north-western India which practices stubble burning in huge numbers.

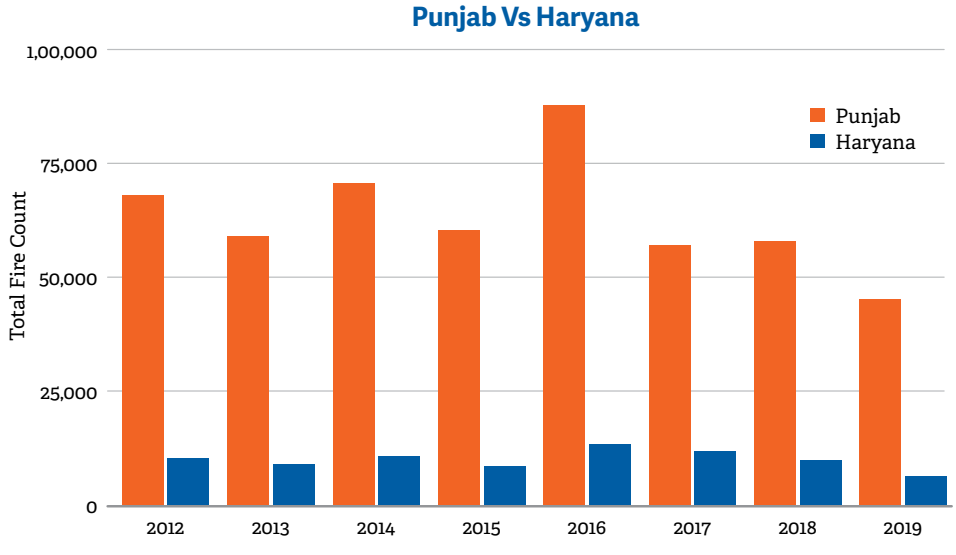
CHAPTER - 2

Hypothesis and Methodology

As we take a closer look, we find a complex inter-relation between agricultural and environmental policies and their obvious and inadvertent outcomes. As alarming as it sounds, the issue of stubble-burning is not novel, but has become profound since the last 10 years. Interestingly, this issue has more prevalence in Punjab as compared to other northern states. Figure 3 highlights that Punjab has five to eight times more active fire hotspots than Haryana (Somvanshi, 2020). It is intriguing that what led to the spike in the stubble burning incidents was the policy intervention introduced to control the injudicious utilization of groundwater resources. A recent study conducted by Singh et al. (2019), has also tried to highlight tradeoffs between the groundwater conservation policy introduced in 2009 and air pollution from agricultural fires in northwest India. This has actually raised a question if the existing policies have sufficiently addressed the fundamental causes of the problem. An analysis, therefore, is needed to diagnose the interlinkages between these policies and its complex and far reaching implications. Through this study, we hypothesize that the practice of stubble burning is not linked to a single factor but a multitude of other factors that influence the problem directly/ indirectly.

The practice of stubble burning is not linked to a single factor but a multitude of other factors that influence the problem directly/ indirectly.

Figure 3: Punjab and Haryana total fire counts



(Source: Redrawn using data from Somvanshi, 2020)

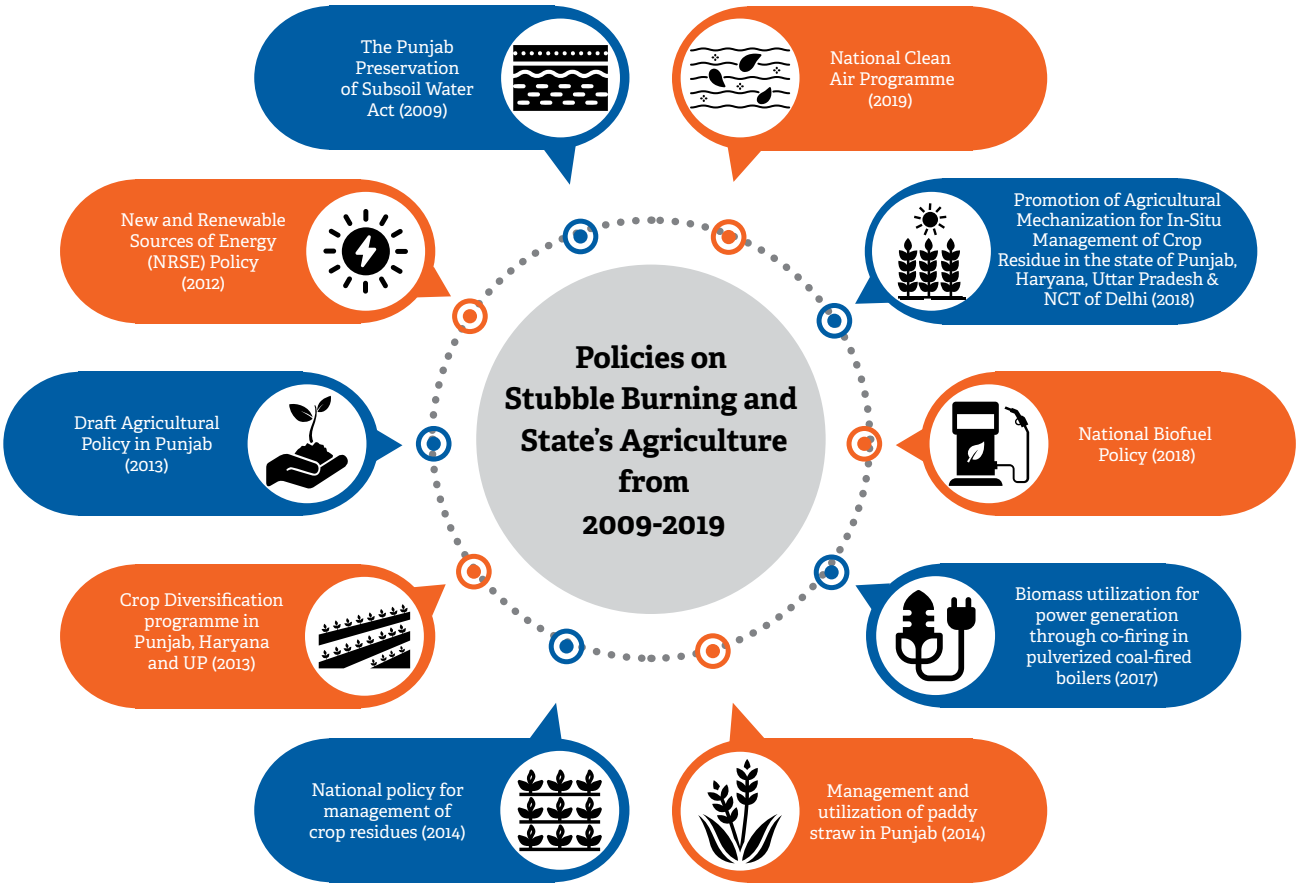
2.1 Study Objectives

This study is an attempt to understand the impacts of policies on the issue of crop residue burning in Punjab. The main idea behind this exercise is to establish the critical gaps existing in the system which fosters the prevalence of residue burning. This study also tried to review all the challenges associated with continued stubble burning and bring to the limelight the multifaceted nature of the issue.

2.2 Study Methodology

To achieve the above mentioned goals, extensive literature review was undertaken to scrutinize the measures and policies introduced by the central and the state government in the last 10 years (2009-2019) in Punjab. The study has analyzed the agricultural data from various published sources of Government of India and Government of Punjab. Based on these analyses, the main issues were identified and way forward and recommendations are suggested in this context.

2.3 Policies on Stubble Burning and State's Agriculture from 2009-2019



CHAPTER - 3

Background

3.1 Green Revolution and transformation in India

In the post-independence era, agriculture became the backbone of India's economy. The Green Revolution which initiated in 1964–65 transformed India into a self-sufficient agricultural giant. This agriculture-led growth clubbed with liberalization policies of the 1990s could be credited with catalyzing the country's remarkable change. In a few decades, India became the fifth-largest economy globally, beating France and the United Kingdom. Pingali et al., (2019) showed that at least half of the Indian states doubled their incomes in the first 35 years' post-independence and then doubled their revenues again in approximately half the time owing to the green revolution.

The success of the Green Revolution was made possible by the introduction of high-yielding varieties of seeds, increased use of chemical fertilizers, irrigation and other modern farming methods.

Initially, the success of the Green Revolution was observed most noticeably in the highly irrigated areas of India, especially in Punjab and Haryana in the north-western region. The success of the Green Revolution was made possible by the introduction of high-yielding varieties of seeds, increased use of chemical fertilizers, irrigation and other modern farming methods. However, Indian agriculture faced several problems starting from 1980s in the form of degradation of natural and environmental resources like soil and water, rising cost of cultivation and declining profitability, dwindling of farm productivity and so on. As a result, the unprecedented agricultural growth soon started to witness stagnation in production. The average yearly growth rate in real terms in agriculture and its allied sectors has remained almost the same in the last six years, in turn impacting farmers' income (MOF, 2019). The annual growth rate in real terms was 2.88 percent from 2014-15 to 2018-19, according to the Economic Survey. The estimated growth rate in the year 2019-20 was just 2.9 percent (Jitendra, 2020).

3.2 Change in agricultural practices after the Green Revolution

Due to the variations in agro-climatic conditions, levels of adoption of modern technology, procurement policies and market conditions, agricultural growth output has varied across different regions of the country over time. The regional variations in the cropping patterns in India are shown in the figure 4. The eastern and northern regions still have around four-fifths of their total cropped area under cereals (Paltasingh et al., 2017). The northern region comprises the two major beneficiaries of the Green Revolution, namely Punjab and Haryana. In the rest of the regions there has been a significant shift in the cropping patterns from cereals to non-cereals. A study done by Birthal et al., (2014) also showed that while crop production growth has been driven by technology in the rice-wheat dominated regions, especially in the northern region, the western and southern regions have relied more on crop diversification as a growth strategy.

Figure 4: Change in cropping patterns across India: regional variations(1968-2005)

Region	Year	Cereals	Pulses	Food grains	Oil seeds	Fibres	Condiments and spices	Others	Non-food grains
Eastern	1968	78.72	12.59	91.30	3.23	2.51	0.34	2.61	8.70
	1980	75.05	12.83	87.89	5.07	3.73	0.71	2.60	12.11
	1990	73.98	11.95	85.83	7.33	2.95	0.88	3.01	14.17
	2000	79.65	6.90	86.55	5.38	3.84	0.85	3.38	13.45
	2005	79.01	7.07	86.08	5.54	3.60	1.06	3.72	13.92
Northern	1968	68.26	15.19	83.46	4.94	7.31	0.26	4.02	16.54
	1980	72.37	10.75	83.12	5.26	9.13	0.22	2.27	16.88
	1990	74.87	7.45	82.32	5.09	10.07	0.08	2.44	17.68
	2000	83.12	1.76	84.87	4.03	8.22	0.05	2.82	15.13
	2005	80.41	1.73	82.14	6.33	8.85	0.14	2.55	17.86
Western	1968	59.98	9.72	74.64	12.03	11.94	0.53	0.86	25.36
	1980	58.14	11.02	73.64	13.13	11.20	0.73	1.30	26.36
	1990	52.17	12.88	69.42	18.94	9.12	0.78	1.75	30.58
	2000	50.07	15.47	65.54	18.75	12.35	0.78	2.58	34.46
	2005	44.93	15.99	60.92	24.94	11.03	0.66	2.45	39.08
Central	1968	63.82	18.29	82.10	12.41	1.92	0.13	3.44	17.90
	1980	66.07	15.94	82.00	12.36	1.55	0.27	3.82	18.00
	1990	63.59	16.82	80.41	12.88	1.38	0.38	4.94	19.59
	2000	60.15	15.13	75.28	16.85	1.26	0.47	6.13	24.72
	2005	58.18	16.86	75.03	16.15	1.52	0.60	6.70	24.97
South	1968	66.16	9.58	75.77	13.11	6.08	1.65	3.39	24.23
	1980	60.31	12.54	72.85	14.21	6.23	2.93	3.78	27.15
	1990	50.95	13.93	64.88	22.75	5.41	2.82	4.14	35.12
	2000	50.08	15.87	65.96	18.60	6.29	3.45	5.71	34.04
	2005	48.76	14.89	63.65	22.50	5.70	2.83	5.32	36.35

(Source: Paltisingh et al., 2017)

3.2.1 Agriculture in Punjab

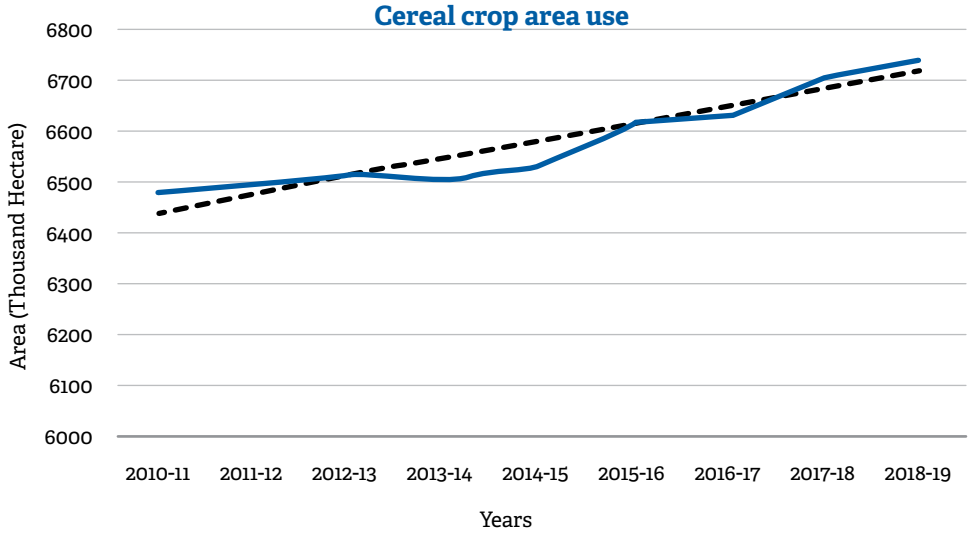
Punjab has been a significant food-producing state of the country. Its agricultural growth is closely associated with the well-known 'Green Revolution', which saw the development and adoption of new, high-yielding varieties of wheat, rice, and other food crops. The production of wheat and rice grew rapidly and yielded high production and financial returns. The rapid growth was associated with technology diffusion in the state in the 1970s and 1980s. Comparative advantages of good soil, availability of surface and groundwater, efficient workforce, and other infrastructure developed over the years have contributed significantly to growth in agriculture in the state in the last few decades. Punjab comprising only 1.5 percent of the country's total geographical area, contributes 13-14 percent towards the country's total food grain production. As per the Statistical Abstract of Punjab (2018), the state has contributed about 25.5 percent of rice and 35.5 percent of wheat to the central pool, earning itself the name of "India's granary" as well as "India's Wheat bowl". However, the sector is lately experiencing slower growth as the state's cropping intensity and irrigation potential have been fully exploited, and the productivity growth has also reached a saturation point (Vasudeva, 2019).

Comparative advantages of good soil, availability of surface and groundwater, efficient workforce, and other infrastructure developed over the years have contributed significantly to growth in agriculture.

3.2.2 Cereal crop dependence:

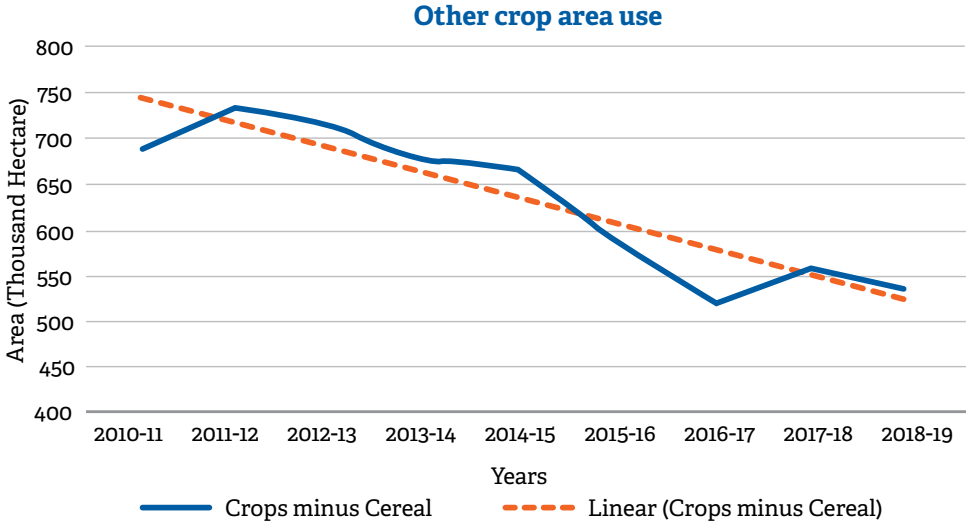
The state has witnessed a considerable change in cropping patterns in the post green revolution era, focusing extensively on wheat-paddy crop rotation. The net sown area under wheat and rice has increased manifolds during the last five decades, whereas the size under oilseeds, pulses, maize, other cereals, etc. has decreased sharply. In 2013, this rice-wheat cropping system covered 81% of the gross cropped area of the State (Grover et al., 2017). Figure 5 shows how the area has increased under the cereal production over the years.

Figure 5: Increase in Area under Cereal crops production in Punjab (in 000 hectares)



Data Source: Statistical Abstract of Punjab 2018)

Figure 6: Decrease in Area under other crops in Punjab (in 000 hectares)



In Punjab over 20 million tonnes of crop residue is produced every year, out of which 80% is burnt on the farm.

The high yielding varieties have replaced the multi-cropping pattern with a monoculture of wheat and rice, resulting in the exploitation of natural resources of the state, mostly water and soil. Most high yielding varieties are highly input- intensive leading to higher irrigation for water and growing use of fertilizers and pesticides for their optimum growth and yield. With the adoption of the rice-wheat cropping pattern in the state, crop diversity has decreased (as shown in Figure 6) considerably due to reduced area under crops like gram, maize, bajra, pulses, groundnut etc which positively impact soil quality (Kumar et al., 2015).

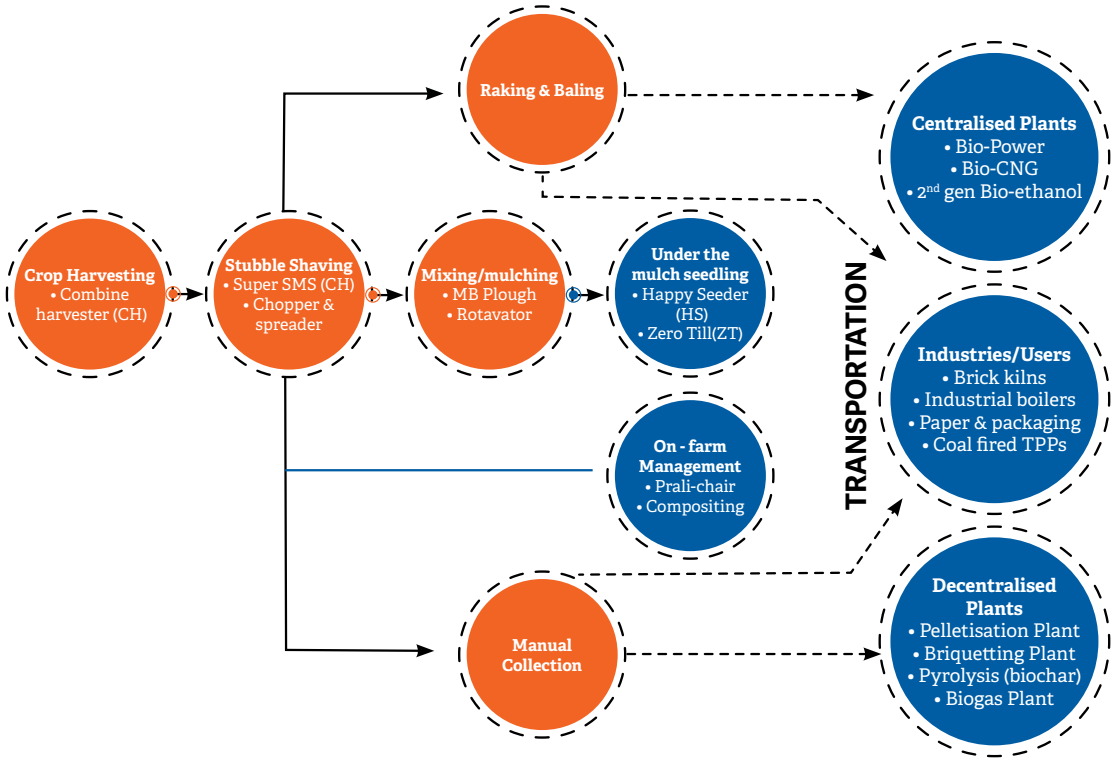
3.3 Why farmers burn stubble?

A crucial aspect of rice wheat cropping is the short window between rice harvesting and wheat cultivation. A delay in sowing wheat can adversely affect the wheat crop. With only a few days between the rice-harvesting season and the wheat-sowing time, farmers often burn the paddy stubble to eliminate it quickly. According to Yadav (2019), in Punjab over 20 million tonnes of crop residue is produced every year, out of which 80% is burnt on the farm. A survey of farmers in Punjab shows that 41% of farmers attributed crop stubble burning to a short window of time available between harvesting paddy and sowing wheat, while 48% said that burning is more economical and faster (Kumar et al., 2015). Besides the short window, the machine Combine harvester, which helps in timely harvesting crops, saving money as well as allowing reduced supervision of labour has also contributed to residue burning (Gupta, 2012). The combine leaves behind paddy stubbles of around 14-15inch (around 40 cm) long stalks in the fields that farmers have to then find a way to get rid of. The cost of getting this stubble removed is Rs. 3,500/ hectare which is quite high for the farmers to bear (MOF, 2019). This could also be interpreted as one of the reasons why farmers prefer to use the traditional approach of burning to clear fields rather than experimenting with other alternatives.

3.4 Alternatives available to control the burning

There are various measures suggested by government to counter crop residue burning which can be categorised into in-situ treatments and ex- situ treatments. Figure 7 shows different ways the agriculture residue can be treated.

Figure 7: Alternatives to agricultural residue burning



(Source: NITI Ayog, 2018)

3.4.1 In-situ crop residue management

In situ management refers to the on-site management of crop residue. The technical measures used are 'straw incorporation' and 'straw mulching'. In both these measures, the residue is incorporated in the field itself and is thus used to increase the nutrient value or fertility of the soil (Kumar et al., 2015). For this purpose, specialised machinery is required at different stages of farming. There are many machines available to incorporate stubble within the soil, such as Rotavators, Choppers, Happy Seeder, etc.

Stubble Shaving:

Chopper and Spreader: The Paddy straw chopper cum spreader machine has been developed by Department of Farm Machinery and Power Engineering, Punjab Agricultural University. Following the combine harvester process, this machine cuts, chops and spreads the paddy straw left (standing and loose straw) in the field. This chopped straw can be used as a mulch or can be mixed into the soil, and various tillage methods and sowing techniques can be used to sow different crops.

There are various methods of managing the stubble, both in-situ (on site) and ex-situ (off site)

Super Straw Management System (SMS) is a piece of machinery attached with the combine harvester machine, which cuts the standing paddy straw into small pieces and spreads it uniformly in the field. The farmers then are not required to burn paddy straw before sowing the next crop.

Mixing and Mulching:

Plougher: the paddy can be incorporated in the soil with the use of MB Plough.

Rotavator chops the straw into small pieces and sows it into the soil. The paddy straw is fully incorporated by this method and it decays at much faster rate after its contact with soil.

Under the mulch seeding:

Zero till: this drill machine is used for no tillage system requiring no previous seed bed preparation after harvesting paddy and sowing of wheat crop effectively in one operation.

Happy seeder machinery which does the triplet work -it not only harvests the crop and chops the straw, but it also sows the wheat seeds and mulches the chopped straw into the soil, which helps maintain the moisture content in the ground. All the machines help in preventing environmental degradation and loss of soil nutrients. An attachment called straw management system (SMS) can be attached behind the combine which spreads the loose straw falling at the rear during the harvesting operation.

On farm management:

Composting is the natural process of degradation of organic matter by micro-organisms. As a rich source of organic matter, compost plays an important role in sustaining soil fertility and thereby helping to achieve sustainable agricultural productivity (Misra, Roy and Hiraoka, 2003). In recent years, interest in composting has increased because of the social demand for an environmentally friendly waste treatment technology and advent of organic farming. It is the most acceptable method of recycling of organic matter and agriculture residues (Antil and Raj, 2012).

3.4.2 Ex-situ crop residue management

Off the field utilization of crop residue is termed as ex-situ crop residue management. Paddy residue is used as a feedstock for power generation. It is also being used as a source for animal feed (Bhuvaneshwari et al., 2019). However, rice residue as fodder for animals is not a very popular practice among farmers because of the high silica content present in the rice residue. In ex-situ management, stubble is cut and then collected from the fields with the help of machines like baler which collects and compresses the stubble into bales. These bales are then used in stubble based industries such as cardboard, paper industry, sugar mills, brick kilns etc. Biomass pellets can also be made from paddy residue and can be used in biomass based power plants for power generation. It is estimated that agriculture residues alone substitute 25% of coal consumption in the generation of electricity and consequently reduces the coal import burden. The biomass stubble is also being utilised to produce CNG, ethanol etc to help curb the stubble burning incidents and create additional income to farmers. Lately, we are also hearing about converting the stubble into a sustainable, durable building material. A recent inititative called 'Strawcture Eco' gained quite popularity in which Agribiopanels made out of crop waste were used to build self-sufficient solar powered, fully functional COVID centre units in Bihar and Jalandhar (Sharma, 2021). Furthermore, with ex-situ treatment farmers are earning by selling their stubble to industries and dairy owners.

CHAPTER - 4

Policies and Programmes

This chapter provides an overview of the policies which have been introduced to deal with the issue of stubble burning. The chapter also presents the outcomes which were desired to be fulfilled by these policies and an evaluation of what has been achieved till date.

The government of Punjab acknowledged the overexploitation of groundwater as a pressing concern and mandated the Preservation of Subsoil Act to contain it.

4.1 The Punjab Preservation of Subsoil Water Act (2009)

The government of Punjab acknowledged the overexploitation of groundwater as a pressing concern and mandated the Preservation of Subsoil Act[1] to contain it. In order to save and restore the depleting groundwater resources, the legislation pushed back rice planting from May, when farmers were solely dependent on groundwater reserves, to June to bring cultivation closer to the monsoon season. Any farmer, who contravenes the provisions of the Act, shall be liable to a penalty of rupees ten thousand for every month or part thereof, per hectare of the land till the period such contravention continues.

Desired Outcomes:

- Reduce the depletion of groundwater tables by about 30 cm.
- Effective checks on the early transplantation of rice are expected to help control the fall in groundwater tables, decrease the amount of irrigation water to be applied, and save electricity.
- State agriculture department estimated that Punjab will save 24 lakh million cubic metres of water by stretching the notified date to June 20.

Present Status:

This legislation has been quite successful in saving up to 7-8 per cent of water as compared to May transplanting but according to Central Ground Water Board Report 2017 (CGWB, 2017):

- The groundwater withdrawal has exceeded on an average from 149% in 2013 to 152% in 2016-17 with some areas exceeding 300%.
- 109 blocks in Punjab are overexploited out of 138.
- There are 1.4 million tubewells in Punjab which are over-exploiting ground water resources.
- Land use for agriculture has saturated in Punjab.

[1]http://dswcpunjab.gov.in/contents/docs/Pb-preservation-of-Subsoil-Act,2009.pdf

4.2 New and Renewable Sources of Energy Policy (2012)

Introduced in 2012, the policy[2] seeks to promote renewable energy in the State including power generation from biomass and agricultural residue. The policy also got revised in 2019 to provide guidelines for better utilisation of agricultural residue.

Desired Outcomes (in perspective of Stubble Burning):

- To achieve biomass/ agriculture residue generated target of 600MW by 2022.
- The policy mentions that the Punjab Energy Development Agency (PEDA) shall take up Research and Development projects in the biomass, especially paddy straw combustion for power generation through Rankin cycle/gasification in pilot mode.

Present Status (in perspective of Stubble Burning):

- A total of 11 Biomass power projects of cumulative capacity 97.50 MW are commissioned and in operation in the state which utilize 8.8 Lac Metric ton of paddy straw per annum. Two Biomass power project of 14 MW is under execution which shall be commissioned by June 2021 and shall utilize 1.26 Lacs Metric ton of paddy straw per annum (PEDA, 2020).
- The Punjab Energy Development Agency (PEDA) has invited expression of interest from the interested project developers for setting up of 150 MW capacity 100% rice straw-based biomass power plants on viability gap funding-based competitive bidding (Datta et al., 2020).
- Punjab government has proposed to allocate 100 MW standalone Biomass power projects and 25 MW Biomass Solar Hybrid Power Projects (PEDA, 2020).

4.3 Draft Agricultural Policy in Punjab (2013)

The policy[3] recognized that any strategy for further agricultural development need to tackle sustainability issue along with overall growth objectives. The draft policy envisages substantial crop diversification (from paddy and wheat) as a solution for Punjab's agrarian crises. It is the first serious road map to steer Punjab's agriculture towards a new dynamic, necessitated by a sharp decline in its water and soil health, and falling farm incomes.

Desired Outcomes:

- To promote sustainability, the policy aims to make concerted efforts to reduce the area under paddy cultivation by 40 per cent from current levels in a span of 5–7 years.
- As per the policy, area under paddy should be restricted to 16 lakh hectares for maintaining the ground water balance.

Present Status:

The policy has not been able to create the desired impact and is still in its draft stage. Till date, paddy cultivation is being favoured by the farmers because of various incentives provided on its production.

[2]http://www.cbip.org/Policies2019/PD_07_Dec_2018_Policies/Punjab/2-RE/1%20summary%20Punjab%20New%20and%20Renewable%20Sources%20of%20Energy%20Policy-2012%20.pdf

[3]https://punjab.gov.in/wp-content/uploads/2019/04/Agriculture-policy-of-punjab.pdf

4.4 Crop Diversification programme in Punjab, Haryana and UP (2013)

The programme[4] was introduced to demonstrate and promote the improved production technologies of alternate crops for diversion of paddy cultivation and to restore the soil fertility through cultivation of leguminous crops that generate, heavy biomass and consume lesser nutrient intake crops.

Desired Outcomes:

- Under this programme in Punjab, the aim is to diversify the 1,40,000 hectares of paddy being cultivated to other crops.
- At least 5% of area under paddy in identified blocks would be diverted towards alternate crops during 2013-14.

Present Status:

The programme has proven to be ineffective because of various reasons (later discussed in the study). The funds allocated for this programme have also reduced over the years (Table 2).

Table 2: Allotment of funds for CDP

Allocation of funds	Amount (in lacs)
2013-14	24950.00
2014-15	25000.00
2015-16	7500.00
2016-17	7947.00
2017-18	1766.00
2018-19	706.66

(Source: NFSM,2018)

4.5 National policy for management of crop residues (2014)

The policy[5] was introduced to provide various interventions to control burning of crop residue to prevent environmental degradation and loss of soil. It is the first nationwide policy introduced which also provides strategies to deal with the issue.

Desired Outcomes:

The policy envisages adoption of technical measures and extending central financial assistance for various interventions. Various ex-situ options for management of crop residue burning such as production of Prali-Char, Bio-char, pellets, briquettes, Bio-CNG, bioethanol (alternate fuel for brick kilns), industrial boilers, paper and packaging, coal-fired TPPs, were promoted. The policy also promotes the in-situ management to prevent loss of invaluable soil nutrients, minerals and improvement of general soil health.

Present Status:

- To promote the diversified use of crop residue, the central government has announced various programmes in 2018 such as Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue, National Biofuel Policy etc.
- The policy promoted the remote sensing techniques and aerial surveillance used to identify the burning locations.

[4]http://agricoop.nic.in/sites/default/files/CDPGuidelines_0.pdf
[5]http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf

It outlined in-situ management strategy of paddy straw incorporation on fields and provides information on alternative options for utilizing paddy straw and challenges witnessed in collection.

4.6 Management and utilization of paddy straw in Punjab (2014)

The document[6], while adopting a holistic perspective to paddy-straw management introduced the concept, 'Earn, Don't Burn', which advocated for an integrated approach to prevent loss of resources from paddy straw burning. In addition to making a strong case for reducing the area under paddy cultivation, the white paper also outlined an in-situ management strategy of paddy straw incorporation on fields.

Desired Outcomes:

As per the White Paper, the state government has an estimated target to use 5.73 million tonnes of paddy straw in 2016–17. Also, industries utilizing paddy straw as raw material can seek incentives under 'Fiscal Incentives for Industrial Promotion – 2013' scheme of the Government of Punjab.

Present Status:

The paper made a strong case for reducing the area under paddy cultivation. It outlined in-situ management strategy of paddy straw incorporation on fields and provides information on alternative options for utilizing paddy straw and challenges witnessed in collection and storage of the straw which later helped in formulating the guidelines on "Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue".

4.7 Biomass utilization for power generation through co-firing in pulverized coal-fired boilers (2017)

In order to promote the use of biomass pellets, Central Electrical Authority (CEA) drafted a policy[7] where all fluidized bed and pulverized coal units (coal-based thermal power plants) of public- and private power-generating utilities are advised to use 5–10% blend of biomass pellets, primarily agro residues, along with coal.

Desired Outcomes:

With the overall thermal power generation capacity of 203 GW, the estimated daily biomass pellets requirement would be about 146,498 tonnes (assuming 2.75 lakh tonnes of biomass pellets for 7% blending in a thermal power plant of 1000 MW capacity). This would utilize about 53.5 Mt of crop residues annually, which is about 30% of the total annual surplus crop residue in the country. (CEA, 2019).

Present Status:

- Central Electrical Authority has developed/issued the specification for the biomass pellets and provide technical assistance/advice to utilities on how to use bio-mass pellets for blending with coal in coal based thermal power plants (CEA, 2018)
- The government has also planned to install 60MW biomass based plant for the production of biomass pellets[8]

[6]http://www.punenvis.nic.in/index2.aspx?slid=4752&mid=7&langid=1&sublinkid=1008
[7]http://www.cea.nic.in/reports/others/thermal/tetd/policy_biomass_utilization.pdf

4.8 National Biofuel Policy (2018)

Originally introduced in 2009 and later revised in 2018, the policy[9] aims to increase usage of biofuels in the energy and transportation sectors of the country during the coming decade. The policy not only widens the feedstock base which now also includes crop residues for the production of biofuels but also indicates the roadmap for achieving the blending targets while contributing to National Energy Security, and Climate Change mitigation.

Desired Outcomes:

By converting biomass to compressed Bio-gas and Bio-CNG, the plants will help control stubble burning and create additional income to farmers. The project will also create rural employment & entrepreneurial opportunities, besides providing a green organic source of compost for soil enrichment.

Present Status:

- Currently, there are eight Bio-CNG projects being implemented in the state. In 2021 and 2022, the bulk of these projects will be commissioned. It is estimated that these projects would require paddy stubble of about 3-lakh metric tonnes annually (Chaba,2020a).
- Punjab government has signed an MoU with Hindustan petroleum corporation limited, Indian Oil Corporation, Verbio India private limited and Rika biofuel development limited for setting up Bio-gas & Bio-CNG plants in the state (Diprpunjab,2018; Business Standard, 2018).

[8]http://www.ppcb.gov.in/Attachments/Reports%20and%20Documents/ActionPlanstubble.pdf

[9]http://petroleum.nic.in/sites/default/files/biofuelpolicy2018_1.pdf

[10]https://farmech.dac.gov.in/revised/1.1.2018/Guidelines%20(Amended)%20of%20Straw%20Management%20Scheme.pdf

4.9 Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue in the State of Punjab, Haryana, Uttar Pradesh & NCT of Delhi (2018)

A revised version of "Sub Mission on Agricultural Mechanization", the programme[10] promotes the in-situ management of crop residue by retention and incorporation into the soil through the use of appropriate mechanization inputs which further help in restoring soil nutrients lost due to burning.

The Centre has approved the scheme with the total outgo from the Central funds of Rs. 1151.80 crore (for Punjab Rs. 591.65 crore in 2018-19 and Rs. 560.15 crore in 2019- 20).

Desired Outcomes:

The scheme has the components on

- establishment of farm machinery banks for custom hiring of in-situ crop residue management machinery;
- financial assistance to farmers for the procurement of agriculture machinery and equipment for in-situ crop residue management; and
- information, education, and communication for awareness on in situ crop residue management

Present Status:

- In 2019-20, the number of machines delivered fell to 14,625 from 28,609 in 2018-19 because of unavailability of machines (Pandey, 2020).
- Punjab government claims that it has set up 7,378 custom hiring centres (CHC) over the 2 years and has announced another 5,200 CHCs will be set up this year to meet the target of having one CHC in each village (Ramachandran, 2020).
- Under the scheme, farmers from Punjab have been given subsidy of nearly Rs. 460 Crore on 50,815 farm machines. The GoI has already listed around 180 manufacturers from Punjab to ensure supply of farm equipment/ machinery in this regard (The National Graph, 2020).
- In the State of Punjab, the area managed by different in-situ crop residue management machinery provided during 2018-19 was 1602822 hectares. The area managed specifically by the happy seeders was 449529 hectares (MoAFW, 2019)

The goal of the NCAP is to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe.

4.10 National Clean Air Programme (2019)

The National Clean Air Programme (NCAP) was launched in 2019 by the Central Government as a long-term, time-bound national policy to address air pollution in a comprehensive manner across the country. The goal of the NCAP[11] is to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe. NCAP also recognises the issue of stubble burning to be one of the responsible factors for poor air quality.

[11]http://moef.gov.in/wp-content/uploads/2019/05/NCAP_Report.pdf

Desired Outcomes of NCAP in perspective of Stubble Burning:

The programme has provided various action points to tackle the stubble burning issue which includes:

(i) evaluation of the various schemes and their impact on reduction of air pollution in Delhi and the NCR.

(ii) evaluation of economic feasibility of ex-situ treatment

(iii) availability of Remote Sensing Monitoring data for crop burning by the farmers.

(iv) Capacity building.

Present Status of NCAP in perspective of Stubble Burning:

In order to stop stubble burning, the Centre has allocated more than Rs 1,600 crore under two schemes, one of them to tackle pollution in Delhi-NCR and the other to discourage stubble burning. An amount of Rs 1,178.47 crore has been released for the scheme aiming at "Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi" and around Rs 460.96 crore was released for 2019-20 for a separate programme 'Control of Pollution'. This aimed at providing assistance for abatement of pollution to state pollution control boards and committees and for implementation of the National Clean Air Programme as major components (Money control, 2019). Additionally, an ordinance was promulgated for setting up a broad based Commission for Air quality management in NCR and adjoining areas to provide for a coherent approach to tackle the problem of air pollution (Vibhaw and Jain, 2020).

CHAPTER 5

Policy Discussion

After analysing the policies proposed by the State and Central government of India to aid the transition in Punjab agriculture to combat issues like stubble burning, we established many interlinkages between policies, observed/expected impacts and outcomes. The discussion in this chapter mostly revolves around policy-related functionality issues from the last 10 years (2009-2019), that may have directly or indirectly influenced the problem of stubble burning.

The current situation in Punjab is so grim that the quality of groundwater has declined to the least due to its exploitation.

5.1 Ground water exploitation

The state of Punjab has been grappling with the issue of water crisis since many decades. In a bid to address the issue of groundwater exploitation, the state government passed the ***"Punjab Preservation of Sub-Soil Water Act"*** in ***2009***. The Act prohibited sowing nursery of paddy before May 10 and transplantation before June 15 to bring cultivation closer to the monsoon season, thereby reducing additional pressure on the groundwater table. After the act was implemented, the average annual rate of decline in the water table decreased from 0.9m (2000-2008) to 0.7m (2008-2012) but, the higher shares of tube wells per total cropped area and increased population density have led to a significant decline in the groundwater tables (Tripathi, Mishra and Verma. 2016). A study by Sekhri also observed the increase in number of irrigation applied or more water used per irrigation by the farmers after the policy change (Sekhri, 2013). The study also noted that the mechanism cannot be established in the absence of farm-level data on the number of irrigation applications and the use of water.

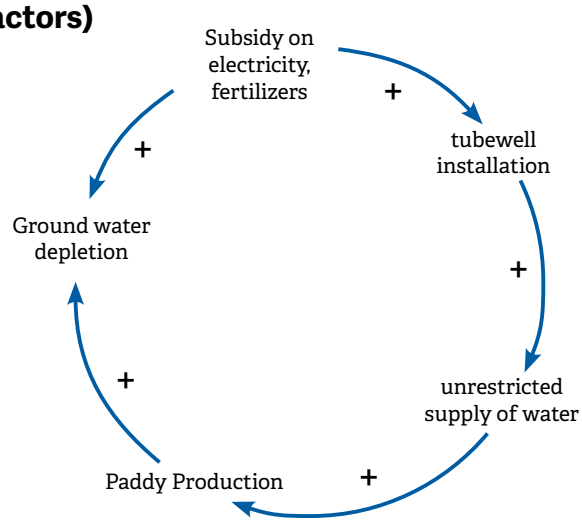
Despite the initial success of the policy, the current situation is so grim that Punjab's ground water development index is highest in the country at 172% (Garg, 2017). This demonstrates the exploitative essence of Punjab's groundwater irrigation. Recent study by CGWB also predicted that with the current rate of extraction, the ground water resources of the state will be exhausted in the next 20-25 years and Punjab will be rendered a desert (CGWB, 2019). The receding water table is attributed to the water intensive principal crops such as paddy promoted during the green revolution. Comparing the groundwater use of the principal crops (rice, wheat, maize, cotton) with their land productivity, a significant misalignment in the cropping pattern and the available water use is visible (Sharma et al., 2018). On an average, production of one kilogram of paddy in Punjab requires 5337 litres groundwater whereas in West Bengal it requires around 2605 litres of water to grow the same amount (CACP, 2015). Owing to high groundwater utilisation, the groundwater productivity (when the output is divided by the ground water usage) of paddy is the least among other crops (Srivastava et al., 2015). This illustrates that the most productive state in terms of land

productivity is not the most efficient when other production factors, such as water, are taken into account.

The root cause of this misalignment can be credited to various programs and policies that favours rice and wheat monoculture as shown in figure 8. The Central government's favourable attitude towards paddy cultivation along with the provision of free electricity, are the primary drivers that encouraged farmers to continue with the paddy production, irrespective of the unfortunate situation of the groundwater depletion faced by the state (Vasudeva, 2019). The additional subsidies provided by the government on electricity, water and fertilisers also influenced farmers to extract the groundwater at unsustainable rates which directly raised the cost of agricultural production (Pandey, 2014).

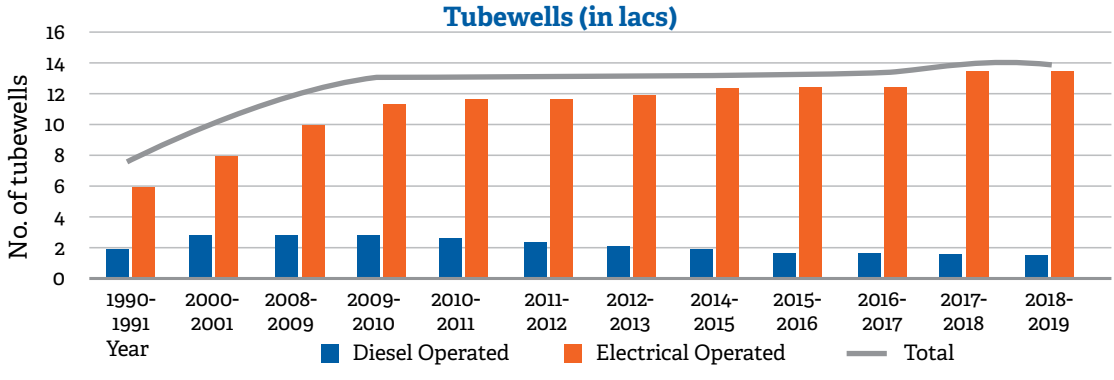
The Central government's favourable attitude towards paddy cultivation along with the provision of free electricity, are the primary drivers that encouraged farmers to continue with the paddy production

Figure 8: Causal Diagram showing Ground water exploitation dynamics ("+" sign indicates positive relationship between two factors)



- Over the years (shown in figure 9), the subsidised credit and power for energising tubewells has prompted the farmers to replace diesel operated pumps with the electric pumps to access the groundwater resources freely (Srivastava et al., 2015). Combined with free electricity policy, the pumps kept running without any restrictions, thus eliminating any incentive to rationalize the use of groundwater.

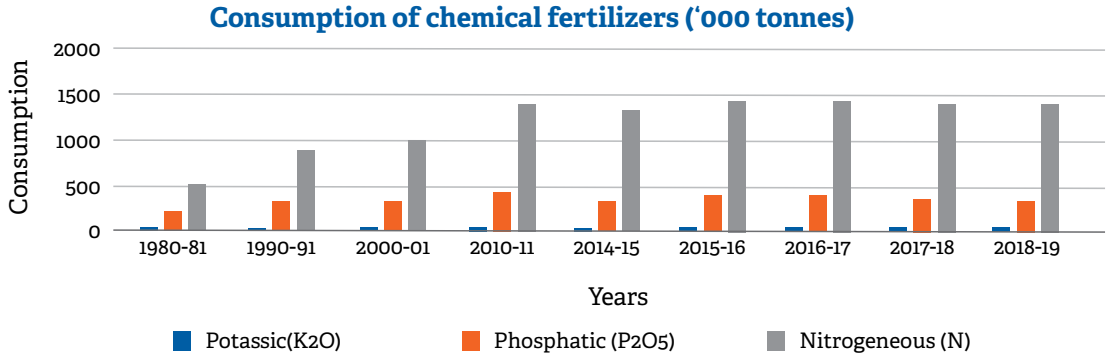
Figure 9: Tubewells Installation in Punjab



(Data Source: Statistical Abstract Of Punjab 2018)

- The paddy cultivation has not only resulted in mining of the ground water (i.e. withdrawal is more than the annual recharge) but also contributed to deteriorating ground water quality caused due to the increased consumption of fertilizers. If the paddy is sown later, it becomes prone to pests and diseases which had forced farmers to increasingly depend on pesticides and chemical fertilizers. Figure 10 shows the increase in consumption of chemical fertilizers in Punjab over the years

Figure 10: Consumption of Chemical Fertilizers in Punjab



(Data Source: Punjab ENVIS Centre)

Recognizing the harmful effects of rice and wheat monoculture on the water table and the environment, other measures such as '***Crop diversification programme***' was also introduced in ***2013*** to diversify the cropping pattern from paddy cultivation to less water intensive crops, thereby aiming to help in restoring the ground water levels. Due to absence of compatible policy guidelines, this programme was also proved to be ineffective in replenishing the ground water. As of today, the rice and wheat monoculture still rules the production charts and continues to deepen the water crisis in Punjab.

The over-reliance on the paddy and wheat has led to various socio-economic as well as environmental concerns

Shortened cropping cycle: An important feature and limitation of the ***'Punjab Preservation of Sub-Soil Water Act'***, also seen as the main factor responsible for stubble burning within the rice wheat cropping cycle is the short window between rice harvesting and sowing of wheat (Pandey et al., 2020). An interesting finding from a recent study by Singh et al., (2019) has suggested that the shifting of the paddy cultivation date has indirectly impacted the issue of stubble burning in Punjab. The research revealed that prior to the water conservation law, 86% paddy was planted on or before June 28 which fell to 40% after the inception of the law and accordingly, the harvesting shifted from 40% to 14% pre-June in 2009. The delayed sowing led to delayed harvesting and left very little time to ready the soil bed for sowing wheat, forcing farmers to resort to a quick-fix solution of burning paddy residue in the field (Mohanty, 2020). This act has inadvertently pushed Punjab into a beleaguered state as it is hit by a double whammy of depleting ground water resources for itself and increased pollution crisis for both itself and the residents of IGP and central India in winter.

5.2 Multiple Cropping System

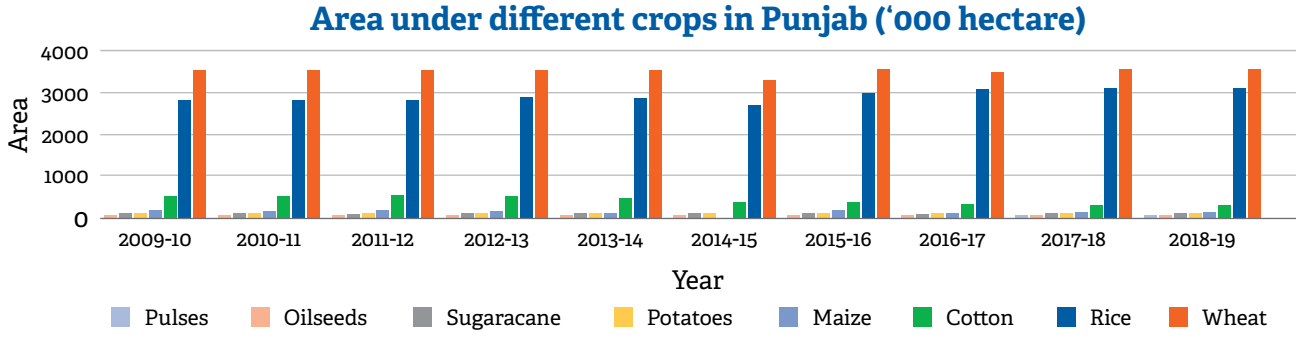
Conventionally, Punjab was a non-rice producing area which was more suitable for the production of wheat and maize but post green revolution, with higher level of mechanisation, better irrigation systems and availability of hybrid variety, rice and wheat monoculture was favoured. Surprisingly, the law 'Punjab Preservation of Subsoil Water Act (2009)' introduced to save the ground water resources by pushing the transplantation dates closer to monsoon, has unintentionally altered the landscape of the state. Before the act, the farmers used to grow multiple crops and could fall back on the other crops for sustenance if one variety failed. However, the pattern got changed largely after the act and the farmers were left with no choice but to continue with the rice and wheat monoculture. The government provisions of subsidized inputs such as water, electricity, fertilizers, assured market outputs and short variety of rice and wheat, also supported the changed cropping pattern (Chhatre, Devalkar and Seshadri, 2016).

The over-reliance on the paddy and wheat has led to various socio-economic as well as environmental concerns such as ground water depletion, decline in soil fertility, rise in water pollution due to over usage of chemicals and soil erosion (Kaur and Kaur, 2018). The programmes like ***'Crop diversification (2013)'*** which aim to diversify the land under paddy to other crops were introduced in the hope that the farmers will shift from the monoculture. Although, various provisions are provided under this scheme, most farmers have not found it remunerative to diversify from paddy cultivation to other principle crops. Despite the government's unswerving, but failed crop diversification efforts, rice and wheat still occupy much more land than the other crops as shown in figure 11. There are various reasons due to which the programme has proven to be ineffective.

- The programme talks about improving the soil health, arresting of ground water as well as enhancing farm income but doesn't lay down a clear pathway to achieve the same. In the absence of market linkages for alternate crops and assured existing market support for the paddy, the shift to other crops doesn't sound economically viable for the farmers.

- With the perpetually-booming incentives exclusively focusing on the paddy and wheat cultivation in place, it is obvious that the farmers will be drawn towards the practices which can earn them profit and higher net returns. The advantages that paddy and wheat yields in the short time as compared to the alternate crops points towards the unsuccessful translation of the policy objectives.
- Increasing stubble burning incidents and the associated pollution crisis also requires immediate attention. The advent of new and better rice varieties maturing within 125 days assure to put a cap on the burning problems. However, promoting the adoption of new rice varieties could have an inverse effect and it could impede the efforts done to achieve the desired outcomes of the crop diversification programme.
- The programme fails to give attention to issues related to the storage and transportation of the alternate crops. The focus should also be given to the infrastructural units such as establishment of the agro-processing units, cold storage facilities etc.
- The honorarium provided under the scheme is not enough to convince the farmers to sustain diversification. The incentives favouring the rice and wheat cultivation are far more than the incentives available for the alternate crops.
- While on one hand, the government is actively promoting crop diversification programme, on the other hand, the financial support provided is hindering diversification. This was reflected in the total funds allocated for crop diversification programme in Punjab. The year 2018-19 saw a huge decline of 97% in the allocation of funds. During 2013-14, this amount was announced to be around 24,950 (INR in lakhs) whereas the funds allotted during 2018-19 were just 706.66 (INR in lakhs). Since this directly implied lack of sufficient funds and adequate support from the government, this programme has received a cold shoulder from the farmers, especially small and marginal farmers who couldn't afford experimentation.
- Since this scheme has been promoted by the Central government, the release of funds is supported through Centre-State formula which means that if the centre pays 60%, the state must pay the remaining 40%. This could be attributed as the biggest impediment to the funds being inadequate because, most of the time, the state government didn't have enough money to cover even 40% of the share, and the Centre wouldn't release its share unless the state did (Chaba, 2020b).

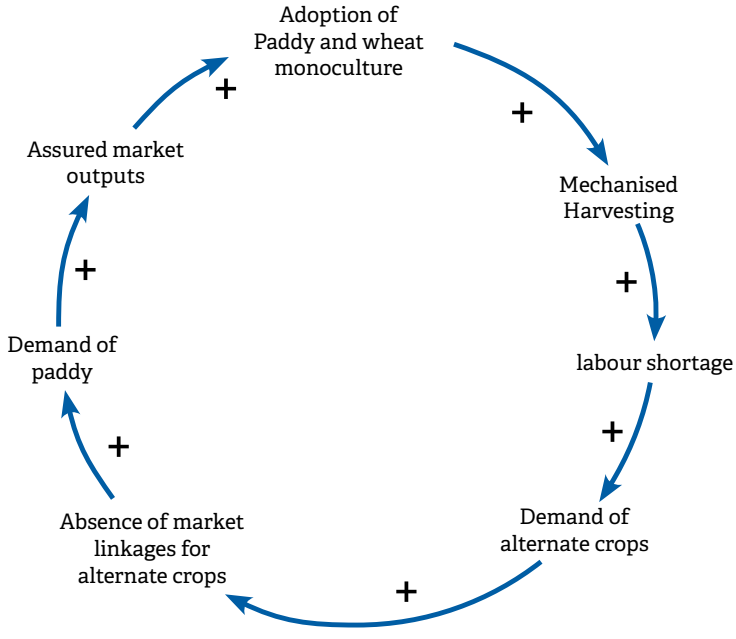
Figure 11: Crops produced in Punjab (2009-19)



(Data Source: Statistical Abstract Of Punjab 2018)

To promote sustainable agriculture in Punjab, the '***Draft Agriculture Policy***' was also formulated in 2013 by the state government, which envisages substantial crop diversification from paddy that the state has been growing since the sixties. The draft policy also aimed to address several of these issues by incentivizing farmers to increase the area under cultivation of alternate crops that are less water intensive. Nonetheless, the favourable market system and other incentives (as shown in figure 12) are still encouraging farmers to focus on the rice and wheat cultivation and this policy also was unable to create the desired impact.

Figure 12: Causal Dependence on paddy ("+" sign indicates positive relationship between two factors)



5.3 Market Dynamics and Problems for the small farmers

"What farmers want is a market — where the purchase of their products is guaranteed and they get an assured remunerative price" (Vasudeva, 2019)

The choices shaping the existing cropping system in Punjab have undergone significant changes over time. As discussed in the previous thematic area, the area and production under the paddy crop has escalated drastically since the inception of green revolution. Price, yield and subsidized access to groundwater were found to be significantly influencing the area under rice cultivation in Punjab. The relatively higher Minimum Support Price (MSP), better yield and increased profitability led to a large shift in the area under rice at the cost of other crops (Ali, Sidhu and Vattac, 2012). It is evident that the marketing infrastructure & services and government food grains management (regarding price and procurement) clearly favour cereal crops.

As a part of the national policy, the minimum support price for wheat and rice, the state's two major crops, and their procurement played a significant role in sustaining agricultural

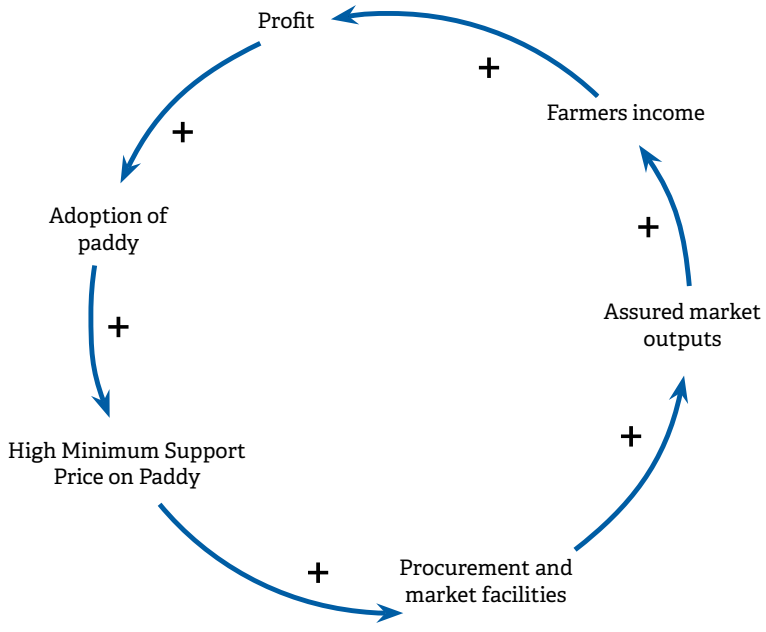
development, and thereby raising rural incomes. The responsive farmers who adopted new varieties and other technologies played a central role in the process of agricultural transformation. This paved the way to the development of a full-fledged market ecosystem for paddy and wheat cultivation augmented by the network of numerous farmers following the similar practices in a given neighbourhood (Maertens and Barrett, 2013). Compared to paddy/wheat, the supply chain of the alternate crops is not well developed and is subjected to various uncertainties and significant challenges at each stage (Chhatre, 2016). The study done by NITI Ayog also revealed that MSP of wheat and paddy has contributed towards the adoption of modern technologies such as improved seed varieties, better method of ploughing, expansion of market networks and increase in use of fertilizers and pesticides (NITI Ayog, 2016). With paddy and wheat giving better returns and the state lacking a successful procurement model for alternate crops, the farmers found it financially unviable to adopt other practices. Minimum Support Price could also be considered as the reason why the diversification is still not popular among the farmers' communities.

Over the years, Punjab agriculture has become highly resource centric. Over capitalization in agriculture coupled with stagnated yield rate, crop failures due to weather uncertainties, price instability have led to low level of income of farmers leading to indebtness (Kaur, 2018). It may be seen that in the case of paddy, the large farmers although less in number, possessed higher percentage of land and enjoy more benefits from MSP and other incentives given by the government (NITI Ayog, 2016). Owing to the landholding distribution, the largest amount of subsidies also goes to medium and large farmers despite the fact that the subsidies have been justified, in part, to benefit the smallholders (IFPRI, 2007). The capital intensive mode of production for cereal crops turned out to be non-viable for the small peasantry and hence they are being involuntarily manoeuvred towards shifting away from farming (Singh and Bhogal, 2014). The rate of increase in cultivation cost has been much faster than that of produce prices. Therefore, the increase in income from farming has not been sufficient to meet the domestic and farm expenditure which led a large number of farmers in a debt trap and forcing many to commit suicide. Lately, the cases of frauds from the commissioning agents are also burgeoning. With commissioning agents buying the produce from farmers and leasing money for harvesting wheat and paddy with higher interest rate, the small and marginal farmers tend to remain in debt. The strain of debt trap is so strong that of the total farmer suicides in Punjab from 2000-2008, majority were small and marginal farmers operating less than 2 ha of land (Singh and Bhogal, 2014).

Compared to paddy/wheat, the supply chain of the alternate crops is not well developed and is subjected to various uncertainties and significant challenges at each stage

Thus, food procurement policy in Punjab which to some extent is responsible for the change in cropping pattern, not only has an impact on the environment but also affects the livelihood of small and marginal farmers. The policy which worked as a catalyst of growth in Punjab's agriculture has become detrimental to the sustainability of its agriculture (Gulati et al. 2017).

Figure 13: Causal Diagram showing Market dynamics ("+" sign indicates positive relationship between two factors)



5.4 Straw Management

Various policies and programmes recognise the importance and potential of paddy straw. The state and national policies like ***'New and Renewable Energy sources (2012), Biomass utilization through co-firing in pulverized coal-fired boilers (2017), National policy on Biofuels (2018)'*** aim to utilise the residual straw on the ground and use it for power generation, generation of biofuels etc. These programmes have the potential to control crop residue burning and further reduce GHG emissions. However, various challenges are creating hindrances in the smooth utilisation of paddy straw.

Sheer dearth of storage facilities and increased transportation cost have placed an additional burden on the farmers

Collection of straw comes as the first step to start successful and attractive energy production system. However, the introduction of combine harvesters has made rice straw collection a major challenge and has created bottlenecks in the rice straw supply chain (Balingbing et al., 2020). It was realized that due to the limited man power and short window for straw collection, collection through balers seems to be the most feasible and economical option. Contrary to popular belief, the committee[12] constituted in 2018 to look into the issue of crop residue burning considers removal of paddy straw for ex-situ treatment to be not environmentally friendly as it would damage soil health in the long run. The committee is of the view that the Punjab government support should only be confined to those techniques that promote incorporation of paddy straw in the soil and should not encourage ex-situ treatments through subsidy and incentives. (MoAFW, 2019). This conflict in the opinion of the state and central government adds to the confusion among farmers to select the best alternative.

Sheer dearth of storage facilities is also becoming a huge issue. Since the supply outweighs the demand, it becomes very challenging to store all the stubble collected in one place. Moreover, the problems get intensified as stubble has to be collected within a specified amount of time. The storage of biomass material for a longer time affects the quality of the straw as the moisture content of the biomass can't be controlled leading to potential complications in the plant technologies (Rentizelas et al.,2009). The lack of storage facilities coupled with high storage cost and delay in procurements lead to post harvest wastage of wheat and rice and also affects the overall feasibility of the biomass enterprise. This highlights that the existing facilities are not capable enough to manage surplus supply of wheat and rice.

Additionally, the cost of transportation of biomass has placed additional burden on the farmers and the biomass power plants. Since the cost of transportation is in direct proportion to the distance from the power plant (MNRE, 2009), it becomes difficult and uneconomical for the power plants to procure stubble beyond 50 km and also for the farmers to bring biomass directly to the factory gate or to the nearest collection centre. It is important to note that due to the fact that the processing of material and transportation costs for value-adding solutions are still higher as compared to using the other more traditional options, the proposed alternate options are not all economically viable.

5.5 Experimentation with the in-situ machineries

In pursuance to Budget 2018, a Central Sector Scheme on ***'Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue'*** in the states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi' for the period from 2018-19 to 2019-20 was announced. The Government of India and the State governments of Punjab and Haryana rolled out the programme in right earnest in 2018 to position Crop Residue Management (CRM) machineries in the field before harvesting of paddy so that it was available to farmers for sowing of wheat. The scheme provided for higher level of subsidy to farmers for purchasing a bouquet of machineries for in-situ crop residue management. Subsidy of 50% of the cost of machines to individual farmers and 80% for Cooperative Societies, Farmers' Interest Groups and other collectives of farmers was provided to reduce their financial burden. The programme promotes the in-situ management of crop residue by retention and incorporation into the soil through the use of appropriate mechanization inputs which further help in restoring soil nutrients lost due to burning.

Currently, the farmers are not very happy with the experimentation and are facing various challenges associated with the machines. Table 3 clearly demonstrates that in 2019-20, the number of machines delivered fell to 14,625 from 28,609 in 2018-19.

[12]A committee was set up in 2018 by Ministry of Agriculture and Family Welfare to review the scheme "Promotion of agricultural mechanisation for in-situ management of crop residue in states of Punjab, Haryana, Uttar Pradesh and NCT of Delhi"

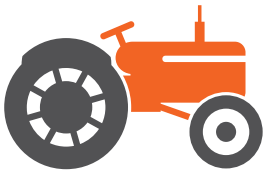
Table 3: Machines given under the subsidy scheme in Punjab

Machines given under the subsidy scheme in Punjab	Machines delievered 2018	Machines delievered 2019
Zero Till Drill	3438	4312
Paddy-straw chopper	1702	2910
Happy Seeder	9758	2936
RMB Plough	3033	2012
Mulcher	2793	1277
Super SMS	3634	528
Cutter-cum-spreader	NA	356
Rotary Slasher	475	157
Super Seeder	NA	112
Rotavator	3690	NA
Shrub Master	86	16
Total	28609	14625

(Source:MoAFW,2019 and Nirmal 2019)

The most popular machine which is being promoted by the government - Happy Seeder has also seen a drastic decline in the distribution because of the following reasons:

- In Punjab, majority of tractors available have the capacity of 30-40 horsepower which is not sufficient to pull the happy seeder machine as it requires tractors with the capacity of 65 horse power or more (Kumar, 2019). This setting places additional pressure on farmers to hire the tractors which can work the happy seeder machine. Even though there has been provision of subsidy on these machines by the government but still, these initiatives tend to remain unfeasible specially for the small and marginal farmers.
- Happy Seeder is not being considered as a worthwhile investment by the farmers as the machine is used for 20-25 days only and then is kept idle for the remaining year.
- Some Happy seeders machines are developing snags and lack of after sales support from the vendor left farmers with no other option but to resort to crop burning and traditional method of sowing.
- The other constraint farmers are facing is that Happy Seeder can't till land beyond 8 acres per day which causes delay in sowing of wheat.
- The gap in supply and demand chain for the in-situ machineries are also forcing farmers to burn the stubble. With limited number of suppliers, it is not possible to fulfil the huge demand of equipment in a limited period of time.



In 2019-20, the number of machines delivered fell to 14,625 from 28,609 in 2018-19.

- Due to the unavailability of the machines, the year 2019 witnessed a decline in the distribution of happy seeder, with only 2,936 being delivered compared to 9,758 in 2018.
- There was a common refrain from the farmers that the manufacturers had raised their costs, and had taken the lion's share of the subsidy.
- The farmers who operate the Happy Seeder are also not well trained due to which the technical problems in the machine arise and farmers are ill-equipped to handle the issues.
- For the small farmers, the cost of hiring the machine is steep. Moreover, there is no standardized rental rate. Farmers can end up paying anywhere between Rs 2,000 and Rs 6,000 per acre. Hence, it makes more sense to pay a fine of Rs 2,500 on paddy burning than hire a machine.

5.6 Labour Shortage

Earlier, sowing and harvesting was staggered to ensure there is no labour shortage. With the enactment of the '***Punjab Preservation of Subsoil Water Act'***, harvesting of rice and sowing of Rabi gets pushed to the months of October/November. This clashes with the festive season (Dushehra, Deepawali, and Chatth) in north India and impacts the availability of labour which is a critical input in management of rice straw and preparation of field for the next crop (Pandey et al., 2020).

The labourers in Punjab were mainly the migrant workers from the states of Uttar Pradesh and Bihar (Mukherjee, 2016). Post the green revolution, there has been an escalating shift from manual labour to mechanical labour as the removal of paddy straw is a labour-intensive process (Lohan et al., 2017, Mukherjee, 2016). Labour shortage may in turn explain the increase in crop residue burning as paddy harvesting is completely mechanised. Since more care is needed for transplantation of younger, thinner saplings, labour is also becoming more expensive. Another policy that could be related to the shift is the all-India implementation of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) (Reddy et al., 2014). The launch of MNREGA scheme assured the high income opportunities in the home towns of these seasonal workers (Mukherjee, 2016) and may have decreased the seasonal migration of workers to Punjab and led to labour shortages.

Due to the shortage of labour, programmes like crop diversification are less popular among the farmers. Additionally, the already widespread transition to mechanized harvesting in Punjab has diminished dependence on manual labour.

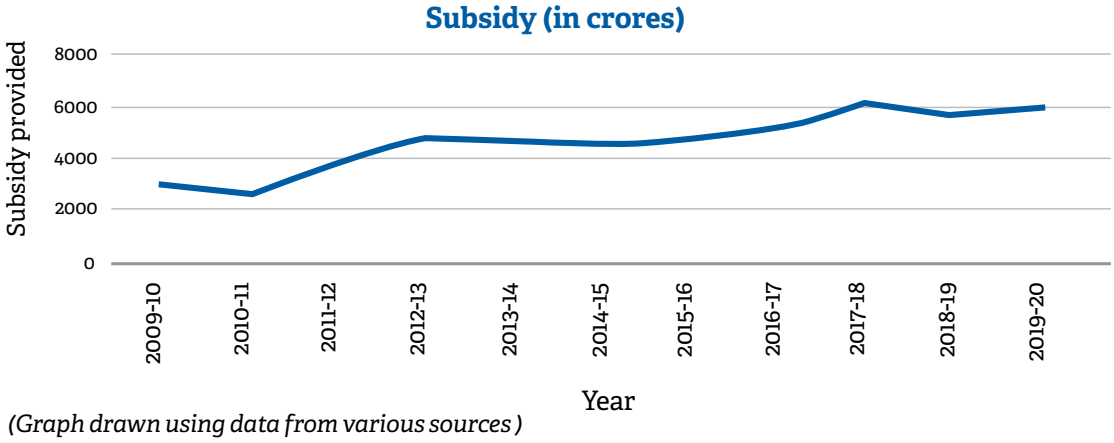
5.7 Subsidies

Agricultural subsidies are an integral part of farming in Punjab. However, it is interesting to note how the subsidies provided by the government to reduce the farmers burden have paradoxically led to the plethora of problems, including stubble burning intensification. As discussed in the previous thematic areas, the subsidies in one way or the other has helped in the continuation of the rice and wheat cultivation, thereby leading to environmental degradation and attacking the agricultural sustainability in the state.

The power subsidy has imperilled the ground water table and promoted unsustainable utilisation of the resources.

With respect to the groundwater exploitation, power subsidies have been perceived to be one of the major reason contributing to the issue. The power subsidy has imperilled the ground water table and promoted unsustainable utilisation of the resources. Punjab provides farmers with free and unmetered electricity, but an unmetered power supply makes it difficult to estimate agricultural power consumption or how much government subsidy is due (Gulati and Pahuja, 2015). The increasing cost of power subsidy in the recent decades (shown in figure 14) has put an unsustainable burden on state budgets and is the prime cause of bankruptcy of the state boards in India (Pandey, 2014). At present, Punjab is supplying free power to 14.16 lakh electricity-run tubewells of the agriculture sector which are getting power through 5,900 Agricultural Pumpset Feeders (APFs). The state government pays around Rs 6,000 crore power subsidy bill to Punjab State Power Corporation Limited (PSPCL) every year under its 'free power scheme' which is in place since 1997 (Chaba 2020c). The total power subsidy to the farm sector in 2019 is estimated at 9,674 crores (Bajwa, 2019). Singh (2012) pointed that if the electricity subsidy is withdrawn, the relative profitability, particularly of rice, which requires maximum number of irrigations would be quite adversely affected and would possibly promote diversification to other crops.

Figure 14: Power Subsidies provided by the Government in Punjab



(Graph drawn using data from various sources)

The supporting government policy on chemical fertilizers subsidy also provoked indiscriminate use of chemicals. This has not only led to deterioration of the environment but also degraded and contaminated the natural resources base, and is now posing a threat to human health. With farmers adopting water intensive crops, used fertilizers that required protective irrigation saw a massive surge. The consumption of fertilizers for paddy is 75-100 kg per acre as compared to the national average of 10 kg per acre (Mansharamani and Shrivastava, 2020). There is a subsidy of Rs 10,000 to 12,000 per metric tonne on urea (Chaba, 2020c). Punjab's average fertilizer usage of 380 kg/hectare is almost triple the national average of 131 kg/hectare. (Garg, 2017). This excessive use of fertilisers can result in inefficient use and high losses of Nitrogen to the environment, which can impact air and water quality.

It is clear that costs of these subsidies now outweigh its benefits. For both major cereal crops (rice and wheat), Punjab seems to be reaching a situation where decline in fertilizer response ratio, stagnation in yield level, and declining soil fertility has already set in (IFPRI, 2007). If the current rate of environmental abuse continues, then agricultural distress in the state is inevitable.

Relationship between the challenges and stubble burning

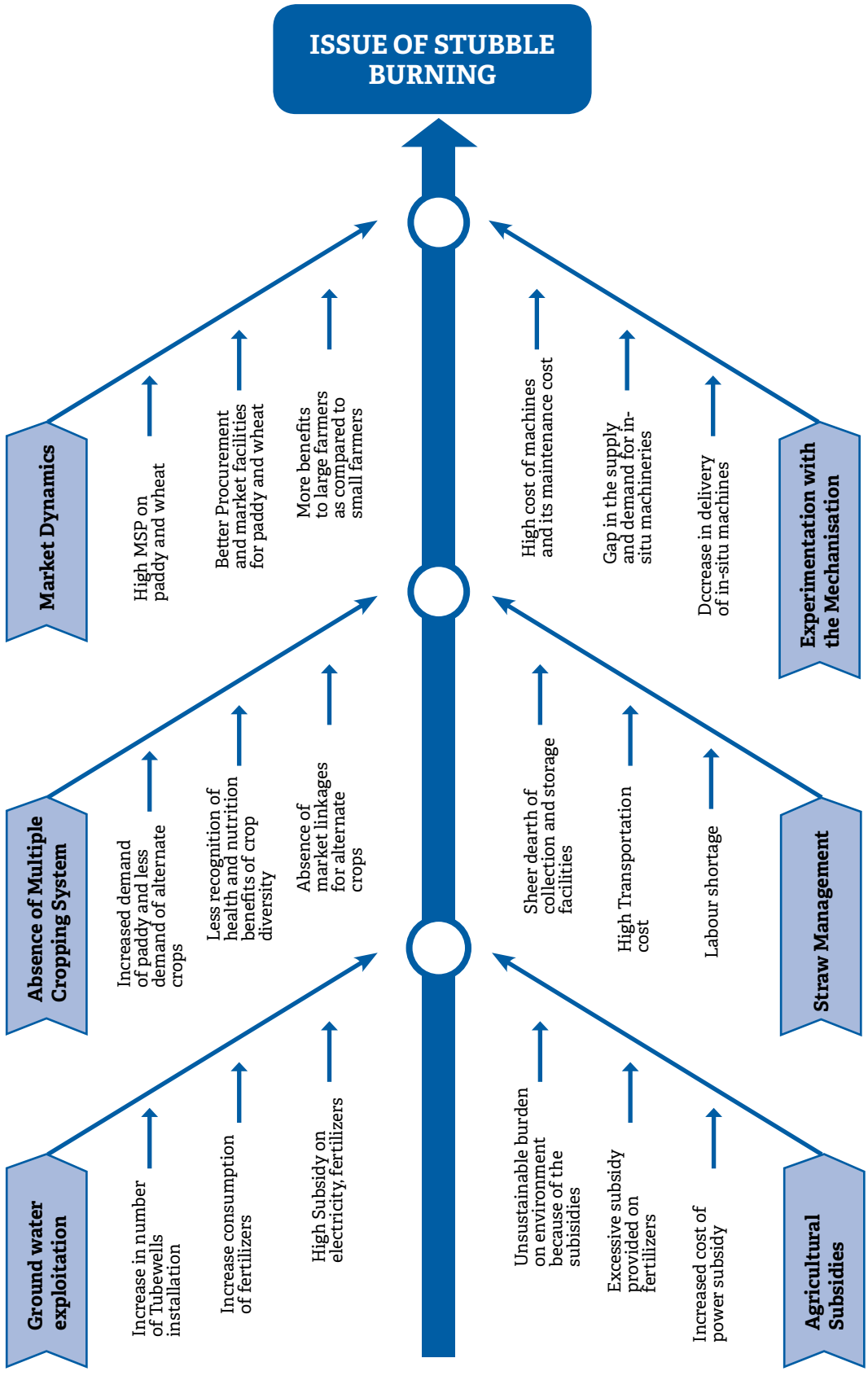
Despite the prohibition on crop residue burning by the State Governments of Punjab, Haryana and Uttar Pradesh under the Section 19(5) of the Air Act 1981, the practice of crop stubble burning is still prevalent and rampant in Indo-Gangetic Plains and continues to be a threat to human health and wellbeing (Vidhi Centre for Legal Policy, 2017; Abdurrahman et al., 2020). Many policies have been rolled out over the years to address the issue of stubble burning. But the major policy to address the issue was formulated in 2014. The ultimate goal of ***'National Policy for Management of Crop residues (2014)'*** was to prevent environmental degradation and loss of soil nutrients and minerals by promotion of in-situ management (incorporation in soil, mulching, baling/binding for use as domestic/industrial fuel, fodder) of crop residue (MOA, 2014). In 2015, NGT provided various directions to implement the policy but the legal orders were not able to create the desired effect as the stubble burning incidents rose rapidly right after the NGT directions.

The ***'National Clean Air Programme (NCAP)'***, which was launched in 2019 to address the national crisis of air pollution, also does not provide a clear roadmap for dealing with the fundamental causes of stubble burning. Thus far, the government has been unable to put a cap to the problem despite enacting different pollution legislations and regulatory mechanisms.

It is evident from the analysis that the agricultural distress in Punjab is undoubtedly a bigger web and stubble burning is nothing but one thread of this web. The viable solutions can only be found after acknowledging the complexity of this web. It is myopic to discuss and diagnose stubble burning in isolation. Therefore, an attempt has been made to represent the gaps, concerns and challenges identified from the analysis and with reference to the secondary literature review.

The diagram presented in Figure 15 is called a "fishbone" diagram or a cause and effect diagram, which helps in identifying possible causes of a problem. The problem or effect is displayed at the head or mouth of the fish and what leading to the effect are the causes the problem. The figure clearly demonstrates that not one but multiple factors like high dependence on agricultural subsidies, exploitation of ground water, prevalent market support for rice and wheat, absence of multiple cropping system, experimentation with the machineries and inadequate straw management facilities have exacerbated the issue of stubble burning in Punjab.

Figure 15: Causes and Effects leading to the issue of Stubble burning



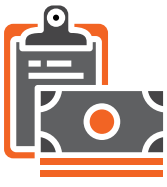
CHAPTER - 6

Recommendations

6.1 Establishing Review Process

For the past decade, the Centre and State government have been introducing many different measures in the form of policies, programmes and have also been subjected to court orders to control stubble burning. New policies and measures are introduced almost every year without any evaluation on existing policies to understand the gaps. This is one of the primary reasons for multiple agriculture issues arising in Punjab. Once a policy is proposed with targets, they should be subjected to external evaluation at the end of the program or mid-way, or have some form of legal framework mandated to follow its evaluation. The lack of a review and evaluation process existing in the system right now has led to many failures with respect to policies proposed for sustainable agriculture interventions in Punjab. The last decade has seen many new policies to improve agricultural practices and stop the practice of stubble burning, yet no clear accomplishment of past policies or interim or end-line evaluations makes it difficult to understand which programme is actually helping. If the existing and future programmes and policies are not subjected to external evaluation or judicious review, the growing issues on agriculture and stubble burning are unlikely to improve. Instead of penalizing and taking legal actions against the farmers, complete monitoring, learning and evaluation of the issues at hand needs to be taken by the policy making bodies.

6.2 Strengthening Financial deliveries & infrastructure



The costs through subsidies have skyrocketed and unsustainable use of these subsidies has only aggravated the agricultural crisis in Punjab.

The ill-effects of stubble burning on soil fertility, and sustainable agriculture practices has been disseminated widely by public and private institutions in Punjab. But these sustainable practices and options are economically not viable to small and marginal farmers. The issue of financial aid has been raised by farmer organizations, which has led to farmers defying the ban on stubble burning unless paid compensation (Times of India, 2019). The approach of being dependent on subsidy-driven agriculture systems has not been sustainable for long-term solutions (Pandey, 2020). As discussed in the previous chapter, the costs through subsidies have skyrocketed and unsustainable use of these subsidies has only aggravated the agricultural crisis in Punjab. To address the multiple thematic issues arising from ineffective policies, long-term solutions to improve infrastructure need to be developed.

6.3 Revisiting Market Dynamics

Government agencies face difficulties in storage and maintenance of food grains procured. With this inadequate infrastructure, expansion in procurement is also not possible. To improve the MSP system and

encourage farmers to diversify from cereal crop, 'deficiency payments' can be backed by the governments. Under Price Deficiency Payment, farmers are proposed to be compensated for the difference between the government-announced MSPs for select crops and their actual market prices. If the market prices fall below MSP, 50 per cent of the difference between price and MSP will be paid to a farmer under this system. Many studies and reports suggests that deficiency payments can be an incentive, if the government starts strengthening the infrastructure and procures produce through a good network of channels. MSP needs to be backed by either effective procurement or a system of deficiency payments; only then can the benefit of support prices reach farmers and be able to provide the price security that it intends to ensure (Aditya et al., 2017; Chhatre et al., 2016).

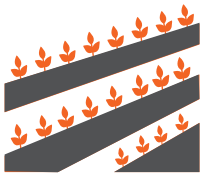
If the right mix of crops is appropriately chosen, farmers can improve their returns and move away from cereal crop dependency. But the governments need to strengthen their farm-to-table supply chain infrastructure for alternate crops (Sandhu, 2019). The positive growth of an agriculture sector is not only dependent on advancement of technology but also on the backbone of strong agricultural infrastructure and good supply chains. Adequate infrastructural units such as establishment of the agro-processing units and cold storage facilities help in raising production and lowering the unit cost of activities. But these facilities are very poor in the state right now. Without a strong infrastructure, a change in methods or behaviour is difficult to achieve (Singh & Kour, 2014). The lack of infrastructure, to support change, exposes farmers to considerable risk, making it cumbersome to move away from the existing cereal crop rotation cycle. To address this risk, public policy interventions should be provided in the form of well-designed crop insurance, skill development to handle vegetable crops/non-cereal crops, combined with supply chain innovations (Sandhu, 2019).

6.4 Facilitating Sustainable Management Practices for Crop Residue

The State Action Plan on Climate Change of Punjab (2014) points at the intensification of rice cultivation as the biggest challenge to its agricultural sector. It cautions resource depletion leading to water shortages, soil fertility depletion and livelihood crisis owing to rising future climate impacts (Rattani et al., 2019). This necessitates urgency for adoption of sustainable management practices which helps improve and sustain agriculture and farmer's practices on the whole. Given the resources needed in the form of labour, water, machinery and financial constraints hindering the process of crop residue management in Punjab, other simple, cost-effective measures which will be practically doable and welcomed by the farmers have to be identified and encouraged.

6.4.1 Composting

Composting is a natural process of rotting or decomposition of organic matter by micro-organisms (Misra, et al., 2003). Composting is hardly a new concept for managing domestic waste, but is surely a new growing prospect in the agriculture sector (Bhuvaneshwari et al., 2019). Paddy residues are high in organic content, which makes them ideal for compost similar to manure and food waste. Using composting to remove and manage stubble can provide extra nutrition to soil by managing and incorporating it back into the soil, thereby achieving a sustainable cycle to move forward. (Singh & Prabha, 2017) experiment on bio-composting performed in UP shows a significant increase in agronomic properties of



The crop diversification recommendation should be based on socio-economic and long-term sustainability.

the rice and wheat crops. As a rich source of carbon and organic matter, compost amended soil increases yield, poses resistance to external factors such as droughts, disease and toxicity. With increasing climate impacts aggravating agriculture issues in this region, composting should be taken into account. The challenge associated with domestic composting versus agriculture composting is economical and not technical. The end product of domestic/municipal composting does not always secure a sturdy market. This is completely not applicable to agricultural composting, as the on-site compost can be easily fed back into the same agricultural lands (Misra, et al., 2003; Shilev et al 2007; Hettiarachchi and Ardakanian, 2016)

A new 'Pusa decomposer' has also been launched to effectively and quickly manage stubble. The product was developed by the Indian Agriculture Research Institute (IARI) in New Delhi as a solution to the problem of stubble burning. The solution when applied on the standing stubble, decomposes it in 25 days as compared to other methods which take 3 months. After successful pilot research, the IARI has tied up with many companies to ramp up the production of decomposer for mass consumption by next year. How effective this initiative will be on mass consumption is something to look forward to.

6.4.2 Crop Diversification

Crop diversification is being promoted in Punjab since 2013. It provides an opportunity to utilize land and water resources according to varying climate patterns, shifting monsoon and volatile agricultural markets. The COVID-19 pandemic has hit the small and marginal farmers as well as farm labourers. The worst impact has been the breakdown of food supply chain. For farmers who are stymied by breakdown in supply chain, shortage of labour and other factors, this is an opportunity to experiment with new crops other than cereals. With the states trying to recover their activities following the pandemic, there is now a lot of support from the government to move away from labour-intensive and water-intensive crops (Padhee & Pingali, 2020; Khanna, 2020).

Moreover, diversification from paddy crop is the need of the hour to move away from ground water depletion and its health impacts from air pollution as a consequence of stubble burning. The crop diversification recommendation should be based on socio-economic and long-term sustainability. For a farm-level, the approach should align with environmental, social, and economical factors. Contextualizing the crop based on a particular area's soil, water and fertility factors should determine the way forward to reap the benefits of farm level heterogeneity. Assisting small and marginal farmers to phase out from one-crop fits all to diversification based on favourable factors needs to be studied and promoted by the governments. At community level, the same approach of learning the conditions and factors to establish a vibrant cropping system that will yield results needs to be considered. The monoculture system of favouring cereal crops needs to be reduced considering the depleting water resources and a system chosen which will enhance a sustainable agricultural productivity (Sandhu, 2019).

Crop Diversification is one of the possible way forward in reducing stubble burning but the process to make it happen won't come easy. Awareness building amongst farmers of

these programs and options needs to be conducted. The facilitation of interactive sessions where the farmers and researchers learn from each other should be introduced. Ground-level extension work with solid yield outcomes need to be shown to change the mindset and conditioned behavior. The need of the hour is to diversify and explore the potential of other crops, especially pulses and horticulture. Alternatives to cereal crops have to be either at par or above in terms of price and profits. Policy intervention combined with a supporting market with good price for all crops is the key. The right mix of crops can also have beneficial outcomes on socio-economy of farmers and reducing water intensity of cropping (Aditya et al., 2017; Chattre et al., 2016; Sandhu, 2019). Crop diversification also has advantages for enhancing the nutrient diversity of diets in these communities.

The research on climate change adaptation needs to not only focus on understanding the linkages between the various factors but also on finding solutions particularly from policy output perspectives.

6.5 Encouraging more Research Opportunities

Many new national and international research findings and methods have come out or have been adapted in Punjab to support the agricultural sector. Strengthening the local research institutions is required to conduct research to identify and adapt to depleting labour, irrigation and soil conditions. The soil type of Punjab varies across the state, so state recommendation on favouring plants and crop based on its yield capacity needs to be assessed. The over-dependence on cereal crop cultivation has taken a toll on soil micronutrients (Kaur and Sharma, 2017). The cereal crop dependence has also led to higher doses of chemical fertilizers and pesticides, with lesser use of farm compost and non-recycling of crop residue leaving the soil deficient of nutrients (Shukla et al., 2014). This presents an opportunity for research community to hypothesize, understand and recommend solutions to farmers on how to move away from a monocycle cereal system to sustainable crop cycle which factors in the site situation (soil quality, water resources, labour and planting dates) and also yields good results economically. The research on climate change adaptation needs to not only focus on understanding the linkages between the various factors but also on finding solutions particularly from policy output perspectives. In addition, research aimed at understanding the various interventions and interlinkages should also be encouraged to facilitate in filling up the gap between science, policy and practice.

6.6 Promoting Farmers Outreach and Education

One of the studies from Punjab Agricultural University to understand the adoption level of recommended agricultural practices found that majority of farmers are well equipped with knowledge of good farming practices and aware of issues posing threat to sustainable growth of agriculture in the state. But the persistence of monoculture cropping pattern is emerging mainly on account of behavioural challenges as well as barriers to implementation and uptake of newer programs and policies. The farmers are growing non-recommended crops and varieties in their zones, over utilizing ground water because of power subsidy, over-fertilizing, experimenting with monoculture cropping pattern because of market dynamics, and burning stubble to prepare the fields for the next crop. All these are failures of outreach

department in educating the farmers on best practices. This non-compliance with state recommendation is found even among farmers with good experience and educational level. This general lack of awareness among farmers and extension advisors on management practices contributes to the most of crop production failures and other issues (Tollefson and Wahab, 1994; Kuehne et al., 2017; Pannell et al., 2016; Alston et al., 1995). There is a need for a new integrated approach that would bring farmers, extension specialists and researchers together. If the farmers learning from other stakeholders are minimum, approaches such as extension facilitation between farmers could be conducted to let them learn from one another through their own peers. A collaborative learning extension programme where advanced farmers, extensions workers and other local farmers can learn best practices could help in changing behavioural patterns, which is perhaps the most pertinent issue in combating stubble burning. Such adoption programmes are already in practice in other parts of India, and have seen benefits among farmers (Lacy et al., 2000). The State government has already assigned nodal officers to oversee the compensation exercise, to prevent stubble-burning, and to increase awareness of alternate technologies. But, these measures have not been fruitful. The outreach department needs to diversify their approach based on the best working practice that is available in the particular state. The state agriculture department needs to understand the local site situation and available options as in machines, etc. and then spread awareness on their pros and cons for these options. This step by step approach may help eliminate confusion and ease the adoption of new technologies by removing socio-economic barriers and other behavioural impediments. This may help farmers move away from the age old practice of stubble burning (Reddy, 2020).

6.7 Placing more emphasis on Public Health

Media plays a critical role in bringing health issues into mainstream discussions. The smog engulfing the IGP in the months of October-November from stubble burning has become a repetitive annual event. The issue and its associated health impacts receive national attention on media. Various science-communication happens around this issue of stubble burning to mass media. However, the impacts of burning on the health of the farmers gets often overlooked which should be emphasized. Researchers would need a proper database of health and air quality from Punjab to create a strong case for the health effects of stubble burning on the farmer's population. The general public and media persons should be able to access this database for health advisories.

Most of the information on stubble burning and related health impacts is communicated through national media, while there is a need to strengthen and encourage participation from regional as well as local vernacular media. For this, capacity building of local journalists and reporters working on this subject needs to be upgraded. This will also help promote awareness building amongst all sections of society besides encouraging appropriate allocation of resources, where most required. With a stronger health evidence and advisories, the perspective of health in this issue can be developed among farming community practising stubble burning.

6.8 Strengthening Multi-sectoral Thinking and Action

As explained in the thematic section, the issue of stubble burning was neither built over a short period of time nor are the farmers and agricultural sector to be blamed for this. The practice of stubble burning has economic, environmental, agricultural, social and transboundary public health implications. Farmers need to be involved in future consultative processes, otherwise the issue of transboundary transport of air pollutants from stubble burning will continue and evolve into a bigger health issue. Effective communication between farmers, state, central, academic and other policy making bodies should continue with urgency to control this. A functioning effective committee which oversees this issue and keep stocks of programmes and policies to end the practice of stubble burning needs to be in place. The committee should have policymakers from different states, central advisory bodies, and experts from air pollution control, agriculture sector, meteorology, procurement and public health, which is central to this topic of transboundary air pollution. The lack of collaboration among various stakeholders involved in the control of stubble burning issue contributes to non-attainment of success in the fight against air pollution. There is a need to facilitate communication, cooperation, and partnership among policymakers, leaders and decision-makers along with representatives of the farming communities themselves.

Farmers need to be involved in future consultative process otherwise the issue of transboundary transport of air pollutants from stubble burning will continue and evolve into a bigger health issue

Stubble burning is an issue which goes beyond the agriculture sector. The end product of cereal crops (stubble) should be viewed as a resourceful biomass and multi-sectoral thinking and strategy needs

to be proposed to the farming community on how to resourcefully use this end product. The government and other stakeholders have already found many innovative ways in which this stubble can be used rather than be burned on the field. Deep diving into the issues mentioned in the previous section to understand and develop solutions to bridge these gaps can go a long way. Waste material which can be resourceful to other sectors (soil, food, energy etc.) gets wasted because of non-contextualizing or improper understanding of local conditions. The issue at hand cannot be solved unless various stakeholders and policymakers bring in a higher-level of integration that goes beyond the disciplinary boundaries (Hettiarachchi and Ardakanian, 2016; Bhuvaneshwari et al., 2019)

Way Forward

The main idea behind this exercise was to identify and establish the critical gaps existing in the system which fosters the prevalence of crop residue burning. As a follow up of this study, we intend to extend this investigation by going on the ground to understand the farmers' perspective on the issue and to explore if they have received the desired benefits from the policies implemented.

CHAPTER - 7
Conclusion

Stubble burning is an immensely complex problem which not only brings at the forefront the issue of residue management, but also reflects upon the agrarian crisis that the region has been facing and subjected to. The onus and blame is often pointed towards the farming community in Punjab. However, the real reasons have socio-economic roots and policy implementation failures. There are many takeaways from this policy analysis report and the policymakers need to think about long-term, self-sustaining mechanisms which can run independent of subsidies. There is also a need to dedicate attention to the role and sustainability of the existing subsidised inputs, if the issue of agriculture distress is at all to be comprehensively addressed. The stakeholders need to be empowered with assistance, and knowledge of tools available to them from the state.

The fact should never be ignored that the issue of stubble burning is linked to livelihood, health and safety of the farmers.

Avoiding thinking from the stubble burning after-effects point of view and taking decisions from the root cause is critical. Emphasis on health impacts outreach needs to be increased. With the world recovering from a pandemic, the importance of health and well-being of mankind has once again come to the limelight. Government advocacies and outreach on health impacts to the people in the state and the impacts felt by people in IGP & central India need to be emphasized. For changes in behavioural practice, awareness on larger public health implication caused by stubble burning also needs to be raised in the farming community. A deeper solution lies in respecting the concerns and constraints faced by the farmers. There is a fierce urgency to bring together stakeholders from other sectors like agriculture, public health, environment advisory bodies, procurement and so on, to plan, learn and evaluate the progress of policies to completely eliminate the issue at hand. The fact should never be ignored that this issue is linked to livelihood, health and safety of the farmers.

References

Abdurrahman, M., Chaki, S. and Saini, G. (2020). Stubble burning: Effects on health & environment, regulations and management practices, Environmental Advances, 100011. https://doi.org/10.1016/j.envadv.2020.100011

Aditya, K. S., Subash, S. P., Praveen, K. V., Nithyashree, M. L., Bhuvana, N., & Sharma, A. (2017). Awareness about minimum support price and its impact on diversification decision of farmers in India. Asia & the Pacific Policy Studies, 4(3), 514-526.

Ali, S., Sidhu, R. S. and Vattac K. (2012). Effectiveness of Minimum Support Price Policy for Paddy in India with a Case Study of Punjab. Agricultural Economics Research Review Vol. 25(No.2) pp 231-242

Allen, A., Voiland, A. (2017). NASA Earth Observatory, Haze Blankets Northern India. Available online: https://earthobservatory.nasa.gov/images/91240/haze-blankets-northern-india

Alston, J.M., Norton, G.W. and Pardey, P.G., (1995). Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornell University Press.

Antil, R. S., & Raj, D. (2012). Chemical and microbiological parameters for the characterization of maturity of composts made from farm and agro-industrial wastes. Archives of Agronomy and Soil Science, 58(8), 833-845.

Bajwa, H. (2019, Dec 29). Punjab government mulls ending power subsidy to big farmers. The New Indian Express. Retrieved from: https://www.newindianexpress.com/nation/2019/dec/29/punjab-government-mulls-ending-power-subsidy-to-big-farmers-2082424.html

Balingbing, C., Hung, N.V., Nghi, N.T., Hieu, N.V., Roxas, A.P., Tado, C.J., Bautista, E., Gummert, M. (2020). Mechanized Collection and Densification of Rice Straw Sustainable Rice Straw Management Springer, Cham. https://doi.org/10.1007/978-3-030-32373-8_2

Bhuvaneshwari, S., Hettiarachchi, H., & Meegoda, J. N. (2019). Crop residue burning in India: Policy challenges and potential solutions. International journal of environmental research and public health, 16(5), 832.

Birthal, P. S., Joshi, P. K., Negi, D. S. and Agarwal, S., (2014). Changing Sources of Growth in Indian Agriculture: Implications for Regional Priorities for Accelerating Agricultural Growth.

Business Standard (2021, February 2021) Punjab's stubble burning incidents up 44.5% in 2020: Centre tells SC. Retrieved from: https://www.business-standard.com/article/current-affairs/punjab-s-stubble-burning-incidents-up-44-5-in-2020-centre-tells-sc-121020300934_1.html

Business Standard. (2018, June 11). BioCNG to be manufactured from paddy straw: Minister. Retrieved from: https://www.business-standard.com/article/pti-stories/biocng-to-be-manufactured-from-paddy-straw-minister-118061100980_1.html

CACP (2015). Price Policy for Kharif Crops : The Marketing Season 2015-16. Retrieved from https://cacp.dacnet.nic.in/ViewReports.aspx?Input=2&PageId=39&KeyId=547

CEA (2018). Technical specification for agro residue based bio-mass pallets (non- torrefied/ torrefied) for co- firing in coal based thermal power plants. Retrieved from https://cea.nic.in/wp-content/uploads/2020/04/final_spec_biomass.pdf

CEA (2019). All India installed capacity of power Stations. Available online: http://www.cea.nic.in/reports/monthly/installedcapacity/2019/installed_capacity-03.pdf

CGWB (2017) Ground Water Year Book of Punjab and Chandigarh (UT) 2017-2018. Retrieved from: http://cgwb.gov.in/Regions/NWR/Reports/2017-18%20PUNJAB%20GWYB.pdf

CGWB (2019) Ground Water Year Book of Punjab and Chandigarh (UT) 2018-2019. Retrieved from http://cgwb.gov.in/Regions/NWR/Reports/2018-19%20PUNJAB%20GWYB.pdf

Chaba, A. (2019, November 28). Punjab groundwater crisis: What it will take to move from paddy to maize [Indian Express]. Retrieved from https://indianexpress.com/article/explained/punjab-groundwater-crisis-what-it-will-take-to-move-from-paddy-to-maize-6140351/

Chaba, A. (2020a, September 13). How Punjab plans to spin paddy stubble into gold? [Indian Express]. Retrieved from: https://indianexpress.com/article/explained/biomass-power-plants-bio-cng-bioethanol-how-peda-plans-to-spin-paddy-stubble-into-gold-6590158/

Chaba, A. (2020b, November 03). Centre should support crop diversification in Punjab like it did during Green Revolution: Experts [Indian Express]. Retrieved from: https://indianexpress.com/article/cities/chandigarh/centre-should-support-crop-diversification-punjab-experts-6919312/

Chaba, A. (2020c, February 05). Punjab set to suffer Rs 900 crore loss due to Centre slashing fertiliser subsidy. [Indian Express]. Retrieved from: https://indianexpress.com/article/india/punjab-set-to-suffer-rs-900-crore-loss-due-to-centre-slashing-fertiliser-subsidy/

Chauhan, A., & Singh, R. P. (2017, July). Poor air quality and dense haze/smog during 2016 in the Indo-Gangetic plains associated with the crop residue burning and Diwali festival. In 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 6048-6051). IEEE.

Chhatre, A., Devalkar, S. & Seshadri, S. (2016). Crop diversification and risk management in Indian agriculture. Decision 43, 167–179 https://doi.org/10.1007/s40622-016-0129-1

Datta, A., Emmanuel, M.A., Ram, N.K. and Dhingra, S. (2020). Crop Residue Management: Solution To Achieve Better Air Quality. New Delhi: TERI. Available at : https://www.teriin.org/sites/default/files/2020-01/crop-residue-management.pdf

De Leeuw, F. A. (2002). A set of emission indicators for long-range transboundary air pollution. Environmental Science & Policy, 5(2), 135-145.

Diprpunjab. (2018) Punjab govt signs MoU with IOC for setting up Bio-gas & Bio-CNG plants. Retrieved from:http://diprpunjab.gov.in/?q=content/punjab-govt-signs-mou-ioc-setting-bio-gas-bio-cng-plants

Draxler, R. R., & Rolph, G. D. (2003). HYSPLIT (HYbrid Single- Particle Lagrangian Integrated Trajectory). NOAA Air Resources Laboratory, Silver Spring, MD. Model access via NOAA ARL READY Website.

MOF (2019). Economic Survey (2019-20). Sustainable Development, Energy and Climate Change. Available at http://mofapp.nic.in:8080/economicsurvey/

Elferink, M., & Schierhorn, F. (2016). Global Demand for Food is Rising. Can we meet it. Harvard Business Review, 7(04), 2016.

Gadde, B., Bonnet, S., Menke, C., & Garivait, S. (2009). Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines. Environmental Pollution, 157(5), 1554-1558.

Garg, L. (2017, August 28). Beyond the Green Fields of Punjab Lies a Mounting Agrarian Distress [The Wire] Retrieved from: https://thewire.in/agriculture/beyond-the-green-fields-of-punjab-lies-a-mounting-agrarian-distress

Grover, D. K., Singh, J. M., Kaur, A., & Kumar, S. (2017). State Agricultural Profile –Punjab. Agro-Economic Research Centre Department of Economics and Sociology Punjab Agricultural University Ludhiana.

Gulati, A., Roy, R. and Hussain, S. (2017). Getting Punjab Agriculture Back on High Growth Path: Sources, Drivers and Policy Lessons. Retrieved from https://icrier.org/pdf/Punjab%20Agriculture%20Report.pdf

Gulati, M. and Pahuja, S. (2015). Direct Delivery of Power Subsidy to Agriculture in India. Retrieved from: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/SE4All-%20Direct%20Delivery%20of%20Power%20Subsidy%20to%20Agriculture%20in%20India_Optimized.pdf

Gupta, P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C., ... & Garg, S. C. (2004). Residue burning in rice–wheat cropping system: Causes and implications. Current science, 1713-1717.

Gupta, R. (2012) Causes of Emissions from Agricultural Residue Burning in North-West India: Evaluation of a Technology Policy Response. SANDEE Working Paper No.66-12

Health Effects Institute. (2020). State of Global Air 2020. Special Report. Available at https://www.stateofglobalair.org/

Hettiarachchi, H., and Ardakanian, R. (2016). Managing water, soil, and waste in the context of global change. In Environmental resource management and the nexus approach (pp. 1-7). Springer, Cham.

IFPRI (2007). Withering Punjab Agriculture: Can It Regain Its Leadership? Retrieved from https://pdf.usaid.gov/pdf_docs/Pnadk223.pdf

Jain, N., Bhatia, A., & Pathak, H. (2014). Emission of air pollutants from crop residue burning in India. Aerosol and Air Quality Research, 14(1), 422-430.

Jeff, S., Prasad, M. and Agamuthu. (2017). International Solid Waste Association, Asia Waste Management Outlook: Summary for Decision-Makers. Asia Waste Management Outlook.

Jiang, H., Frie, A. L., Lavi, A., Chen, J. Y., Zhang, H., Bahreini, R., & Lin, Y. H. (2019). Brown carbon formation from night time chemistry of unsaturated heterocyclic volatile organic compounds. Environmental Science & Technology Letters, 6(3), 184-190.

Jitendra, Venkatesh, S., Kukreti, I., Pandey, K., Niyogi, D.G., Mukerjee, P. (2017, May 31) India's Burning Issues of Crop Burning Takes a New Turn. [Down to Earth]. Retrieved from: https://www.downtoearth.org.in/coverage/river-of-fire-57924

Jitendra (2020, January 31). Economic Survey 2019-20: Agriculture growth stagnant in last 6 years. DownToEarth. Retrieved from: https://www.downtoearth.org.in/news/agriculture/economic-survey-2019-20-agriculture-growth-stagnant-in-last-6-years-69076.

Kaur, A., & Sharma, M. (2017). Adoption Level of Recommended Agricultural Practices by Punjab Farmers. Journal of Krishi Vigyan, 6(1), 1-9.

Kaur, G. (2018). Crises of Agriculture in Punjab: Setbacks to Diversification and Role of State International Journal of Advanced Scientific Research and Management, Volume 3 Issue 8; 2455-6378

Kaur, M. and Kaur, P. (2018). Diversification and Specialisation of Punjab in Growing Various Crops: A District Level Approach. Economic Affairs, Vol. 63, No. 4, pp. 963-972, DOI: 10.30954/0424-2513.4.2018.20

Khanna, R. (2020, March 27). COVID 19: Punjab's rural economy takes a big hit. [Down To Earth] .Retrieved from: https://www.downtoearth.org.in/news/agriculture/covid-19-punjab-s-rural-economy-takes-a-big-hit-70045)

Kuehne, G., Llewellyn, R., Pannell, D.J., Wilkinson, R., Dolling, P., Ouzman, J. and Ewing, M., 2017. Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. Agricultural Systems, 156, pp.115-125.

Kumar, A. (2019, Nov 06). Why Farmers Are Forced to Choose Stubble Burning Over Happy Seeder. The Quint. Retrieved from: https://www.thequint.com/news/india/air-pollution-in-delhi-ncr-stubble-burning-in-punjab

Kumar, P., Kumar, S., & Joshi, L. (2015). The extent and management of crop stubble. In Socioeconomic and Environmental Implications of Agricultural Residue Burning (pp. 13-34). Springer, New Delhi.

Lacy, J., Clampett, W. and Nagy, J., 2000. Bridging the rice yield gap in Australia. Bridging the Rice Yield Gap in the Asia-Pacific Region, p.47.

Lal, R. (1997). Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO2-enrichment. Soil and tillage research, 43(1-2), 81-107.

Lohan, S.K., Jat, H.K., Kumar, A.K., Sidhu, H.S., Choudhary, M., Peter, J., Sharma, P.C. and Jat, M.L. (2017). Burning issues of paddy residue management in north-west states of India Renewable and Sustainable Energy Reviews 81 (2018) 693–706

Maertens A and Barrett CB. (2013) Measuring social networks' effects on agricultural technology adoption. Am J Agric

Mahadevan, R. (2003). Productivity growth in Indian agriculture: the role of globalization and economic reform. Asia Pacific Development Journal, 10(2), 57-72.

Mansharamani ,A and Shrivastava, A. (2020, March 02). Hazards of using fertilisers in Punjab. [Down to Earth]. Retrieved from: https://www.downtoearth.org.in/blog/agriculture/hazards-of-using-fertilisers-in-punjab-69548

MNRE (2009). Final Report on Review of Performance of the Grid- connected Biomass-based Power Plants Installed in India. Retrieved from: https://biomasspower.gov.in/document/Reports/Report%20on%20review%20of%20performance%20of%20the%20grid%20connected%20biomass%20based%20power%20plants%20installed%20in%20India.pdf

Misra, R. V., Roy, R. N., & Hiraoka, H. (2003). On-farm composting methods. Rome, Italy: UN-FAO.

Mittal, S. K., Singh, N., Agarwal, R., Awasthi, A., & Gupta, P. K. (2009). Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. Atmospheric Environment, 43(2), 238-244.

MOA (2014). National Policy for Management of Crop Residues (NPMCR). Available online: http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf

MoAFW (2019). Review of the scheme "Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue in states of Punjab, Haryana, Uttar Pradesh and NCT Of Delhi"

Mohanty, P. (2020, Oct 26). Rebooting Economy 40: Why Punjab farmers burn stubble? Retrieved from: https://www.businesstoday.in/opinion/columns/indian-economy-agriculture-why-punjab-farmers-burn-stubble-crop-residue-paddy-burning/story/419879.html

Money control (2019). Over Rs 1,600 cr central funds to combat pollution, stubble burning: RTI. Retrieved from: https://www.moneycontrol.com/news/india/over-rs-1600-cr-central-funds-to-combat-pollution-stubble-burning-rti-4728881.html

Mukherjee P. (2016, October 12). Crop Burning: Punjab and Haryana's killer fields. [Down to Earth]. Retrieved from: https://www.downtoearth.org.in/news/air/crop-burning-punjab-haryana-s-killer-fields-55960

Nagendran, R. (2011). Agricultural waste and pollution. In Waste (pp. 341-355). Academic Press. Pages 341-355, https://doi.org/10.1016/B978-0-12-381475-3.10024-5

NFSM (2018). Brief Note on CDP. [online]. Available at https://nfsm.gov.in/ReadyReckoner/CU2/CUII_Brief.pdf

Nirmal R. (2019, November 17) Where are the Happy Seeders that Punjab's farmers were promised? [The Hindu Business line]. Retrieved from: https://www.thehindubusinessline.com/economy/agri-business/where-are-the-happy-seeders-that-punjabs-farmers-were-promised/article30000119.ece

NITI Aayog (2018). Note on Bio-mass Management in India. Submitted to the Task Force on Biomass Management. New Delhi, India.

NITI Ayog (2016). Evaluation Study On Efficacy of Minimum Support Prices (MSP) on Farmers. Retrieved from: https://niti.gov.in/writereaddata/files/writereaddata/files/document_publication/MSP-report.pdf

Padhee A & Pingali P. (2020, May 12). Lessons from a pandemic to repurpose India's agricultural policy. [Nature India]. Retrieved from: https://www.natureasia.com/en/nindia/article/10.1038/nindia.2020.83

Paltasingh K R., Goyari P., Tochkov K. (2017) Indian Agriculture after Green Revolution: An Overview . In Indian Agriculture after the Green Revolution

Pandey R (2014). Groundwater Irrigation in Punjab: Some Issues and Way Forward. Retrieved from: https://www.nipfp.org.in/media/medialibrary/2014/09/WP_2014_140.pdf

Pandey, R., Kedia, S., and Malhotra, A. (2020). Addressing Air Quality Spurts due to Crop Stubble Burning during COVID19 Pandemic: A case of Punjab. Retrieved from: https://www.nipfp.org.in/media/medialibrary/2020/06/WP_308_2020.pdf

Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F. and Wilkinson, R. (2006). Understanding and promoting adoption of conservation practices by rural landholders. Australian journal of experimental agriculture, 46(11), pp.1407-1424.

PEDA (2020). Biomass Power Projects. Retrieved from Punjab Energy Development Agency. [online]. Available at: https://www.peda.gov.in/biomass-power-projects

Pingali, P., Aiyar, A., Abraham, M., & Rahman, A. (2019). Transforming food systems for a rising India (p. 368). Springer Nature.

Punjab ENVIS Centre. [Online]. Available at http://www.punenvis.nic.in/

Ramachandran A. (2020), Delhi: Crores allocated, but winter smog from stubble burning likely this year too. [Citizen Matters]. Retrieved from: https://citizenmatters.in/delhi-punjab-haryana-stubble-burning-winter-smog-and-covid-21241

Ravindra, K., Singh, T., & Mor, S. (2019). Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. Journal of cleaner production, 208, 261-273.

Reddy D. N., Reddy A.A., Nagaraj, N and Bantilan, C. (2014). Impact of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) on Rural Labour Markets, Working paper series no. 58. Patancheru-502324, Andhra Pradesh, India: International Crops Research Institute for the Semiarid tropics. 40 pp.

Reddy, A. (2020, October 11). How Can We Solve the Problem of Stubble Burning? [The Wire] Retrieved from: https://science.thewire.in/environment/stubble-burning-punjab-haryana-rice-harvesting-wheat-sowing-delhi-air-pollution/)

Rentizelas A., Tolis A. and Tatsiopoulos I.P. (2009), 'Logistics issues of biomass: the storage problem and the multi-biomass supply chain', Renewable & Sustainable Energy Reviews, Vol. 13 (4), pp. 887-894.

Ross, S. (2018), 'Countries That Produce the Most Food', Investopedia. Available online: https://www.investopedia.com/articles/investing/100615/4-countries-produce-most-food.asp#ixzz5WRqV85mY

Sahai, S., Sharma, C., Singh, S. K., & Gupta, P. K. (2011). Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India. Nutrient Cycling in Agroecosystems, 89(2), 143-157.

Saini, G (2020, August 16) Delhi pollution: Punjab, Haryana to bank on more machines, biomass plants to reduce stubble burning [Outlook India]. Retrieved from: https://www.outlookindia.com/newsscroll/delhi-pollution-punjab-haryana-to-bank-on-more-machines-biomass-plants-to-reduce-stubble-burning/1916872

Sandhu, H. (2019). Crop Diversification in Punjab, Issues and Analysis Retrieved from: https://abhipedia.abhimanu.com/Article/State/NDc5OAEEQQVVEEQQVV/Crop-Diversification-in-Punjab-Punjab-State

Sarkar, S., Singh, R. P., & Chauhan, A. (2018). Crop residue burning in northern India: Increasing threat to Greater India. Journal of Geophysical Research: Atmospheres, 123(13), 6920-6934.

Sekhri, S. (2013). "Sustaining Groundwater: Role of Policy Reforms in Promoting Conservation in India," India Policy Forum, National Council of Applied Economic Research, vol. 9(1), pages 149-187. Retrieved from: http://testnew.ncaer.org/image/userfiles/file/IPF-Volumes/Volume%209/4_Sheetal%20Sekhari.pdf

Sharma B., Gulati A., Mohan G., Manchanda S., Ray I., and Amarasinghe U. (2018). WATER PRODUCTIVITY MAPPING of MAJOR INDIAN CROPS. Retrieved from: https://www.nabard.org/auth/writereaddata/tender/1806181128Water%20Productivity%20Mapping%20of%20Major%20Indian%20Crops,%20Web%20Version%20(Low%20Resolution%20PDF).pdf

Sharma, S. (2021, August 22). "As an entrepreneur, you need to be comfortable with discomfort": Strawcture founder Shriti Pandey. [Money Control]. Retrieved from: https://www.moneycontrol.com/news/trends/features/as-an-entrepreneur-you-need-to-be-comfortable-with-discomfort-strawcture-founder-shriti-pandey-7369791.html

Shilev, S., Naydenov, M., Vancheva, V., & Aladjadjiyan, A. (2007). Composting of food and agricultural wastes. In Utilization of By-products and Treatment of Waste in the Food Industry (pp. 283-301). Springer, Boston, MA.

Shukla A K, Tiwari P K and Prakash C (2014). Micronutrients deficiencies vis-à-vis food and nutritional security of India. Indian J Fert 10(12): 94-112.

Singh K. (2012). Electricity Subsidy in Punjab Agriculture: Extent and Impact Ind. Jn. of Agri. Econ. Vol.67, No.4

Singh, B., McDonald, A.J., Srivastava, A.K. and Gerard, B. (2019). Tradeoffs between groundwater conservation and air pollution from agricultural fires in northwest India. Nat Sustain 2, 580–583 https://doi.org/10.1038/s41893-019-0304-4

Singh, D. P., & Prabha, R. (2017). Bioconversion of agricultural wastes into high value biocompost: a route to livelihood generation for farmers. Adv Recycl Waste Manag, 2, 1-5.

Singh, P., & Kour, J. (2014). Role of infrastructure in the growth of agriculture in Punjab, IOSR. J. Economics and Finance, 17-20.

Singh, R. P., Dhaliwal, H. S., Sidhu, H. S., Manpreet-Singh, Y. S., & Blackwell, J. (2008). Economic assessment of the Happy Seeder for rice-wheat systems in Punjab, India. Conference Paper, AARES 52nd Annual conference, Canberra. Australia: ACT

Singh, S. and Shruti, B. (2014): "Depeasantization in Punjab: Status of Farmers Who Left Farming", Current Science, Vol 106 (10): 1364-1368

Somvanshi, A. (2020, October 8). Counting north India's stubble fires: Stronger data science needed to study winter smog. [Down to Earth]. Retrieved from: https://www.downtoearth.org.in/blog/pollution/counting-north-india-s-stubble-fires-stronger-data-science-needed-to-study-winter-smog-73708

Srivastava S.K., Chand R, Raju S.S., Jain R, Kingsly I., Sachdeva J, Singh J and Kaur A. (2015) Unsustainable Groundwater Use in Punjab Agriculture: Insights from Cost of Cultivation Survey, Ind. Jn. of Agri. Econ. Vol.70, No.3

Statistical Abstract of Punjab (2018). Economic and Statistical Organisation of Punjab. Available at https://www.esopb.gov.in/static/PDF/Abstract2018.pdf

Streets, D. G., Bond, T. C., Carmichael, G. R., Fernandes, S. D., Fu, Q., He, D., ... & Woo, J. H. (2003). An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. Journal of Geophysical Research: Atmospheres, 108(D21).

The National Graph (2020, August 09). Punjab Cm Orders Social Pre Audit Of Stubble Management Scheme For Kharif Season 2020. Retrieved from : http://www.thenationalgraph.com/eng/news/354

Times of India (2019, November 1) Punjab: 'Financial aid, machines will end farm fires', Retrieved from: https://timesofindia.indiatimes.com/city/ludhiana/punjabfinancial-aid-machines-will-end-farm-fires/articleshow/71846694.cms

Tollefson, L.C. and Wahab, M.N.J. (1994). Better research-extension-farmer interaction can improve the impact of irrigation scheduling techniques. World Bank, Washington, DC.

Tripathi, A., Mishra, A. K., & Verma, G. (2016). Impact of Preservation of Subsoil Water Act on Groundwater Depletion: The Case of Punjab, India. Environmental management, 58(1), 48–59. https://doi.org/10.1007/s00267-016-0693-3

Vasudeva, V (2019, August 17). Paddy, tube wells and depleting groundwater: Why Punjab's water resources are under strain [The Hindu]. Retrieved from https://www.thehindu.com/news/national/other-states/paddy-tube-wells-and-depleting-groundwater/article29112950.ece

Vibhaw, N and Jain, S (2020). Ordinance Passed to Constitute a Commission to Control Air Pollution in the National Capital Region (NCR) And Adjoining States. [Mondaq]. Retrieved from: https://www.mondaq.com/india/clean-air-pollution/1003864/ordinance-passed-to-constitute-a-commission-to-control-air-pollution-in-the-national-capital-region-ncr-and-adjoining-states

Vidhi Centre for Legal Policy. (2017). Cleaning Delhi's Air: Implementation Action Plan. Retrieved from: http://www.indiaenvironmentportal.org.in/files/file/Delhi+Air+Pollution+Implementation+Action+Plan.pdf

Washenfelder, R. A., Attwood, A. R., Brock, C. A., Guo, H., Xu, L., Weber, R. J., ... & Cohen, R. C. (2015). Biomass burning dominates brown carbon absorption in the rural south-eastern United States. Geophysical Research Letters, 42(2), 653-664.

Yadav R.S. (2019, June 04). Stubble burning: A problem for the environment, agriculture and humans. [Down to Earth]. Retrieved from: https://www.downtoearth.org.in/blog/agriculture/stubble-burning-a-problem-for-the-environment-agriculture-and-humans-64912

Yadav, S., Koli, P., Mina, U., & Devi, S. (2017). Crop residue burning and air pollution. Popular Kheti, 5, 105-109.

Zhang, H., Hu, D., Chen, J., Ye, X., Wang, S. X., Hao, J. M., ... & An, Z. (2011). Particle size distribution and polycyclic aromatic hydrocarbons emissions from agricultural crop residue burning. Environmental science & technology, 45(13), 5477-5482.

Zhang, Q., Jiang, X., Tong, D., Davis, S. J., Zhao, H., Geng, G., ... & Ni, R. (2017). Transboundary health impacts of transported global air pollution and international trade. Nature, 543(7647), 705-709.

Centre for Chronic Disease Control

WHO Collaborating Centre for Surveillance, Capacity building and Translational Research in Cardio-Metabolic Diseases