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Understanding the Transition to Sustainable Agriculture in Rural Punjab, India: Integrating Farmers and Experts Insights

A thesis presented in partial fulfilment of the requirements for the degree of

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Abstract

The United Nations Member States aim to achieve the Sustainable Development Goals (SDGs) by 2030; however, the most recent Global Sustainable Development Report (2023) shows that several goals, including Goal 2, Goal 11, Goal 13, Goal 16, and Goal 17, remain far from reaching the 2030 ambition. Within this global context, this thesis assesses the capacity of Punjab's agricultural system, known as India's food bowl, to contribute to SDG 2 Target 2.4 - sustainable food production and resilient agricultural practices.

The study identifies the key enablers and barriers shaping Punjab farmers' capacity to adopt sustainable agriculture practices, drawing on qualitative insights from forty-eight farmers across three districts in the Malwa region. It also incorporates perspectives from nine experts, including a university researcher, extension officers, officials from the farm advisory centre, cooperative society, ATMA, and non-governmental organisations. Together, these insights inform the targeted actions required from government and institutional actors. The thesis also presents a Bottom-Up Staircase Model for Advancing Sustainable Agriculture Transitions in Punjab, illustrating how farmers, local institutional support systems, district-and state-level agencies, and national bodies can work together to strengthen sustainability outcomes and ensure the judicious use of natural resources for present and future generations. In doing so, the thesis also aligns with SDG 13, Climate Action (Target 13.3), by advancing knowledge on pathways that strengthen resilience and adaptive capacity for Punjab's agricultural system.

Although the study is based on a small pilot sample, the recurrence of priority themes across all three districts demonstrates that the issues identified are widely shared, and the convergence between farmers' lived experiences and experts' assessments strengthens the validity of the recommended actions. Methodologically, the thesis adapts the FAO SDG 2.4.1 farm survey module, originally designed for quantitative monitoring, into a qualitative tool to generate rich insights into farmers' perceived capacity to contribute to sustainability goals. As many countries, including India, face challenges in collecting data on SDG 2.4.1 due to survey design and implementation constraints (FAO, 2019b), this study demonstrates how the FAO framework can be contextualised to assess farmers' capabilities, support needs, and readiness for sustainability transitions. While grounded in Punjab's agricultural context, the study offers insights relevant to other regions that adopted Green Revolution technologies or where farmer perspectives are considered essential for designing effective sustainability transitions.

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This thesis was a long-term project for me, and I am very pleased to finally reach the stage of submitting it. For this dream project, first and foremost, I want to acknowledge my God and my Gurus, from Guru Nanak Dev Ji to Guru Gobind Singh Ji, whose teachings guide a life of service, care for the community, and acting responsibly toward the planet. I also thank my role models, my Nana Ji, the late Sardar Nacchattar Singh, and my Nani Ji, the late Sardarni Naseeb Kaur, for imparting to my siblings and me the importance of life and the value of living with purpose and service (sewa). Because of your teachings, I have pursued this work.

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Table of Contents

Abstract ..... **ii**
Acknowledgements ..... **iii**
Table of Contents ..... **iv**
List of Figures ..... **viii**
List of Tables ..... **x**
List of Acronyms ..... **xi**
Use of AI ..... **xii**
Chapter One – Introduction and Context **1**
1.1 Introduction 1
1.2 Research Aim and Questions 2
1.3 Background of Punjab 3
1.3.1 Geographical and Historical Context of Punjab's Agriculture 3
1.3.2 Regional Context: Majha, Malwa, and Doaba 4
1.3.3 Governance and Institutions 7
1.4 Research Focus of the Study 8
1.5 Definitions of Agricultural Systems Referenced in This Study 11
1.6 Outline of Thesis 12
Chapter Two - Current Agriculture Practices in Punjab: Impact on the Economy, Environment and Social Well-being of the Farming Community **15**
2.1 Introduction 15
2.2 Current Agriculture Practices in Punjab 15
2.3 Impact of Current Agriculture Practices on Economic, Environmental, and Social Well-being 17
2.3.1 Impact on the Economy 17
2.3.2 Impact on Environment 22
2.3.3 Impact on Social Well-being 30
2.4 The Transition to Sustainable Agriculture in Punjab 35
2.5 Conclusion 37
Chapter Three – Sustainable Agriculture: Concepts and Policy Context in India **39**
3.1 Introduction 39
3.2 Sustainable Agriculture: Concept and Principles 39
3.3 National Policy Context for Sustainable Agriculture in India 41
3.4 Sustainable Agriculture Policy Context in Punjab 43
3.5 Conclusion 43
Chapter Four - Methodology **45**

4.1 Introduction 45
4.2 Research Aim, Questions and Objectives 45
4.3 Research Design and Rationale 46
4.3.1 Research Design 46
4.3.2 Rationale for Selecting Punjab as the Study Area 48
4.4 Ethical Considerations 49
4.5 Reciprocity, Positionality, and Reflexivity 51
4.5.1 Reciprocity 51
4.5.2 Positionality 52
4.5.3 Reflexivity 53
4.6 Sampling Strategy: Participant Selection 54
4.7 Data Collection and Analysis 59
4.7.1 Data Collection 59
4.7.2 Data Analysis 61
4.8 SDG Target 2.4 and Indicator 2.4.1: Application in This Study 63
4.9 Limitations of the Study 65
4.10 Conclusion 66
Chapter Five – Farmers' Perspectives on Economic Indicators of Sustainable Agriculture .. 67
5.1 Introduction 67
5.2 Indicator 1: Land Productivity - Farm Output Value per Hectare (FOVH) 68
5.2.1 Summary of Farmers' Responses on Farm Output Value per Hectare 68
5.2.2 Farmers' Perspectives on the Farm Output Value 72
5.2.3 Key Enablers and Barriers 76
5.3 Indicator 2: Profitability - Net Farm Income (NFI) 77
5.3.1 Summary of Farmers' Responses Regarding Net Farm Income 77
5.3.2 Farmers' Perspectives on Net Farm Income 80
5.3.3 Key Enablers and Barriers 81
5.4. Indicator 3. Resilience - Risk Mitigation Mechanisms 82
5.4.1 Summary of Farmers' Responses on Risk Mitigation Mechanisms 82
5.4.2 Farmers' Perspectives on Risk Mitigation Mechanisms 84
5.4.3 Key Enablers and Barriers 85
5.5 Conclusion 87
Chapter Six - Farmers' Perspectives on Environment Indicators of Sustainable Agriculture 89
6.1 Introduction 89
6.2 Indicator 1 Soil Health- Prevalence of Soil Degradation Threats 89

6.2.1 Summary of Farmers' Responses on the Prevalence of Soil Degradation Threats . 89
6.2.2 Farmers' Perspectives on the Prevalence of Soil Degradation Threats 92
6.2.3 Key Enablers and Barriers 98
6.3 Indicator 2: Water Use- Variation in Water Availability 100
6.3.1 Summary of Farmers' Responses on Variation in Water Availability 100
6.3.2 Farmers' Perspectives on Variation in Water Availability 103
6.3.3 Key Enablers and Barriers 106
6.4 Indicator 3: Fertiliser Pollution Risk- Management of Fertilisers 109
6.4.1 Summary of Farmers' Responses on Fertiliser Management 109
6.4.2 Farmers' Perspectives on Fertiliser Management 110
6.4.3 Key Enablers and Barriers 112
6.5 Indicator 4: Pesticide Risk - Management of Pesticides 113
6.5.1 Summary of Farmers' Responses on Pesticide Management 113
6.5.2 Farmers' Perspectives on Pesticide Management 116
6.5.3 Key Enablers and Barriers 118
6.6 Indicator 5: Biodiversity - Use of Biodiversity-Supportive Practices 119
6.6.1 Summary of Farmers' Responses on Biodiversity-Supportive Practices 119
6.6.2 Farmers' Perspectives on Biodiversity Supportive Practices 120
6.6.3 Key Enablers and Barriers 121
6.7 Conclusion 123
Chapter Seven - Farmers' Perspectives on Social Indicators of Sustainable Agriculture ... 125
7.1 Introduction 125
7.2 Indicator 1 Decent Employment - Wage Rate in Agriculture 125
7.2.1 Summary of Farmers' Responses on Decent Employment 125
7.2.2 Farmers' Perspectives on Decent Employment 127
7.2.3 Key Enablers and Barriers 129
7.3 Indicator 2: Food Security - Food Insecurity Experience Scale (FIES) 131
7.3.1 Summary of Farmers' Responses on Food Insecurity Experience Scale 131
7.3.2 Farmers' Perspectives on Food Insecurity 131
7.3.3 Key Enabler and Barrier 132
7.4 Indicator 3: Land Tenure - Secure Tenure Rights to Land 132
7.4.1 Summary of Farmers' Responses to Secure Tenure Rights to Land 132
7.4.2 Farmers' Perspectives on Secure Tenure Rights to Land 133
7.4.3 Key Enabler and Barrier 134
7.5 Conclusion 135

Chapter Eight: Agricultural Experts' Perspectives on Transitioning to Sustainable Agriculture in Punjab, India 136

8.1 Introduction 136

8.2 Institutional Support for Transition: Insights from Experts 138

8.2.1 Punjab Agricultural University (PAU) - Research, Training, and Long-Term Sustainability Efforts 138

8.2.2 Krishi Vigyan Kendras (KVKs)- Village Adoption, Machinery Banks, and Demonstrations 139

8.2.3 Farm Advisory Service Centres (FASCs)- Field-Level Problem Solving 140

8.2.4 Agricultural Technology Management Agency (ATMA)- Participatory Extension and Technology Promotion 141

8.2.5 Cooperative Societies- Credit, Inputs, and Structural Limitations 142

8.2.6 Non-Governmental Organisations- Experiential Learning and Alternative Models 142

8.3 Experts' Perspectives on the Economic, Environmental, and Social Dimensions of the Transition 144

8.3.1 Experts' Perspectives on the Economic Viability of the Transition 144

8.3.2 Experts' Perspectives on Environmental Sustainability and Resource Constraints 150

8.3.3 Experts' Perspectives on the Role of Social Structures for the Transition 158

8.4 Answers to Farmers' Concerns by Experts 162

8.5 Conclusion 165

Chapter Nine: Discussion and Conclusions 167

9.1 Introduction 167

9.2 The Current System Farmers Operate Within 168

9.3 Integrating Farmers' and Agricultural Experts' Inputs Using the Five Sustainable Agriculture Principles 170

9.4 Integrative Perspective 181

9.5 Closing Thoughts and Recommendations 186

References 189

Appendix:

1. Recommended amount of chemical fertiliser for wheat crop in the absence of soil test
2. Recommended amount of chemical fertiliser along with some notes for rice crop in the absence of soil test
3. Recommended amount of chemical fertiliser for the potato crop in the absence of a soil test
4. Participant Information Sheet
5. Research Consent Form
6. Survey Module

List of Figures

Figure 1.1	Geographical location of Punjab within India and its regional divisions
Figure 1.2	Punjab River Map
Figure 1.3	District-level map of Punjab showing farmer and expert sample locations included in this study
Figure 2.1	Crop-wise percentage share of the cropped area
Figure 2.2	Area and yield of paddy and wheat in Punjab
Figure 2.3	Crop-wise yields in Punjab and India, 2020-21 (in Kgs/hectare).
Figure 2.4	Percentage Distribution of Gross State Value Added at Constant Prices in Punjab from 1970 to 2017.
Figure 2.5(a)	Number of cultivators in rural Punjab by age group, 2001 and 2011 census
Figure 2.5(b)	Number of individuals in rural Punjab engaged in allied activities by age group, 2001 and 2011 censuses
Figure 2.6	Categorisation Map of Punjab
Figure 2.7(a)	Map showing areas of salinity and chloride-contaminated groundwater in Punjab.
Figure 2.7(b)	Map showing areas of chloride-contaminated groundwater in Punjab
Figure 2.8(a)	Map showing areas of fluoride-contaminated groundwater in Punjab
Figure 2.8(a)	Map showing areas of nitrate-contaminated groundwater in Punjab
Figure 2.9	Number of Punjab Cultivators who committed suicide
Figure 4.1	Number of Farmers Across Different Age Groups
Figure 4.2	Distribution of Sampled Farmers by Combined Farm Size Categories (O = owned, R = rented)
Figure 6.1(a)	Paddy residue is burned to prepare the field for wheat sowing
Figure 6.1(b)	Paddy Residue managed by incorporating it into the soil
Figure 6.2	Artificial canal on the farm of a natural farming practitioner
Figure 6.3	Mustard intercropped with poplar trees on one of the participants' farms
Figure 8.1	Tensiometer
Figure 8.2	Leaf Colour Chart
Figure 8.3(a)	Integrated Farming System Model for one hectare
Figure 8.3(b)	Integrated Farming System Model for one hectare
Figure 8.4(a)	Intercropping crops with Sugarcane, Poplar Trees

Figure 8.4(b)	Wheat planted on a bed
Figure 8.4(c)	Intercropping with Poplar Trees
Figure 8.4(d)	Jeev Amrit Method – Bio Fertiliser
Figure 8.4(e)	Soil Hackers Robotics is used for removing weeds mechanically
Figure 8.4(f)	Bed Planter used on the farm
Figure 8.5(a)	Mechanical Weeding in Bed Planted Organic Wheat
Figure 8.5(b)	Recommended Cropping Systems for Organic Farming
Figure: 8.5(c)	Management of Insect-Pests in Organic Crops
Figure: 8.6(a)	Mushroom cultivation huts
Figure:8.6(b)	Manure Preparation set up
Figure: 8.6(c)	Sample of the harvested produce
Figure 9.1	Farmers' needs and system responses (with key governance gaps).
Figure 9.2	Bottom-up staircase model for advancing sustainable agriculture transitions in Punjab: Integrating farmers' and experts' perspectives

List of Tables

Table 2.1	Levels of pollutants during the three main phases of agricultural activities in Punjab
Table 4.1	Distribution of Farmer Samples Across Malwa Region Districts
Table 4.2	Number of Farmers Practising Different Cultivation Types for Commercial Agriculture
Table 4.3	Classification of Farm Size Categories
Table 4.4	Agricultural Expert Participants (Positions and Organisations)
Table 4.5	SDG 2.4.1 Sustainability Themes and Sub-Indicators Applied in This Study
Table 4.6	Alignment Between FAO SDG 2.4.1 Survey Data Requirements and the Locally Adapted Data Captured in This Study
Table 5.2	Cropping Pattern and Cultivation Type Across Sampled Farmers by Land Tenure Type
Table 5.2	Farmer-Reported Crop Production and Estimated Gross Income Per Hectare (ha).
Table 5.3	Estimated Net Income per Hectare
Table 5.4	Comparison of Net Farm Income per Hectare Between Owner and Lease-holding Farmers
Table 8.1	Agricultural Expert Participants (Positions, Organisations, and Organisation Role)

List of Acronyms

ARYA	Attracting and Retaining Youth in Agriculture
ASR	Anaerobic Seeded Rice
ATMA	Agricultural Technology Management Agency
BTS	Burning–Tillage–Sowing period
CGWB	Central Ground Water Board
CRM	Crop Residue Management
DAP	Diammonium Phosphate
DSR	Direct Seeded Rice
FAO	Food and Agriculture Organisation
FASCs	Farm Advisory Service Centres
FICCI	Federation of Indian Chambers of Commerce & Industry
FIES	Food Insecurity Experience Scale
FOVH	Farm Output Value per Hectare
GIS	Geographic Information System
GVA	Gross State Value Added
HB	Harvesting–Burning period
IFS	Integrated Farming System
INR	Indian Rupee
KCC	Kisan Credit Card
KVKs	Krishi Vigyan Kendras
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Scheme
MSP	Minimum Support Price
NFI	Net Farm Income
NGO	Non-Governmental Organisation
NMSA	National Mission for Sustainable Agriculture
OECD	Organisation for Economic Co-operation and Development
PAU	Punjab Agricultural University

PDMC	Per Drop More Crop
PFS	Pesticide–Fertiliser Spray period
PFT	Pulmonary Function tests
PPE	Personal Protective Equipment
PTR	Puddled Transplanted Rice
RISE	Response-Inducing Sustainability Evaluation Framework
SAP	State Agricultural Plan (or your thesis-specific meaning)
SDG	Sustainable Development Goal
SMS	Super Straw Management System
UN	United Nations
WHO	World Health Organisation

Use of AI

In this thesis, Microsoft Copilot was used to provide feedback on the author's written text and assist with phrasing, clarity, and error correction. Grammarly was used for proofreading, including grammar and spelling checks. These tools supported the refinement of written expression; however, all ideas, interpretations, analytical decisions, and final revisions remain the author’s own. The use of AI follows Massey University’s AI-use framework under the category of AI Collaboration (Massey University, n.d.).

Chapter One – Introduction and Context

1.1 Introduction

Punjab has long been recognised as the “breadbasket of India” due to its major contribution to national food security. This contribution was made possible through the adoption of Green Revolution–associated chemical-intensive agricultural practices introduced in Punjab in the mid-1960s, particularly for the wheat–paddy cropping system (Dutta, 2012). The chemical-intensive practices increased grain production and strengthened economic gains for many farming households. However, Punjab’s long-term dependence on these intensive wheat–paddy systems and high external inputs is also linked to growing environmental pressures, economic stress, and social challenges in rural communities (Jaiswal et al., 2020).

Beyond the regional context, agricultural systems worldwide are increasingly affected by climate change. Rising temperatures, changing rainfall patterns, and increasing climate variability are expected to influence agricultural productivity, water availability, and the stability of food systems (IPCC, 2022). These global concerns are also reflected in international initiatives such as the United Nations Sustainable Development Goals (SDGs), particularly SDG Target 2.4, which promotes the adoption of sustainable and resilient agricultural practices (United Nations, 2015a).

Within this context, this thesis explores how farmers in Punjab position themselves in relation to a transition towards more sustainable food production systems, grounded in farmers' present lived realities, while also engaging with broader institutional frameworks and ongoing policy efforts. Understanding Punjab’s socio-ecological, economic, and institutional landscape is essential for analysing the opportunities and constraints influencing agricultural sustainability transitions in the region.

This study makes three key contributions:

- First, it demonstrates an approach for systematically capturing farmers' perspectives on sustainable agriculture practices by adapting the FAO SDG 2.4.1 survey framework to the Punjab agricultural context.
- Second, it integrates insights from government and non-government stakeholders to identify context-specific, bottom-up pathways for transitioning towards sustainable agriculture.
- Third, it highlights gaps between farm-level realities and existing support systems, thereby identifying areas where targeted interventions are required to better support farmers.

This chapter provides an overview of the research focus, outlines the research aim and guiding questions, and introduces the geographical and institutional context of Punjab's agricultural system. It also briefly introduces the FAO SDG 2.4.1 framework used in the study to guide data collection and concludes with an outline of the thesis structure.

1.2 Research Aim and Questions

The overall aim of this research is to explore the key enablers and barriers influencing the transition towards sustainable agricultural practices in Punjab. By integrating farmers' experiences and institutional perspectives, the study seeks to understand not only what sustainable agriculture requires in principle, but also what makes change feasible in practice. The study is guided by the following research questions:

RQ1: How do the predominant agricultural practices in Punjab impact the economic, environmental and social outcomes for farmers and communities?

RQ2: What perspectives do farmers and other key stakeholders hold regarding the adoption and implementation of Sustainable Agriculture Practices (SAPs) in Punjab, and how do they contribute to this process?

1.3 Background of Punjab

1.3.1 Geographical and Historical Context of Punjab's Agriculture

Punjab is located in the north-west region of India, sharing international borders with Pakistan and domestic borders with Haryana, Himachal Pradesh, Rajasthan, and Jammu and Kashmir, as illustrated in Figure 1.1. The state lies within the fertile Indo-Gangetic Plain in northern South Asia, a vast lowland formed by the long-term deposition of alluvial sediments, which contributed to deep, fertile soils (Zeidan, n.d.). These alluvial soils, together with Punjab's extensive canal irrigation systems and relatively favourable agro-climatic conditions, have supported intensive agricultural production in the region (Ruth, 2025).



Figure 1.1 Geographical location of Punjab within India and its regional divisions (Majha, Doaba, and Malwa). Source: Adapted from (Divyanshu, 2021; "Map of India," n.d.)

The term “Punjab” is historically associated with the “land of five rivers” (Beas, Chenab, Jhelum, Ravi, and Sutlej), reflecting the centrality of water resources to rural livelihoods. After the Partition of India in 1947, the wider Punjab region was split between India and Pakistan. This division also affected how river water was shared across the border. Under the Indus Waters Treaty signed in 1960, Pakistan received primary rights to the three western rivers (Indus, Jhelum, and Chenab), while India received the three eastern rivers (Ravi, Beas, and Sutlej), which flow through Punjab, India (World Bank Group, 2018).

With reliable irrigation and highly cultivable land, Punjab later became a pioneer Green Revolution state in the mid-1960s, contributing to a shift from a more diversified cropping system to an intensive wheat–paddy production system (Dutta, 2012). Presently, around 87% of Punjab’s geographical area is under cultivation, and approximately 97% of this is under irrigation coverage; the farm economy is also characterised by extensive mechanisation (Know India, n.d.).

According to the most recent official census of India (2011) Punjab has a predominantly rural population, with approximately 63% of residents living in rural areas. India’s next national census, originally scheduled for 2021, has been repeatedly delayed and is now planned to conclude in 2027 (Yadav, 2025). As a result, updated official population figures are not yet available. Further details on Punjab’s agricultural profile, including cropping patterns and key agriculture practice indicators, are presented in Chapter Two.

1.3.2 Regional Context: Majha, Malwa, and Doaba

Punjab is divided into three socio-cultural and agro-ecological regions: Majha, Malwa, and Doaba (Divyanshu, 2021; Government of Punjab, n.d.).

- **Majha**, located between the Ravi and Beas rivers (Figure 1.2), includes districts such as Amritsar, Gurdaspur, Tarn Taran and Pathankot, and is often described as the historical-cultural heartland of Punjab.

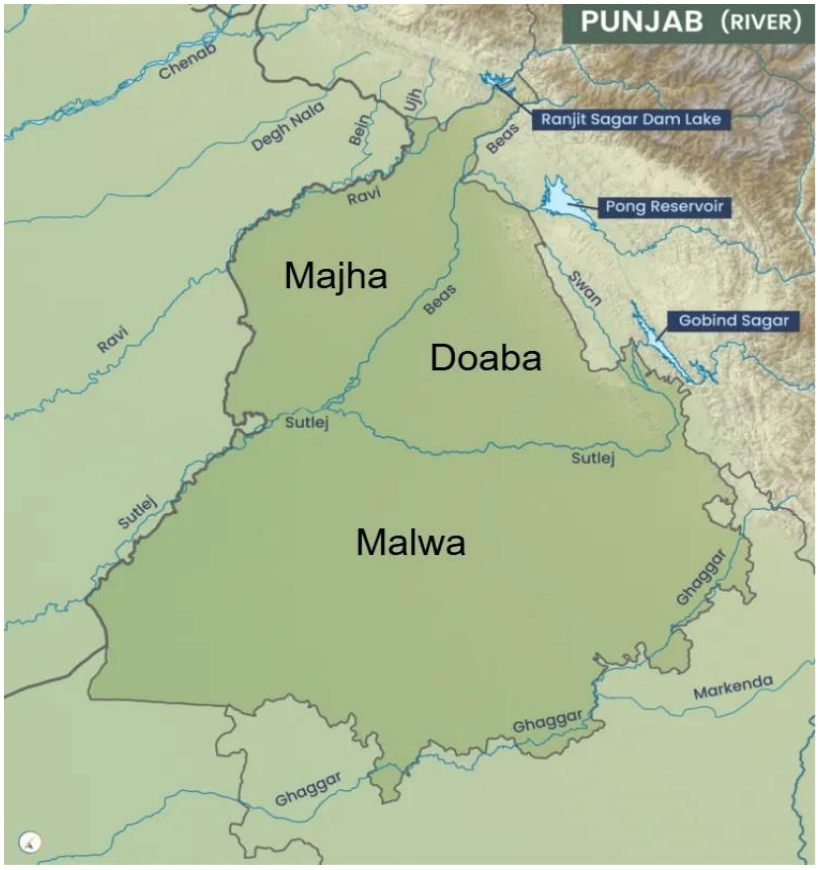


Figure 1.2: Punjab River Map. Source: Adapted from (Lotus Arise, n.d.).

- **Doaba**, situated between the Beas and Sutlej rivers, is characterised by comparatively higher levels of migration and remittance-based economies.
- **Malwa**, the largest region of Punjab, lies to the south of the Sutlej River. This region was a focal area of Green Revolution expansion, dominated by wheat–paddy cultivation and has experienced significant environmental stress, including groundwater depletion and soil quality degradation (Satam, n.d.). Historically, parts of Malwa were also known for cotton cultivation and were often referred to as the "cotton belt." In recent years, the region has been associated with serious health concerns, and parts of it have been labelled as the "cancer belt" (Nanda et al., 2016).

For this study, the Malwa, Punjab's largest agro-ecological region, was selected as the study area for exploring farmers' perspectives, primarily for practical and relational reasons. As my home region, this made it easier to access farmer participants and build trust with them, including those in remote locations. In addition, nine agricultural experts included in this study were selected from across the three regions of Punjab, with the majority from Malwa (seven), and one each from the Doaba and Majha regions. The locations of farmer and expert participants included in this study are shown in Figure 1.3.



Figure 1.3 District-level map of Punjab showing farmer and expert sample locations included in this study. Source: Adapted from (Divyanshu, 2021)

1.3.3 Governance and Institutions

Punjab's agricultural outcomes are influenced not only by farm-level practices but also by the governance systems and institutional support. State agencies, universities, and advisory bodies contribute to agricultural research and extension services, while market systems and procurement policies influence cropping choices and income stability (Agricultural Policy Formulation Committee, 2023). These institutional arrangements played a major role in the success of the Green Revolution (Singh, 2000), and they remain highly relevant to support the present need to transition to more sustainable food production systems because sustainability transitions often require coordinated change across different sectors, not just changes in individual behaviour and farm practices alone (Lah, 2025).

Examples of some key state agencies involved in agricultural development in Punjab:

1) **Department of Agriculture[1]:** The main government body responsible for agricultural policy implementation, farmer advisory services, regulating subsidy schemes, and extension support.
2) **Punjab Agricultural University (PAU)[2]:** A state agricultural university that conducts research, develops crop technologies, and provides scientific recommendations and training to farmers.
3) **Punjab State Farmers' & Farm Workers' Commission (PSFFWC)[3]:** PSFFWC works on initiatives to enhance farm and off-farm incomes, strengthen agricultural practices, and address other rural development challenges, particularly for small and marginal farmers.

[1] Department of Agriculture: https://agri.punjab.gov.in/
[2] PAU: https://web1.pau.edu/
[3] Punjab State Farmers' * Farm Workers' Commission: https://psfc.org.in/

4) **Punjab Mandi Board[4]:** This department controls and supervises the marketing network of sale, purchase, storage and processing of processed and non-processed agricultural produce
5) **Punjab Agro Industries Corporation**[5]: Promotes agro-processing, diversification initiatives, and value-addition opportunities for farmers.
6) **Krishi Vigyan Kendras (KVKs)**: District-level training centres that conduct frontline demonstrations, farmer trainings, and on-field transfer of new technologies.
7) **ATMA (Agricultural Technology Management Agency)**: District platform that coordinates extension activities (trainings, demonstrations, exposure visits, farmer groups) to make extension more decentralised and demand-driven.
8) **Farmer Advisory Service Centres (FASCs)[6]:** FASCs play an important role in direct technology transfer and provide quick technical guidance to farmers on crops, pests, inputs, and other farm-level challenges.

Chapter Eight returns to these governance dimensions by presenting the perspectives of the officials from some of these organisations on the sustainable agriculture transition.

1.4 Research Focus of the Study

Sustainable agriculture has become an increasingly important focus in the current era of climate change, aiming to meet the needs of the present generation while preserving natural resources for future generations (FAO, 2015). There is a growing global consensus advocating intensified efforts to transform food production systems in alignment with key Sustainable Development Goals (SDGs), such as SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) (United Nations, 2015). The effective achievement of these targets requires recognising and supporting the capabilities of

[4] Punjab Mandi Board: https://mandiboard.nic.in/
[5] Punjab Agro: https://punjabagro.gov.in/
[6] FASCs: https://pauwp.pau.edu/fascs/

the primary implementers of agricultural practices - farmers themselves (FAO, 2015). Connecting well-researched theoretical insights from experts with farmers' practical on-field knowledge and lived experiences is crucial for supporting meaningful transitions toward sustainable agriculture (Pretty, 1995; J. Woodhill et al., 2022).

In Punjab, concerns about the long-term sustainability of the agricultural system have been discussed for several decades alongside the achievements of the Green Revolution. While the wheat–paddy production system substantially increased food production and strengthened India's national food security, researchers have progressively highlighted challenges associated with prolonged implementation of intensive agricultural practices, including groundwater depletion, declining soil health, and rising production costs (Chand, 1999; Singh & Benbi, 2016). Over time, these concerns have contributed to growing discussions about crop diversification and the adoption of more resource-efficient farming practices (Gulati et al., 2021; Jodhka, 2006). More recently, climate change and environmental pressures have further intensified these concerns, reinforcing calls for more sustainable and resilient agricultural pathways in the region (Jaiswal et al., 2020; Kaur & Chauhan, 2024; Singh et al., 2024).

A Press release by the Ministry of Agriculture & Farmer Welfare, India (2023), also noted that climate variability is influencing agricultural production patterns and increasing the vulnerability of farming communities across different regions of the country. The recent state-specific Punjab agricultural policy also reflects a stronger focus on the agriculture production system sustainability alongside livelihood security (Agricultural Policy Formulation Committee, 2023). It highlights the need to improve farm profitability while conserving natural resources, emphasising priorities such as crop diversification, value addition, strengthened research–extension linkages, and improved market and institutional support systems to reduce risk for farmers.

The transition toward sustainable agriculture is not only a technical shift in farming methods but also a broader development challenge, as changes in inputs, crops, and farming practices directly affect livelihood security, production risk, and rural well-being (Singh et al., 2024; Jim Woodhill et al., 2022; Zeweld et al., 2020). To explore these sustainability-related challenges and enablers in Punjab from farmers' perspectives, this study utilises the Food and Agriculture Organisation (FAO) Sustainable Development Goal (SDG) 2.4.1 indicator framework, which measures progress towards sustainable agriculture (FAO, n.d.-b). The indicator assesses agricultural sustainability across economic, environmental, and social dimensions and is implemented through a farm-level survey module (FAO, 2021).

However, the FAO factsheet on the main SDG indicators highlights that data for SDG indicator 2.4.1 remain limited, as many countries face challenges in collecting the detailed farm-level information required to monitor agricultural sustainability effectively (FAO, 2020a). The most recent available capacity assessment for India, conducted in 2019, also identified constraints related to the development, adaptation of survey instruments, and training on the methodology for compiling the indicator and applying it to the national context (FAO, 2019b).

In this context, this study provides a small empirical contribution to the broader efforts to operationalise the SDG 2.4.1 framework. While national SDG reporting typically requires quantitative farm-level data for monitoring agricultural sustainability, this research adapts elements of the FAO SDG 2.4.1 survey module within a qualitative-dominant research design to generate in-depth insights into farmers' perspectives on sustainability indicators. By contextualising the survey within the agricultural realities of Punjab and exploring how farmers interpret and respond to sustainability dimensions, the study offers insights into the practical application of the indicator framework at the farm level. Although the research does not generate nationally representative quantitative data, it demonstrates how the SDG 2.4.1

survey approach can be adapted in exploratory research to better understand the social, economic, and environmental dynamics influencing sustainable agriculture transitions. Further details on the framework and its application in this study are discussed in Chapter Four.

To answer the research questions and contextualise the survey module for Punjab's agricultural practices, the thesis first establishes a baseline understanding of the predominant farming practices in Punjab and their economic, environmental, and social implications, as well as the evolving concerns that have prompted discussions about the need for a transition to more sustainable agriculture. These issues are discussed in detail in Chapter Two. It then analyses farmers' and other key institutional stakeholders' perspectives to identify enablers and barriers associated with the transition to more sustainable forms of agriculture, and to conceptualise bottom-up transition pathways grounded in farmers' lived experiences. In doing so, the thesis contributes to a grounded understanding of the sustainability transition in Punjab, centred on farmers' lived realities while also engaging with wider institutional frameworks and ongoing policy efforts.

1.5 Definitions of Agricultural Systems Referenced in This Study

There are four agricultural systems referred to throughout this thesis. The following section provides a brief description of each.

1. **Direct Seeded Rice (DSR):** DSR refers to a crop establishment method in which rice seeds are sown directly into the field, rather than first raising seedlings in a nursery and transplanting them into puddled, flooded fields. Compared with conventional transplanted rice systems, DSR is considered a more resource-efficient approach because it can reduce labour requirements, irrigation water use, and cultivation costs while supporting faster crop establishment and lower greenhouse gas emissions (International Rice Research Institute, n.d.).

2. **Anaerobic Seeded Rice (ASR)**: ASR was explained by one of the NGO's officials interviewed during the field work. The method is called 'the Phagwara Technique'. In this method, instead of transplanting seedlings into puddled, flooded fields, rice seeds are sown directly into moist soil after repeated heavy planking and levelling. This process pushes air out of the soil and creates low-oxygen (anaerobic) conditions needed for rice germination without maintaining standing water. The method aims to reduce early irrigation, labour requirements, and production costs (Good Grow Farms, 2022)
3. **Organic Farming:** Organic farming refers to a farming system that aims to maintain and improve soil health, ecosystems, and biodiversity by relying on natural processes and plant-derived bio inputs rather than synthetic chemicals (FAO, 2020b)
4. **Natural Farming:** In this study, natural farming is defined using one of the NGOs ' practitioner descriptions as a cultivation approach in which no chemical inputs are used, and no bio-inputs are purchased from the market. Instead, inputs are prepared on-farm from farm-based materials. This is treated as distinct from organic farming in this study, as organic farming may involve the external purchase of bio-inputs. Key natural farming practices described by the NGO include intercropping, recycling on-farm waste, and maintaining soil cover with crop residues (Sohangarh Farmversity, n.d.).

1.6 Outline of Thesis

1. **Introduction and Context:**

   Chapter One introduces the research context, background, research questions, and overall focus of the study. It also outlines the governance environment, policy directions, and provides an overview of Punjab's agricultural, institutional, and regional landscape.

2. **Current Agricultural Practices in Punjab:**

   Chapter Two provides a contextual foundation by exploring the economic, environmental, and social implications of predominant agricultural practices in Punjab for farming communities. This chapter also sets the context for exploring farmers' and experts' perspectives on agricultural sustainability transitions in the subsequent chapters.

3. **Sustainable Agriculture: Concepts and Policy Context in India:**

   Chapter Three explores the conceptual foundations of sustainable agriculture and outlines its key principles. It also explores India's national policy context for sustainable agriculture and discusses the challenges associated with achieving sustainability transitions at both regional and broader scales.

4. **Methodology:**

   Chapter Four explains the research design and qualitative-dominant approach adopted in this study. It outlines the sampling strategy, data collection methods, including the use of the FAO SDG 2.4.1 framework as a guiding structure for the research, and explains the adaptation and application of its farm survey module. The chapter further discusses ethical considerations, reciprocity, researcher positionality, and the analytical process used to interpret farmers' and agricultural experts' perspectives.

5. **Farmers' Perspectives on Economic Indicators of Sustainable Agriculture:**

   Chapter Five explores farmers' views on the economic sustainability of their current farming practices, including income stability, production costs, market systems, and livelihood considerations influencing agricultural decision-making.

6. **Farmers' Perspectives on Environmental Indicators of Sustainable Agriculture:**

   Chapter Six explores environmental dimensions, including soil health, water use,

pesticide and fertiliser practices, residue management, and farmers' perceptions of ecological change.

7. **Farmers' Perspectives on Social Indicators of Sustainable Agriculture:**

   Chapter Seven focuses on social sustainability, including labour dynamics, knowledge exchange, community support, and broader social well-being within farming households.

8. **Experts' Perspectives:**

   Chapter Eight presents insights from agricultural experts from governmental and non-governmental organisations, highlighting governance challenges, extension systems, and institutional approaches to sustainability transitions.

9. **Discussion and Conclusions:**

   Chapter Nine brings together the findings across chapters to discuss the implications for sustainable agriculture transitions in Punjab. It develops bottom-up pathways for advancing the transition that balance productivity, environmental stewardship, and social well-being, and offers reflections and recommendations for policy and practice.

Chapter Two- Current Agriculture Practices in Punjab: Impact on the Economy, Environment and Social Well-being of the Farming Community

2.1 Introduction

To make India self-sufficient in food production post-independence, Punjab was strategically selected in the mid-1960s to pioneer the implementation of capital-intensive Green Revolution agricultural practices. This decision was based on its relatively stable and favourable climate conditions, good soil quality, pre-existing canal irrigation network, and a significant population of large landholders (Dutta, 2012). Under the Green Revolution package, the introduction of new high-yielding wheat and rice varieties, supported by essential infrastructure established by the state government, such as rural electrification, link road networks, market yards, minimum support price, and agricultural universities, led to significant success in grain production and brought enormous economic prosperity to the state and its citizens (Singh, 2000). As a result, the irrigated wheat-paddy cropping system became the dominant cropping pattern and continues to dominate Punjab's current agricultural practices.

This chapter explores current, post–Green Revolution agricultural practices in Punjab and discusses their economic, environmental, and social implications for farming communities, thereby addressing Research Objective 1.1. It also highlights how these impacts have contributed to growing sustainability concerns in Punjab agriculture over time.

2.2 Current Agriculture Practices in Punjab

The current agricultural practices in Punjab are still strongly linked to the Green Revolution practices, to contribute to making India self-sufficient in food production post-independence (Singh, 2000). Green revolution practices refer to a complex package of improved seeds and a wide range of management practices concerning the timing, rate and application of various inputs such as pest controls, fertilisers, and water to attain high yields (Huke, 1985).

In the context of Punjab, before introducing new and improved seed varieties, a supportive institutional framework was established, which played a crucial role in the success of the Green Revolution. This platform included the Punjab State Cooperative Supply and Marketing Federation, the Punjab State Warehousing Corporation, the Cooperative Agricultural Bank, the Mandi Board, and the Punjab Agricultural University[7]. These establishments were accompanied by state investments in rural electrification, tubewell irrigation, farm machinery, link road networks, market yards, agricultural credit societies, and incentivising policies, particularly the provision of remunerative support prices and assured procurement by government agencies (Dhillon et al., 2021).

Following these establishments, the first semi-dwarf wheat variety, PV18, derived from the Mexican Wheat germplasm, was released in Punjab in 1966, followed by another revolutionary wheat variety, Kalyan, in 1967 (Dhillon et al., 2021). The success of the semi-dwarf wheat variety led to the introduction of the semi-dwarf rice varieties. The conditions that favoured wheat production also contributed to the successful production of rice. The success of these two crops is referred to as the 'Green Revolution' (Dhillon et al., 2021).

Today, the same wheat-rice cropping system continues to dominate Punjab's cropping system, mainly due to the associated assured income for the production of these two crops (Department of Planning 2023). Consequently, their share of the total cropped area has increased over the years, as shown in Figure 2.1. In 1960-61, approximately 68% of the cropped area was dedicated to diverse crops, including millets (barley, bajra), maize, pulses, oilseeds, and others, with only 5% and 27% allocated to rice and wheat, respectively. However, by 2021-2022, the area for rice and wheat increased to 40% and 45%, respectively, while the area used for all other crops dropped to 15%.

[7] See Chapter 1, Section 1.3.3 for an overview of these institutions and their roles in Punjab's agricultural system.

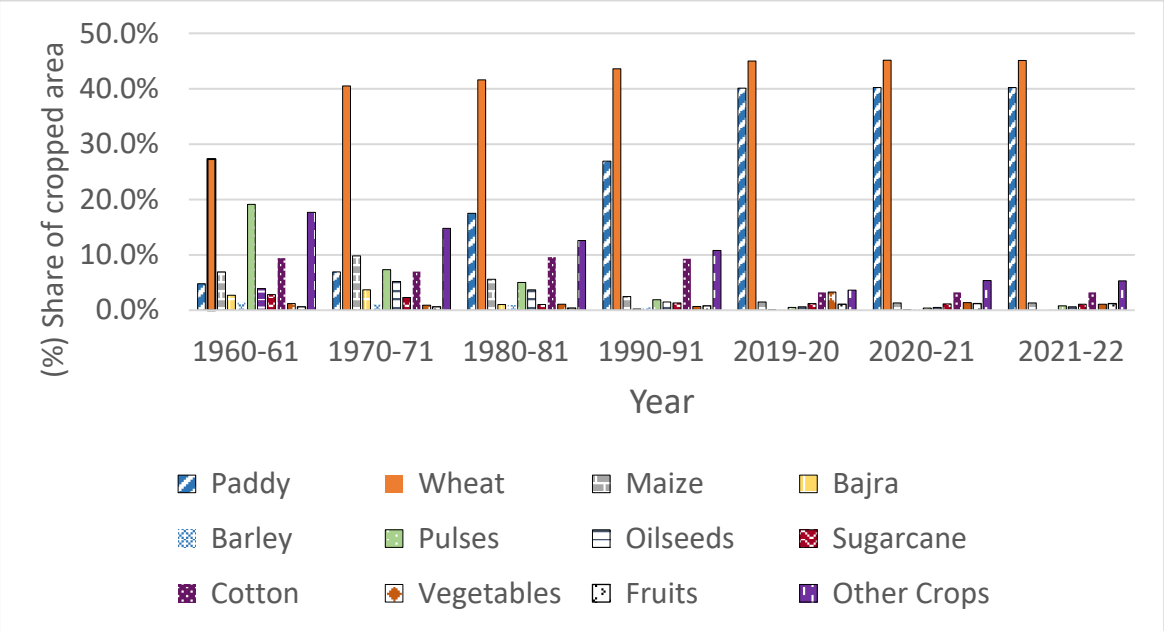


Figure 2.1: Crop-wise percentage share of cropped area. Source (Department of Planning 2023)

The following section highlights the impact of this shift in cropping systems on Punjab's economy, environment, and social well-being.

2.3 Impact of Current Agriculture Practices on Economic, Environmental, and Social Well-being

This section draws on existing literature, government reports, and statistical data to explore the economic, environmental, and social implications of the dominant agricultural practices in Punjab.

2.3.1 Impact on the Economy

To investigate the impacts on the economy, I analysed three common indicators of the economic impact of agricultural practices:

a) Crop yield: The yield gains from major crops per hectare, since the yield gain directly influences farm income,

b) Gross State Value Added (GSVA): The trend in the percentage share of GSVA at a constant price in Punjab, and

c) Workforce in agriculture: The changes in the workforce involved in agriculture and allied activities.

These metrics are described in detail below and were also used in the Punjab Economic Survey (2023) to measure the performance of the agricultural sector and its economic growth, which informed my approach.

a) Crop Yield – The Green Revolution primarily targeted wheat and rice cropping systems. Figure 2.2 shows the area (in hectares) and yield gain (in kg/ha) for both crops in Punjab from 1950 to 2022. The figure shows that yield gains and cultivated areas for wheat and rice increased steadily after the introduction of the Green Revolution package in the 1960s. However, since the 2000s, both the area under cultivation and yields of wheat and rice have plateaued. Despite this, Punjab continues to be India's 'breadbasket', producing higher yields than the rest of the country, as shown in Figure 2.3. This could be attributed to factors such as suitable weather conditions, water availability, and fertiliser use. These factors are further analysed in the sub-sections of the 'Impact on Environment' section.

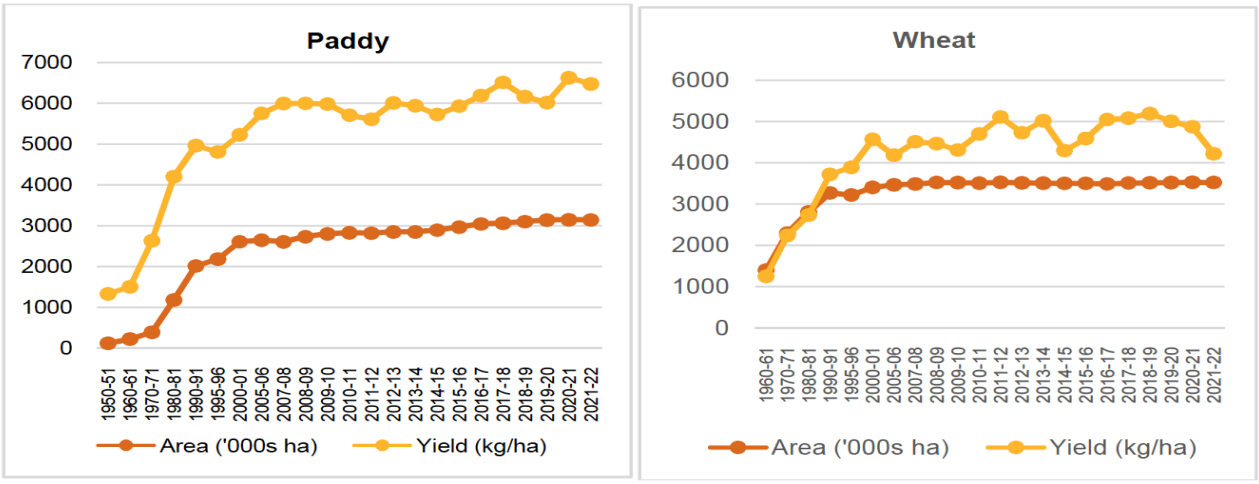


Figure 2.2: Area and yield of paddy and wheat in Punjab. Source (Department of Planning 2023)

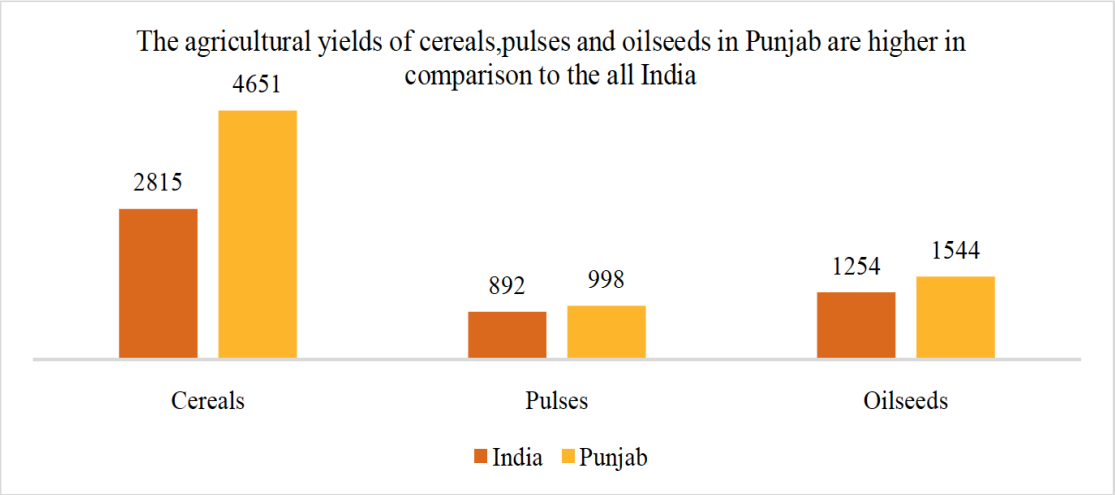


Figure 2.3: Crop-wise yields in Punjab and India, 2020-21 (in Kgs/hectare). Source (Department of Planning 2023)

b) Gross State Value Added (GSVA) – According to the OECD Factbook (OECD, 2011), Gross Value Added measures the contribution to Gross Domestic Product (GDP)[8] made by an individual producer, industry or sector. The impact of Green Revolution practices on Punjab's GSVA is shown in Figure 2.4. In the 1970s, agriculture and allied sectors alone accounted for 57.43% of the total GSVA. This agricultural value made Punjab a prosperous state, improved the socio-economic condition of the farmers, and earned it the status of 'bread basket of India' (Dutta, 2012). However, this contribution has steadily declined, dropping to half by 2004 and further reducing to 15.37% by 2017.

On the other hand, the services sector has been growing since 1993 and is currently the leading sector of Punjab's economy. The Department of Planning (2023) noted that relying on wheat and rice cultivation is unlikely to be the source of future growth in the agriculture sector. Instead, crop diversification and allied sectors could be the way forward.

[8] 'GDP is the final value of the goods and services produced within the geographic boundaries of a country during a specified period of time, normally a year.' The Economic Times (2024). What is 'Gross Domestic Product'. *The Economic Times*. https://economictimes.indiatimes.com/definition/gross-domestic-product#

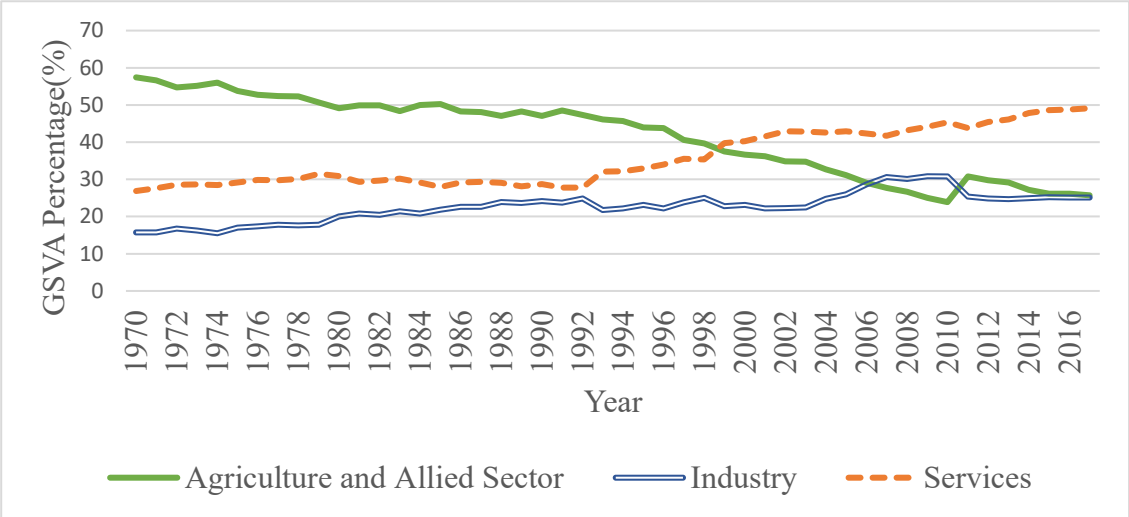


Figure 2.4: Percentage Distribution of Gross State Value Added at Constant Prices in Punjab from 1970 to 2017. Source (Open Government Data Portal Punjab 2020)

c) **Workforce in Agriculture**: As the percentage share of agriculture and allied sectors in GSVA[9] has declined in the post-Green Revolution era, so has the agricultural workforce. In total, the rural agrarian workforce declined by 11% from 2001 to 2011, including cultivators, labourers, and those involved in allied activities.

Figures 2.5 (a-b) compare the rural workforce engaged in agriculture and allied activities by age group, as recorded in the 2001 and 2011 censuses. The decline in the number of cultivators, particularly among the 15-39 age group, and the sharp decline in allied activities across all age groups, indicate reduced profitability in agriculture compared to other sectors. Specifically, there was a 67% drop in rural engagement in allied activities, from 530,515 individuals in 2001 to 172,500 in 2011. In contrast, urban engagement in allied activities increased by 43%, from 39,920 individuals in 2001 to

[9] Gross State Value Added (GSVA)

57,038 in 2011. The available literature provides limited discussion of the factors contributing to the sharp decline of rural engagement in allied activities.

However, the Department of Planning (2023)notes that as agricultural growth reaches a plateau, many farmers, especially small and marginal ones, are selling their land to send their children abroad or migrate to cities for better lifestyles and employment opportunities. It is also important to note that India's 2021 national census had not been conducted at the time of this research; therefore, more recent workforce data were not available to provide insights into the current workforce structure (NDTV, 2024).

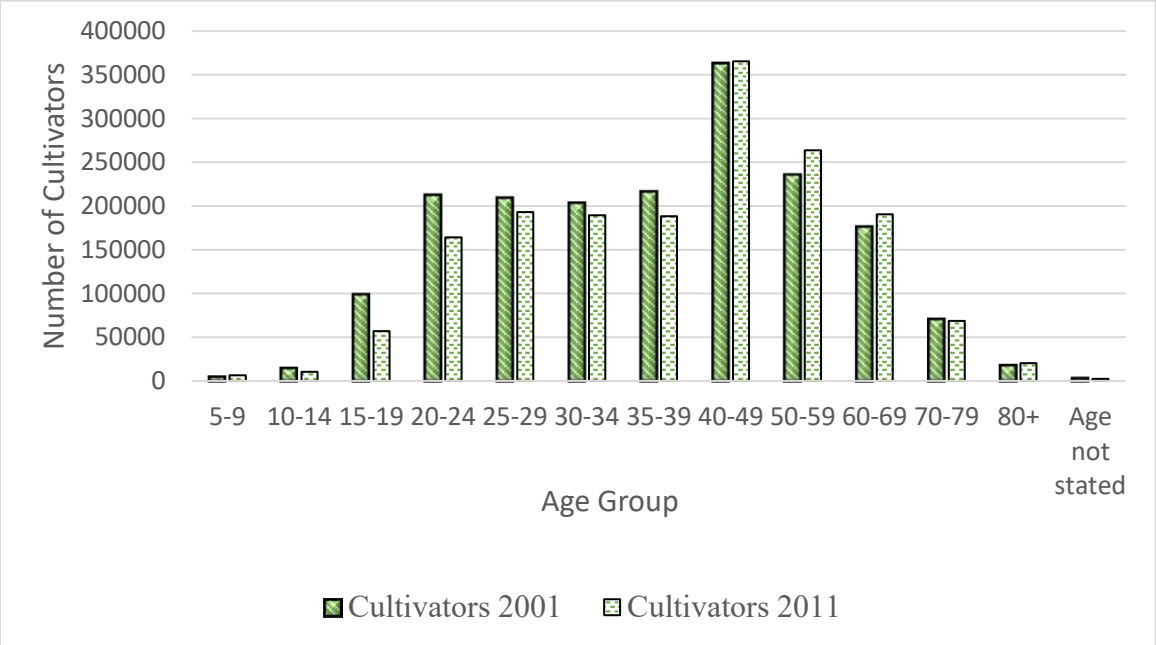


Figure 2.5(a): Number of cultivators in rural Punjab by age group, 2001 and 2011 census. Source (Open Government Data Portal Punjab 2020)

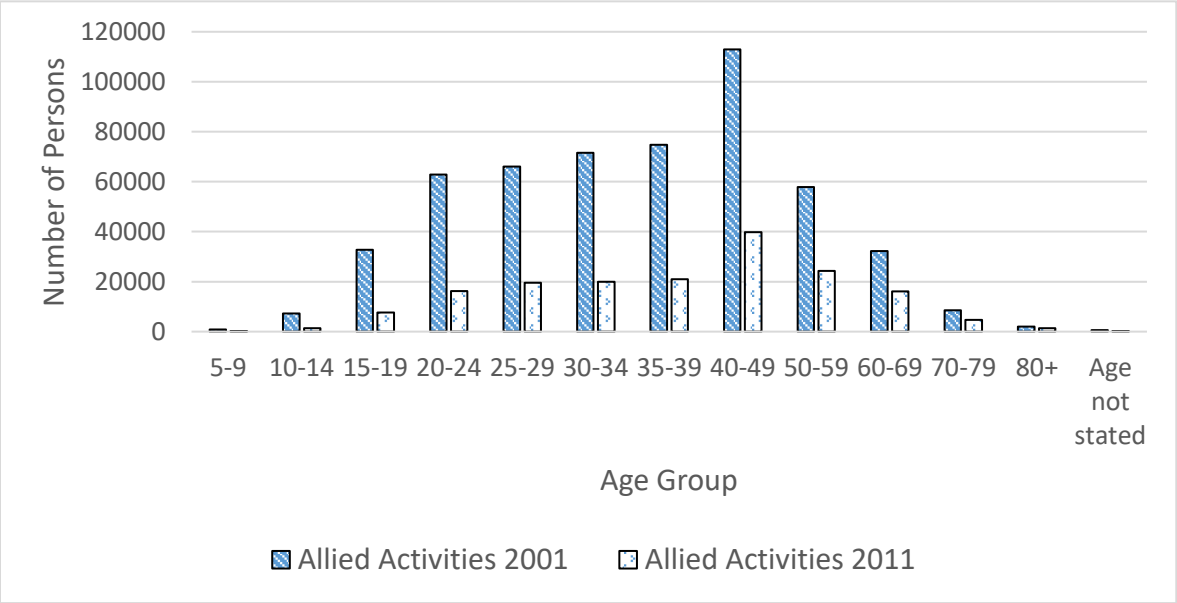


Figure 2.5(b): Number of individuals in rural Punjab engaged in allied activities by age group, 2001 and 2011 censuses. Source (Open Government Data Portal Punjab 2020)

2.3.2 Impact on Environment

To explore the effect of current agricultural practices on the environment, this section assesses the status of three key natural resources closely linked to farming: water, soil, and air. These indicators are selected based on their recognised use in assessing environmental sustainability in agricultural systems (FAO, 2017; OECD, 2001).

a) **Impact on Groundwater Levels and Quality** – Almost the entire cropped area (99%) of Punjab is under irrigation, significantly higher than the all-India average of 54% (STATISTICS, 2020). Water for this extensive irrigation network primarily comes from surface water canals (28%) and tubewells (72%), powered by either diesel or electricity (Department of Planning 2023). Producing the main crops of Punjab, rice and wheat,

requires 3,000–5,000 litres and 1,500–2,500 litres of water per kilogram, respectively (Bouman et al., 2002).

The impact of such extensive water use is assessed in the Groundwater Assessment Report (2024), periodically conducted by the Central Ground Water Board (CGWB) and the State Ground Water Department. The report indicates that annual extractable groundwater is 16.98 billion cubic meters (bcm), while annual groundwater extraction is 27.8 bcm. This level of over-extraction has lowered groundwater levels, with 117 blocks in Punjab classified as over-exploited, 13 as semi-critical, and 3 as critical, as illustrated in Figure 2.6.

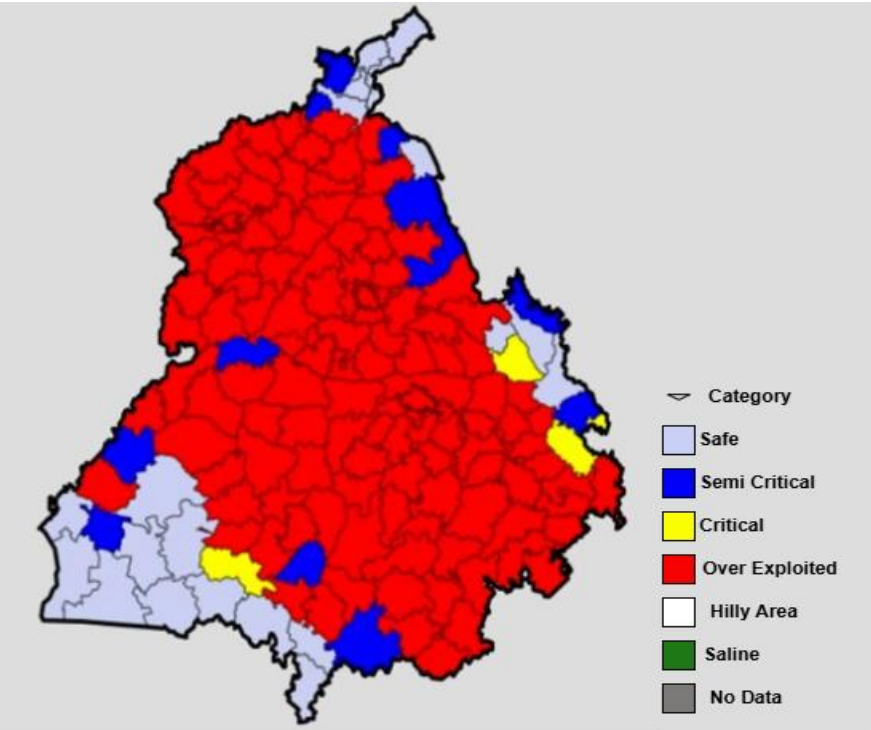


Figure 2.6: Categorisation Map of Punjab. Source (Central Ground Water Board 2024)

Regarding groundwater quality, the CGWB[10] also conducted a study on the quality of groundwater in shallow aquifers in Punjab. The Central Ground Water Board (2024) report shows that water in northern and central areas of Punjab is of suitable quality for drinking and irrigation. However, in the southern and southwestern

[10] Central Ground Water Board

regions, water quality is unsuitable due to high concentrations of either salinity or chloride[11], fluoride, nitrate[12] or a combination of these contaminants. High fluoride levels are particularly found in areas with intensive agricultural activity, possibly due to the use of insecticides, disinfectants, preservatives, or phosphatic fertilisers containing fluoride impurities. This unsuitable quality makes it unfit for irrigation purposes. In the southern and southwestern districts of Punjab, 16% of groundwater samples show very high nitrate concentrations (above 100 mg/l).

High concentrations of contaminants not only affect soil and crop yields but can also have severe impacts on human health. Very high nitrate concentrations can cause infant methemoglobinemia (blue babies)[13], gastric cancer, and adverse effects on the central nervous and cardiovascular systems (Brender, 2020; Majumdar, 2003).

Figures 2.7(a–b) and 2.8(a–b) illustrate locations where different water quality parameters exceed permissible limits. Muktsar, Mansa, Faridkot, and Bathinda – the four Districts to the south of the State - are identified as facing the most severe environmental health crises (Blaurock-Busch et al., 2014). Greying of hair, arthritis, and both skeletal and dental fluorosis are common health problems in those areas (Central Ground Water Board 2014).

[11] 'In ground water the chloride content is mostly below 250 mg/L except in cases where inland salinity is prevalent. However, groundwater having a concentration of chloride more than 1000 mg /L are not suitable for drinking purposes.' Central Ground Water Board (2024). *Dynamic Ground Water Resources, 2023 Punjab*.

[12] 'Nitrate in groundwater generally originates from non-point sources such as leaching of chemical fertilizers & animal manure, groundwater pollution from septic and sewage discharges etc. It is difficult to identify the natural and man-made sources of nitrogen contamination of ground water.' ibid.

[13] 'Blue baby syndrome, also known as infant methemoglobinemia, is a condition where a baby's skin turns blue. This occurs due to a decreased amount of hemoglobin in the baby's blood. When the blood is unable to carry oxygen around the body, the baby turns blue.' Galan, N. (2018). What is blue baby syndrome. *Medical news today*.

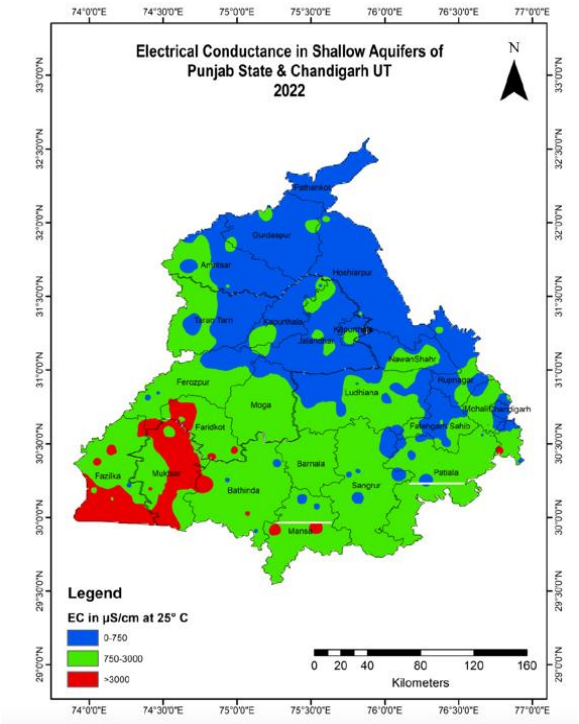


Figure 2.7(a) Map showing areas of salinity and chloride-contaminated groundwater in Punjab. Source: (Central Ground Water Board 2024)

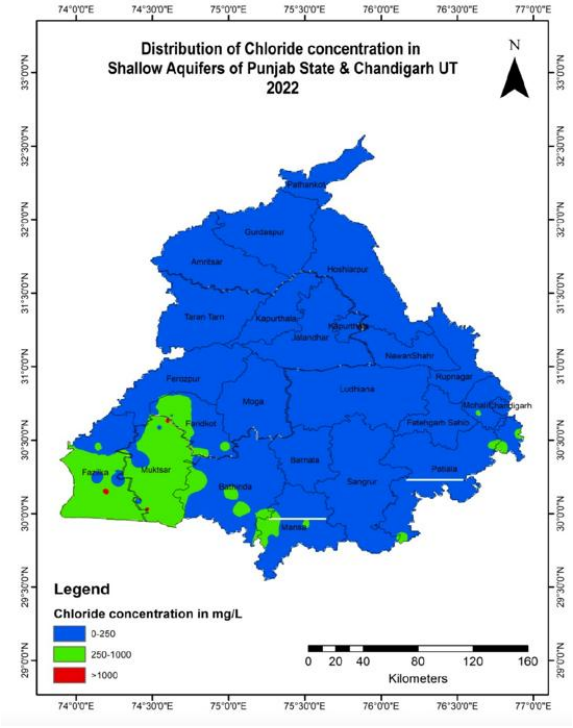


Figure 2.7(b) Map showing areas of chloride-contaminated groundwater in Punjab. Source: (Central Ground Water Board 2024)

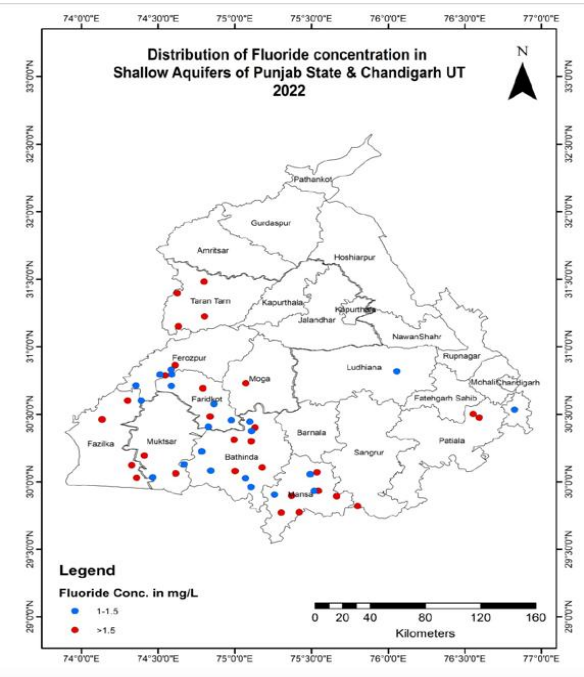


Figure 2.8(a) Map showing areas of fluoride-contaminated groundwater in Punjab. Source: (Central Ground Water Board 2024)

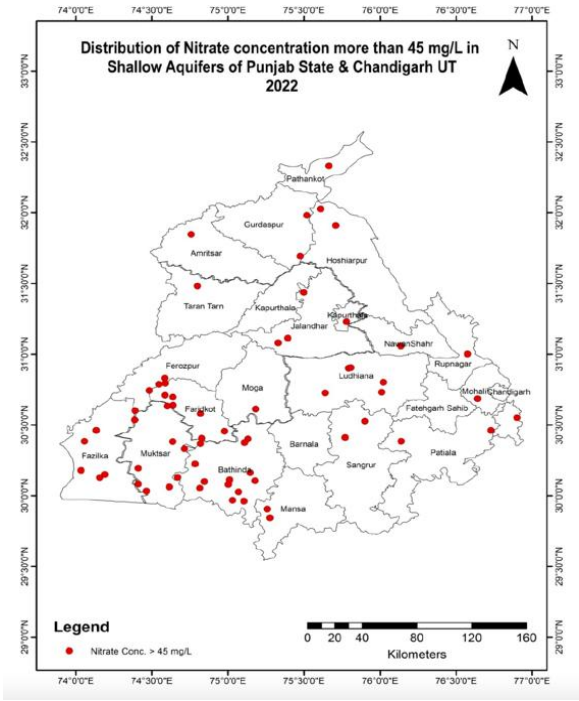


Figure 2.8(b) Map showing areas of nitrate-contaminated groundwater in Punjab. Source: (Central Ground Water Board 2024)

b) Soil Health: To assess Punjab's soil health post-green revolution, Dhillon et al. (2021) conducted a study using a large number of soil and food commodity samples across the state over the decade. Similarly, Sharma et al. (2016) analysed 568 georeferenced soil samples to map soil fertility status using a Geographic Information System (GIS). Both studies concluded that soil organic carbon content, crucial for soil fertility, remains low to medium across Punjab. However, despite substantial potassium (K) removal by the intensive rice-wheat cropping system, there appears to be no immediate K deficiency issue in Punjab soils. (Sharma et al., 2016) reported that the most suitable *pH* values for most of the crops (between 6.5 and 8.7) were present in 95% of samples.

However, (Dhillon et al., 2021) highlighted an imbalance in fertiliser usage ratios in Punjab, aimed at producing more food, not as required by the semidwarf seed varieties of wheat and rice. A similar issue was reported in the Punjab Economic Survey (2023), which indicated that while the ideal Nitrogen, Phosphorus, and Potassium ratio is 4:2:1, Punjab recorded a ratio of 26.9:6.9:1 in 2020-21. Continuous and overuse of chemical fertilisers decreases soil organic matter and beneficial organisms, increases pests, and restricts plant growth. Another aspect of the adverse soil health impact was soil compaction[14] and hardpan[15] formation caused by wetland cultivation (puddling) of rice. Puddling-induced soil structure changes make it difficult to regenerate the structure for the dryland crops following wetland rice (Kalita et al., 2020).

(Dhillon et al., 2021) recommends the regular application of organic manure and crop residues to address the low organic content, diversifying the cropping pattern, and replacing rice on substantial acreage as urgent requirements for agricultural

[14]'Compaction takes place when the soil structure created by the living organisms collapses. Unable to support the rich range of life forms so necessary to a productive soil. Amdrews, C. (2023). *Hardpans – a focus upon those created by human activity*.
https://www.tiyeni.org/static/924f9915f362b8aa16d2991f2ee1747a/hardpans_explainer-piece.pdf
[15] 'Hardpan can be an extreme form of compaction. It is extreme because it takes place over a wide area'ibid.

sustainability. They also emphasise the need to develop strategies to ensure natural soil nutrient recycling, which is currently disrupted by the export of over 80% of crop produce from the state.

c) **Impact on Air Quality:** During the post-harvesting period in Punjab, 42% of the total crop residue, primarily paddy residue, is openly burned in agricultural fields. This is done mainly because paddy residue cannot be used as cattle feed due to its high silica content (Jaiswal et al., 2020). The short gap of 10 to 20 days between harvesting paddy and sowing wheat leaves farmers with few options other than burning the crop stubble (Pandya et al., 2022). Open burning emits various pollutants, including volatile organic compounds and particulate matter, and produces toxic clouds that degrade air quality, visibility, health, and climate (Saggu et al., 2018).

To evaluate the impact of pollutants emitted by agricultural activities, Singh et al. (2021) conducted a study in Fatehgarh district, located in the southeastern part of Punjab. They assessed particulate matter, also known as particle pollution, specifically PM_{10}[16] and $PM_{2.5}$[17] during three main phases of agricultural activities: harvesting-burning period (HB), burning-tillage-sowing period (BTS), and pesticide-fertiliser spray period (PFS). Their findings indicate that particulate matter levels during these phases significantly exceed the annual national ambient air quality standards of 60 ug/m^3 for PM_{10} and 40 ug/m^3 for $PM_{2.5,}$ as shown in Table 2.1(TaransportPolicy.net, 2018). Exposure to these particulates can adversely affect cardiovascular and respiratory health, leading to serious health issues (NSW Health, 2020). PM2.5, in particular, is associated with premature mortality depending on exposure levels and toxicity (Health, 2020).

[16] 'These particles are small enough to pass through the throat and nose and enter the lungs' Health, N. (2020). Particulate matter (PM10 and PM2.5).
[17] 'These particles are so small they can get deep into the lungs and into the bloodstream'. Ibid.

Table 2.1: Levels of pollutants during the three main phases of agricultural activities in Punjab. Source (Dhillon et al., 2021)

Pollutants	HB	BTS	PFS
PM_{10} (μgm^{-3})	151.0 ± 52.3	92.5 ± 38.8	121.7 ± 49.1
$PM_{2.5}$ (μgm^{-3})	94.7 ± 32.9	63.5 ± 28.4	87.8 ± 35.5

Ravindra et al. (2022) monitored the impact of air pollutant $PM_{2.5}$ on the health of the residents of the same Fatehgarh district in 2016. Their research found that, out of a total of 2582 deaths reported at Civil Hospital Fatehgarh from all natural causes, 246 premature deaths were attributable to short-term exposure to elevated $PM_{2.5}$ levels. They argued that these deaths could have been prevented if particle pollution levels had not exceeded recommended guidelines. The study also noted that hospital admissions at major public health facilities were highest in October, a crop-residue-burning month.

Similarly, Saggu et al. (2018) examined the effects of particulate matter on respiratory health by conducting pulmonary function tests (PFTs) on 150 schoolchildren (ages 10-16) in the Malwa region from September 2014 to December 2015. The study observed fluctuations in PFT parameters, Forced Vital Capacity[18], and Forced Expiratory Volume[19] before and after the crop residue burning period. Values of these parameters decreased during burning periods (October-November and April-May) and subsequently recovered in January and February. The authors noted that declines in pulmonary function in childhood are serious health concerns and should not be underestimated, as even small decreases in lung function may have long-term

[18] David, S., & Sharma, S. (2019). Vital capacity.
[19] David, S., Goldin, J., & Edwards, C. W. (2024). Forced expiratory volume. In *StatPearls [Internet]*. StatPearls Publishing.

implications for the development of chronic disease later in life. The study highlights the need for large-scale observational epidemiological studies to explore further the impact of ambient air pollutants on respiratory health.

Moreover, (Ranguwal et al., 2023) quantified greenhouse gas emissions - specifically carbon dioxide, nitrous oxide, and methane - from major crops, including cotton, maize, paddy, wheat and sugarcane, before and after cultivation activities based on 2019–2020 data from 300 farm households across 30 tehsils (town) in Punjab. Their findings show that paddy emitted the highest CO_2 equivalent emissions (6718 kg CO_2 eq. ha^{-1}) among the crops studied, with approximately 60% of these emissions contributed solely by methane (3850 kg CO_2 eq. ha^{-1}), due to paddy cultivation in submerged water. Although methane does not cause direct harm to human health or crop production, it is a primary contributor to the formation of hazardous air pollutants, tropospheric ozone (O_3), which is linked to about 1 million premature respiratory deaths globally (Climate & Clean Air Coalition n.d.).

In response to some of these challenges, the national government banned residue burning in 2015 (Press Information Bureau, 2019). However, to evade penalties, farmers often irrigate the fields after burning to hide the burnt area (Sharma et al., 2016). The state government has set up a Paddy Straw Challenge Fund, offering a USD 1 million award to identify an appropriate technology to address crop residue burning. Financial assistance has also been provided to individual farmers and cooperative societies from 2018-2019 to 2021-22 to purchase agricultural machinery for crop residue management (Department of Planning 2023). However, these efforts have seen limited success, as burning remains a cheaper and faster means of residue disposal compared to recommended alternatives, given the narrow window between harvesting and sowing periods (Department of Planning 2023).

From my own experience during the fieldwork period, particularly between the last two weeks of November and early December - the peak crop residue burning season - air quality in the region deteriorated severely. After approximately 3 p.m., dense smoke and visible black clouds filled the air, making breathing outdoors extremely difficult. It was necessary to keep doors and windows closed to reduce exposure to the smoke. These conditions raise concerns about the prolonged exposure of residents, particularly young children, to such air quality each year and the potential health implications of this exposure. Further discussion of farmers' perspectives and local experiences related to air pollution is presented in Chapter 6.

2.3.3 Impact on Social Well-being

The implementation of the green revolution techniques indeed brought significant economic success to the state in terms of grain production and raised the socio-economic standards of the rural communities. However, it disrupted the traditional cycle, where agricultural communities previously engaged in a mix of subsistence-based and commercial agriculture, and shifted predominantly to commercial practices (Sangha, 2014). Over time, these shifts contributed to several challenges affecting the social well-being of farming communities. In particular, the increasingly capital-intensive and slowing growth of agriculture has been associated with the following social outcomes:

a) **Indebtedness**: Iindebtedness occurs when repayment becomes challenging, leading borrowers to sell assets to manage their debt (Singh et al., 2017). The surplus generated after accounting for production costs and domestic expenses is referred to as the debt-serving capacity, which indicates a farmer's financial status (Singh et al., 2014).

Singh et al. (2014) conducted a study involving 300 farmers across six districts of Punjab to examine the magnitude and determinants of indebtedness, as well as the debt-servicing capacity of farmers in Punjab. The study found that the average sampled

farming household owes Rs 4,74,215.99[20], of which 70.02% is allocated to purchasing farm inputs and machinery. This proportion of debt increases as farm sizes grow, and the remaining percentage is allocated to other domestic needs. The situation of the marginal farmers is particularly concerning, as their debt-serving capacity was negative by Rs. 4,953[21]. This indicates that these farmers cannot even cover their domestic expenses with their generated income. Small farmers in the state have some capacity to repay their debt, but it is insufficient to repay their outstanding debt fully. The reliance on market-purchased inputs, such as machinery, fertilisers, and pesticides, makes agriculture increasingly expensive, particularly for small- and marginal-scale farmers (Singh et al., 2017).

According to the sampled farmers in Singh et al. (2014) study, one of the main reasons for their indebtedness was the low prices of farm produce and low profit margins due to stagnant crop productivity and high interest rates charged by commission agents. 80% of the sampled farmers view availing institutional or bank loans as complicated and time-consuming. Other contributing factors include high expenditures on healthcare, education, house construction, and social ceremonies.

b) Depeasantization: Depeasantization refers to processes through which farming households move away from land-based livelihoods and agricultural production under changing economic and institutional conditions. These processes may occur through multiple pathways, including increasing dependence on markets, rising production costs, technological shifts associated with modern agricultural systems, debt cycles, or the displacement of farming communities by external actors (Rosset & Ule Muñoz, 2025).

[20] Converted to NZD. Value is NZD 8,869.75 - with the rate of 53.46 The Money converter. (2026). *Convert from New Zealand Dollar (NZD) to Indian Rupee (INR)*. https://themoneyconverter.com/NZD/INR
[21] Converted to NZD. Value is NZD 92.64 - with the rate of 53.46 ibid.

In the context of Punjab, evidence from literature suggests a gradual shift away from farming. The Statistical Abstract of Punjab (2022) reports a 21% decline in total operational holding in 2015-16 compared to that in 1970-71. Specifically, marginal (< 1ha), small (1-2ha) and large (>10ha) land holdings have declined by 70%, 20% and 16% respectively.

Several factors could have contributed to this decline. To explore the reason for 'farmers-leaving-farming', Singh et al. (2009) conducted a study involving 589 farmers from 40 villages, with two villages randomly selected from each district of the state. The study found that 71.4% of marginal farmers, 59.9% of small farmers, and 58.2% of medium farmers cited low income from farming as a primary reason. This was followed by land subdivision, which diminishes the viability of holding below four hectares due to capital-intensive, highly mechanised agriculture. Debt repayment and high land lease rates were also significant factors contributing to the decision to leave farming.

Similarly (Singh & Bhogal, 2014) interviewed 288 farmers from 12 villages who had left farming since 1991. The study found that the primary reasons for those farmers leaving agriculture were similar to those identified in (Singh et al., 2009): non-profitable, high land lease rates, transitioning to another profession.

c) **Farmer suicides**: The National Crime Records Bureau (2022) reported 157 farmer deaths in its most recent publication for 2022. The frequency of suicide among Punjab farmers has increased since 2015, with a spike from 2017 to 2019, as shown in Figure 2.9.

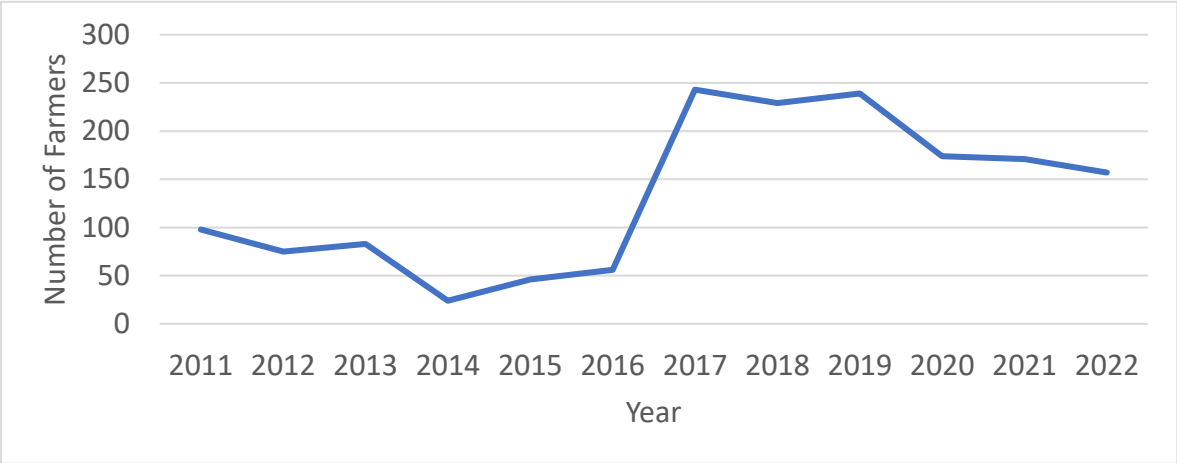


Figure 2.9: Number of Punjab Cultivators who committed suicide. Source (National Crime Records Bureau 2022)

Taki et al. (2021) reviewed verbal autopsy data collected by Baba Nanak Education Society (BNES), a local non-governmental organisation based in Punjab, from 2473 families across 102 villages, of which a family member had committed suicide. The review identified indebtedness and marginal land holdings as the primary reasons for the suicides. In contrast, Saini (2022), through interviews with 1000 farmers in Punjab, found that the push factors to lead them towards suicide are: crop loss, rising input costs, income volatility, declining productivity, market-related issues, lack of insurance, compensation, and infrastructure. These factors cause them greater distress than indebtedness alone.

Alongside economic pressures, the literature also highlights a shift in the social organisation of agriculture in Punjab as a contributing factor to farmer distress and suicides. Earlier, farming was embedded in community-based practices that provided both practical and emotional support; however, the transition to input-intensive and market-oriented agriculture has increasingly shifted decision-making and risk to the level of individual farmers (Gill, 2005; Singh, 2020). The decline of traditional community support mechanisms, combined with economic stress, creates a cycle of vulnerability in which farmers are left to cope with debt, crop failure, and uncertainty in relative isolation,

thereby intensifying psychological stress and contributing to distress outcomes, including suicides (Aggarwal & Bakht, 2024).

Addressing this crisis, therefore, requires not only economic measures but also stronger social support systems, including mental health support, and more sustainable agricultural practices (Aggarwal & Bakht, 2024). In addition, as emphasised by Gill (2005), economic development in the region needs to be participatory in nature to ensure that its benefits reach vulnerable sections of farming communities.

d) **Increased rate of Emigration:** Between 2016 and 2021, 984,000 people moved from Punjab to other countries (Rampal & Agarwal, 2022). To understand the trend and the causes of this increasing emigration from rural Punjab, Punjab Agricultural University conducted a study (2023) of 1,300 households across 44 villages. The study found that among 640 migrant households in those villages, 71.88% were primarily engaged in agriculture. Participants cited several main factors influencing their decision to migrate, including declining educational quality and the agricultural system, unemployment, low income, lawlessness, and corruption.

The study also highlighted that small farmers released by the agricultural sector were not being absorbed into other industries. As a result, unemployment is at an all-time high, leading to widespread distress among farmers and agricultural labourers in rural Punjab. Additionally, (Rai & Kaur, 2019) noted that social factors, alongside economic ones, are contributing to pushing youth away from farming. These social factors include the perception of farming as a low-status occupation, farmers' reluctance to have their children pursue agriculture due to the hardships they have faced, and the consideration that it is better to migrate to cities to do even menial jobs.

2.4 The Transition to Sustainable Agriculture in Punjab

The literature reviewed in the above section indicates that although the Green Revolution enabled Punjab to achieve remarkable yield gains, particularly within the wheat-rice cropping system, it has also led to a range of long-term economic, environmental, and social challenges. Importantly, these concerns have not emerged suddenly but have evolved progressively over several decades. Studies from the 1980s already highlighted the risks of soil degradation and increasing pressure on groundwater resources associated with intensive agricultural practices in Punjab, as well as the need to move beyond a primary focus on production towards more integrated management of agricultural systems to sustain agricultural growth (Kanwar, 1982; Swaminathan, 1982) (Bowen, 1985; Sahuquillo, 1985; Vaishnav, 1983).

Subsequent research in the 1990s and 2000s continued to build on these concerns, documenting environmental degradation, stagnation in productivity, and increasing agrarian distress, while also proposing a range of alternative techniques aimed at improving resource-use efficiency and reducing pressure on natural resources. The recommendations included shifts in cropping patterns, direct-seeded rice method, precision irrigation techniques, and rainwater harvesting for groundwater recharge (Aggarwal et al., 2009; Sidhu et al., 2010). In more recent years, these concerns have further intensified with the growing impacts of climate change. Climate variability is increasingly affecting water availability, crop productivity, and increasing uncertainty and risk at the farm level, thereby reinforcing the need to transition towards more resilient agricultural systems (Gupta et al., 2021; Sidhu et al., 2011; Srivastava et al., 2016).

Sustainable agriculture is not only being discussed in academic discourse, but there have also been important efforts at both the state and national levels. In Punjab, recent policy initiatives have emphasised crop diversification, improved water-use efficiency, and the adoption of resource-conserving technologies as key priorities for ensuring long-term sustainability (Agricultural Policy Formulation Committee, 2023). At the national level, initiatives such as the National Mission for Sustainable Agriculture and the Soil Health Card

scheme reflect efforts to promote climate-resilient and resource-efficient farming practices (Ministry of Agriculture & Farmers Welfare, 2023; Press Information Bureau, 2025) (Press Information Bureau, 2018).

These developments also align with broader global efforts to promote sustainable agriculture, particularly under the United Nations Sustainable Development Goals. Target 2.4 specifically calls for ensuring sustainable food production systems and resilient agricultural practices that not only increase productivity but also maintain ecosystems, strengthen climate resilience, and improve land and soil quality by 2030 (United Nations, 2015a). However, FAO assessments highlight that data on SDG Target 2.4 remains limited, as many countries, including India, face challenges in collecting detailed farm-level data required to measure agricultural sustainability effectively due to limitations in data systems, survey design, and implementation capacity (FAO, 2019b, 2020a).

To address this, the United Nations Statistical Commission recommends the use of proxy indicators as a practical interim solution (United Nations, 2024). In this light, India has developed a set of indicators to monitor progress towards Target 2.4, including measures such as the proportion of net sown area to cultivable land, the percentage of farmers issued Soil Health Cards, and the extent of area under organic farming (MOSPI, 2025). These indicators reflect a policy-level commitment to improving agricultural sustainability through resource management, soil health monitoring, and the promotion of alternative farming practices.

However, despite the presence of such frameworks, the latest SDG India Index report (2024) did not report any inputs on these indicators and instead focuses on broader measures such as crop productivity and food security. This indicates gaps in the monitoring and evaluation of agricultural sustainability at the national level. In this context, there remains comparatively limited empirical research that systematically captures how farmers themselves understand sustainability, the extent to which current practices align with sustainability goals,

and the practical constraints they face in transitioning towards more sustainable systems (FAO, 2015; Jim Woodhill et al., 2022; Zeweld et al., 2020). This gap highlights the need for more grounded, farm-level research that can better connect policy frameworks and sustainability indicators with the lived realities of farmers.

To contribute to this need, this study uses the FAO SDG 2.4.1 indicator framework that enables the assessment of agricultural practices across economic, environmental, and social dimensions, allowing for a more comprehensive understanding of farming systems. By applying indicators of this framework within a qualitative-dominant research design, this study generates detailed insights into current agricultural practices adopted by Punjab farmers, while also capturing region-specific issues such as crop residue burning and intensive groundwater use. In doing so, this study provides a context-specific understanding of how sustainability challenges and opportunities are perceived and experienced by farmers in Punjab, and assesses their capacity to contribute to the transition within the context of existing support systems. Building on these insights, the study also outlines potential bottom-up pathways for transitioning towards more sustainable agriculture practices by integrating perspectives from both farmers and experts.

2.5 Conclusion

Punjab farmers pioneered the Green Revolution, which promoted agricultural practices in the mid-1960s, accounting for 57.43% of Punjab's Gross State Value Added (GSVA) at that time. This brought substantial economic prosperity to the state. However, over time, the resource-intensive nature of the introduced wheat and rice cultivation practices has posed challenges across all three dimensions of agriculture: economic, environmental, and social well-being.

The contribution of the agriculture sector to GSVA has since declined to 25.74%, with the service sector currently leading the state’s economic activity with a contribution of 49.12%.

In terms of natural resources, 117 of 150 water blocks are overexploited, and water from the southern and southwestern regions is unsuitable for irrigation and drinking. Greenhouse gas emissions and pollutants, particularly from crop residue burning, are severely impacting air quality and human health, and contributing to climate change. Additionally, the increasing cost of inputs and decreasing profit margins in commercially oriented intensive agriculture are leading to an increase in youth migration from rural Punjab and, unfortunately, contributing as a push factor to farmer suicides.

Taken together, the findings highlight that the challenges associated with Punjab's agricultural system have evolved progressively over time and have become more intensified under the pressures of climate change. This underscores the urgent need to safeguard natural resources, livelihoods, and the social well-being of farming communities, while ensuring sustainable economic returns. The United Nations Sustainable Development Goals, particularly target 2.4 of Goal 2 Zero Hunger, advocate for transitioning to sustainable food production systems and resilient agricultural practices (United Nations, 2015a). These practices aim not only to enhance productivity and production but also to preserve ecosystems, strengthen adaptation capacities, and improve land and soil quality.

In the following chapters, I aim to explore the adoption of sustainable agricultural practices in the Punjab agricultural landscape. I will assess how much information about the urgency of transitioning to sustainable agriculture, as well as the necessary support and resources for a successful transition, reaches farmers in Punjab. By gathering perspectives from farmers, researchers, extension officers, and government officials, I aim to comprehensively understand the feasibility, enablers and barriers to successfully transitioning to sustainable agriculture in Punjab.

Chapter Three – Sustainable Agriculture: Concepts and Policy Context in India

3.1 Introduction

This chapter explores sustainable agriculture through its conceptual foundations and policy context in India, with a focus on Punjab. It begins by outlining the concept and key principles of sustainable agriculture, emphasising the need to balance economic viability, environmental sustainability, and social well-being within agricultural systems. In doing so, the chapter establishes a conceptual basis for understanding sustainability transitions in agriculture.

The chapter then situates these concepts within India's national policy landscape, focusing on major initiatives such as the National Mission for Sustainable Agriculture (NMSA) and related programmes aimed at promoting resource-use efficiency, climate resilience, and sustainable farming practices. It further explores how these national policy frameworks interact with the structural, economic, and environmental conditions of Punjab's agricultural sector. This provides a critical foundation for understanding how sustainability initiatives are interpreted, adopted, or constrained at the farm level.

Accordingly, this chapter provides:

- an overview of the conceptual foundations and principles of sustainable agriculture;
- a discussion of India's policy context for sustainable agriculture; and
- an analysis of the Punjab policy context for sustainability transition.

3.2 Sustainable Agriculture: Concept and Principles

The Food and Agriculture Organisation of the United Nations (FAO) describe sustainable agriculture as an approach that meets the needs of present and future generations while ensuring profitability, environmental health, and social and economic equity (FAO, 2015). From this perspective, sustainability is not limited to increasing production levels, but also

concerns the viability of farmers' livelihoods, the responsible management of natural resources, and the long-term functioning of agricultural systems. FAO (2015) promotes sustainable food and agriculture as a central pathway for achieving Zero Hunger (SDG2) and contributing to broader Sustainable Development Goals linked to livelihoods, resource stewardship, and resilience, particularly in regions where agriculture remains the backbone of rural livelihoods.

FAO further explains that agriculture becomes unsustainable when it fails to support the people whose livelihoods depend on it. This can occur when farming systems rely on outdated practices, when farmers have limited access to land, water, inputs, or markets, or when agriculture does not provide decent and secure employment. Such conditions often increase farmers' economic vulnerability and contribute to environmental degradation, rather than supporting long-term development (FAO, 2015).

To guide the transition towards more sustainable agricultural systems, FAO outlines five core principles that balance economic, environmental, and social objectives (FAO, 2015):

1. **Improving efficiency in the use of resources:** This emphasises the need to optimise inputs such as water, fertilisers, and energy. In the Punjab context, this is particularly relevant given the over-extraction of groundwater and excessive use of chemical inputs associated with Green Revolution practices (Bhardwaj & Sidana, 2019; Sidhu et al., 2011).
2. **Conserving, protecting, and enhancing natural ecosystems:** This highlights the importance of maintaining soil health, water quality, and biodiversity. This principle is critical in addressing soil degradation and declining water tables observed in intensive farming practices in Punjab (Singh & Benbi, 2016).
3. **Strengthening rural livelihoods and social well-being:** This extends sustainability beyond environmental concerns to include income stability, employment, and

equitable access to resources. In Punjab, rising input costs and fluctuating returns have increased economic pressures on farmers, making livelihood sustainability a key concern (Chawla & Aggarwal, 2025; Singh, 2020; Singh et al., 2014).

4. **Enhancing the resilience of people, communities, and ecosystems:** This principle focuses on the ability to withstand and adapt to shocks such as climate variability, market fluctuations, and resource scarcity. This is increasingly important in the face of climate change and its impact on agricultural productivity and risk in Punjab farms (Conway et al., 2019; Sidhu et al., 2011).
5. **Ensuring responsible and effective governance of natural and human resources:** This underscores the role of institutions, policies, and regulatory frameworks in enabling sustainable practices (Gulati et al., 2017; Pretty, 1995; Swaminathan, 1982). In India, initiatives such as the National Mission for Sustainable Agriculture reflect efforts to promote this principle, although their effectiveness depends on implementation at the local level.

Together, these principles emphasise that sustainable agriculture must reduce environmental harm while simultaneously supporting farm incomes, reducing vulnerability, and improving resilience to economic and climatic shocks.

3.3 National Policy Context for Sustainable Agriculture in India

FAO (2015) emphasises that transitions towards sustainable agriculture require coordinated national strategies and policy integration across sectors. In India, this policy direction is reflected in several national initiatives aimed at enhancing agricultural productivity while safeguarding natural resources and farmer livelihoods. A key programme is the National Mission for Sustainable Agriculture (NMSA), launched in 2014–15, which seeks to make agriculture more productive, sustainable, remunerative, and climate-resilient (Press Information Bureau, 2018).

Other National efforts include the "Per Drop More Crop" (PDMC) scheme, which promotes micro-irrigation technologies, such as drip and sprinkler systems, to improve water-use efficiency (Press Information Bureau, 2023). However, the suitability and uptake of micro-irrigation are context-dependent and limited by crop type, farm infrastructure, local agro-ecological and water-governance conditions (Van der Kooij et al., 2013). The Rainfed Area Development Programme, which promotes integrated farming systems that combine crops with horticulture, livestock, fisheries, and allied activities such as vermicomposting, thereby enhancing income diversification and resilience (Ministry of Agriculture, 2011). Soil Health Management initiatives within NMSA (2018) further promote balanced fertilisation and soil testing to support long-term soil productivity.

Despite these efforts, several challenges continue to constrain the effectiveness of national sustainability initiatives. Recent studies highlight that policy frameworks remain largely oriented towards improving productivity, cost-effectiveness, and profitability, with limited attention to farmer diversity and socio-economic disparities (Chauhan & von Wehrden, 2025). Emerging research also highlights the importance of technological innovation, including precision farming and climate-smart technologies. However, their effectiveness depends on complementary factors such as farmer awareness, institutional support, and community engagement (Singh & Singh, 2024). Furthermore, there is limited large-scale evidence on the economic, social, and environmental outcomes of these initiatives (Gupta et al., 2021; Sampath & Ravikumar)

Scaling sustainable agriculture, therefore, requires stronger evidence-based approaches, including enhanced knowledge exchange, farmer capacity building, targeted incentives, and improved data collection at both national and state levels (Gupta et al., 2021). These considerations are particularly relevant to this study, which adopts a bottom-up perspective to capture local experiences and identify feasible pathways for sustainability transitions.

3.4 Sustainable Agriculture Policy Context in Punjab

In Punjab, sustainability challenges are closely linked to policy-driven agricultural structures. A key constraint is the policy environment that continues to incentivise the intensive input-reliant wheat-paddy cropping system. As long as the government maintains assured procurement of wheat and rice at guaranteed prices, farmers are likely to remain dependent on these crops to minimise risk and secure stable incomes (Singh, 2021). Liu et al. (2021) further argue that existing policy frameworks are increasingly suboptimal, as they generate high environmental costs, inefficiencies in resource allocation, and limited crop diversification. In addition, subsidies, particularly for electricity, continue to encourage excessive groundwater extraction, reinforcing unsustainable resource use patterns.

Punjab also faces broader agrarian distress, including rising production costs, farmer indebtedness, and declining profitability (Gill & Johal, 2024). These conditions reduce farmers' willingness to adopt sustainable practices, particularly when such transitions involve risk or uncertain returns. As a result, while NMSA promotes sustainable practices, its uptake in Punjab remains constrained by economic realities, institutional limitations, and farmer risk perceptions (Chaudhary et al., 2025; Gill & Johal, 2024).

Overall, these insights provide a critical policy context for understanding how sustainability initiatives are reflected, interpreted, and experienced at the farm level in Punjab under current agricultural conditions. These insights also informed the development of this study's survey instruments, including questions on awareness and adoption of the soil health card allocation, water-use efficiency practices, and organic farming. This linkage enables the study to connect farmers' lived experiences with national policy objectives.

3.5 Conclusion

This chapter explored the conceptual foundations of sustainable agriculture and the policy context shaping sustainability transitions in India, with a focus on Punjab. It highlighted that while national initiatives such as the National Mission for Sustainable

Agriculture provide an important framework for promoting sustainable practices, their effectiveness is constrained by structural, institutional, and socio-economic factors.

In Punjab, these challenges are further intensified by policy incentives, resource-intensive farming systems, and economic pressures that limit the adoption of sustainable practices. Overall, the chapter establishes the policy and conceptual context necessary for analysing how sustainability initiatives are experienced at the farm level in Punjab, which is explored in the subsequent chapters.

Chapter Four- Methodology

4.1 Introduction

This chapter outlines the methodological approach adopted to address the research aim of exploring the key enablers and barriers influencing the transition towards sustainable agricultural practices (SAP) in Punjab, India. It also introduces the measurement framework of FAO's SDG Indicator 2.4.1 (proportion of agricultural area under productive and sustainable agriculture), which is used in this study as a structured reference to guide data collection (FAO, 2021).

Although SDG Indicator 2.4.1 is designed to generate quantitative estimates at national or regional scales, this research does not attempt to calculate the indicator statistically. Instead, the FAO SDG 2.4.1 farmer survey module is used as a structured instrument to document farmers' self-reported practices, outcomes, and perceptions across economic, environmental, and social dimensions. This enables the study to examine sustainability at the farm level while remaining sensitive to local realities in Punjab.

The chapter presents the research design and rationale, sampling strategy, ethical considerations, reciprocity, positionality, data collection and analysis methods, including reflection on the evolution of the research design. It concludes by outlining the study's limitations.

4.2 Research Aim, Questions and Objectives

The overarching aim of this research was to explore key enablers and barriers influencing the transition towards sustainable agricultural practices in Punjab, India.

RQ1: How do the predominant agricultural practices in Punjab impact the economic, environmental and social outcomes for farmers and communities?

Obj1.1 Describe sustainable agriculture and its key components.

Obj1.2 Provide an overview of the current predominant agricultural practices in Punjab, and their impact on the economy, environment and social well-being of farmers.

RQ2: What perspectives do farmers and other key stakeholders hold regarding the adoption and implementation of Sustainable Agriculture Practices (SAPs) in Punjab, and how do they contribute to this process?

Obj2.1 Investigate the perspectives and contributions of different stakeholders, including farmers, farm co-operative society leaders, NGOs and development agencies, and regional government officials on the adoption of SAP in Punjab.

Obj2.2 Identify barriers and enablers for the adoption of SAP practices.

Obj2.3 Identify the gaps for the targeted interventions to facilitate the implementation of sustainable agriculture practices.

By answering these questions, the research seeks to understand the capabilities and preparedness of some Punjab farmers to adopt sustainable practices, as well as the extent to which they have been informed of and provided the necessary support and resources for a successful transition. This aligns with the UN **Sustainable Development Goals (SDGs)**, particularly:

- **Goal 2: Zero Hunger**, by promoting sustainable agriculture for food security and improved nutrition.
- **Goal 13: Climate Action**, specifically Target 13.3, by improving education, awareness-raising, and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning systems.

4.3 Research Design and Rationale

4.3.1 Research Design

This study employed a qualitative-dominant, bottom-up research design to ensure that farmers' perspectives were central to understanding the transition towards sustainable

agricultural practices (SAP) in Punjab. A qualitative, bottom-up approach was adopted because it is people-centred and generates knowledge based on local understandings of current and changing conditions, risks, and responses. It also offers adaptability and flexibility in capturing farmers' lived experiences and perspectives, as well as the insights of experts within institutional contexts (Conway et al., 2019)

Although the study was predominantly qualitative, limited descriptive economic estimation was used to support the interpretation of economic viability in the findings. These estimates (e.g., indicative farm output value per hectare and approximate net farm income patterns) were derived from farmer-reported yields/production, reported prices, and reported costs. These figures were used for within-sample comparison and contextual understanding rather than statistical generalisation.

The research was conducted in three phases:

1. **Preparatory Phase:** A literature review was conducted to understand the key components of sustainable agriculture practices (SAP), the need for transitioning from conventional practices in Punjab, and associated economic, environmental, and social implications. Simultaneously, government and NGO action plans were analysed to identify ongoing strategies for supporting the transition.
2. **Survey Phase:** Data were collected from sampled farmers in the Malwa region of Punjab using a survey model adapted from the SDG Indicator 2.4.1 framework (FAO, 2021)
3. **Stakeholder Interviews:** Semi-structured interviews were conducted with eight experts from agriculture-related organisations to gain insights into institutional perspectives on sustainable agriculture. These interviews explicitly addressed the concerns and questions raised by farmers during the survey phase, alongside providing experts' views on existing initiatives, implementation efforts, and policy

directions. This phase played a key role in contextualising and validating the findings emerging from the farmer survey.

4. **Data Analysis:** Thematic analysis was conducted on both survey and interview data to identify key enablers and barriers under economic, environmental, and social dimensions of sustainable agriculture.

4.3.2 Rationale for Selecting Punjab as the Study Area

Punjab was selected as the study area due to both its critical agricultural significance in India and my positional connection to the region. While the geographical and agronomic characteristics of Punjab are presented in Chapter 1, this section outlines the personal, contextual, and research-based motivations that informed this choice.

I was born and raised in Punjab and spent approximately fourteen years living there before moving to New Zealand. During this time, I lived in my maternal grandparents' household, where family members were actively involved in farming. This early exposure to farming provided me with familiarity with farming practices, rural livelihoods, and the socio-cultural contexts in which agricultural decisions are made.

After relocating abroad and pursuing studies in computer science, I became disconnected from day-to-day agricultural activities. However, I remained engaged with Punjab's agricultural challenges through regular communication with family members and regional news. Recurring discussions around severe air pollution during the paddy residue burning period, concerns about soil degradation and the broader impacts of industrial pollution on natural resources, and the growing environmental and social costs of prevailing agricultural and industrial practices in the region kept bringing me back to one thought: I felt a growing responsibility to contribute, in whatever way I could, to this space.

This sustained willingness and awareness, combined with my academic training and research skills, led me to this research topic to understand how farmers in Punjab are

positioned to contribute to a transition towards sustainable agriculture, particularly in the context of the United Nations Sustainable Development Goals (SDGs) and the 2030 targets. Given Punjab's role as the "food bowl of India," its agricultural systems are not only regionally significant but also strategically important at the national level. Consequently, understanding Punjab farmers' preparedness, knowledge, and institutional support mechanisms offers valuable insights into the broader challenges and opportunities associated with sustainable agricultural transitions in high-intensity farming regions. It contributes to efforts to achieve global food security, climate resilience, and sustainable rural livelihoods as envisioned by the SDGs.

Punjab, therefore, provided an appropriate and meaningful setting for this research, particularly as a first step towards initiating dialogues on SAP in rural areas in India, documenting farmers' perspectives, and generating awareness of SAP. This study provided region-specific agricultural knowledge that can inform subsequent implementation efforts, guide policy engagement, support capacity-building initiatives for a successful transition, and advance strong agricultural development outcomes.

4.4 Ethical Considerations

Ethics, as Zina (2021) states, is 'a fundamental responsibility for researchers'. Given that this research involved direct engagement with farming communities and institutional stakeholders in rural Punjab, careful attention was given to ethical conduct throughout the research design and data collection. The study was conducted in accordance with the ethical principles outlined in the Massey University Human Ethics Committee Code of Ethical Conduct (Massey University, 2017), which emphasises respect for participants, voluntary participation, minimisation of harm, and responsible data management.

Ethical approval for this study was obtained through the Massey University Low Risk Ethics process. As part of the in-house ethics review, the project's ethical considerations were

first reviewed by Professor Glenn Banks (Primary Supervisor) and Associate Professor Gerard Prinsen from the School of People, Environment and Planning. This review was guided to strengthen the ethical design and conduct of the research.

The reviewers recommended actively seeking participation from small landholders and, where possible, from female-headed farm households to ensure diverse perspectives are included. They also emphasised the importance of prioritising the depth and quality of information obtained from farmers and experts rather than focusing primarily on participant numbers. In addition, guidance was provided to ensure voluntary participation by offering participants clear options to opt in or withdraw from the study and by conducting interviews in neutral locations, such as public spaces, to minimise perceived pressure to participate.

Further ethical recommendations included preparing participant information and consent sheets in the local language to communicate the aims and nature of the research clearly. The reviewers also noted that written consent may be inappropriate or impractical in some rural contexts and recommended obtaining oral consent prior to data collection. To protect participant confidentiality, they advised using unique identifiers based on region (district), landholding size, tenure type, and agricultural practices instead of collecting personal identifying information. In line with recommendations as a local Punjabi speaker, I ensured that participants clearly understood the study by using the written information sheet in English alongside a full verbal explanation in Punjabi - the language most familiar to participants and audio-recorded this explanation as part of obtaining informed oral consent. The English versions of the participant information sheet and consent information are provided in the Appendix.

Following the reviewer recommendations, all the above measures, including strategies for voluntary participation, inclusive engagement of diverse farm households, participant information and consent procedures, and confidentiality safeguards, were incorporated into

the fieldwork plan. As a result, the project was assessed as Low Risk, with approval granted on the basis that appropriate safeguards were in place to address issues of consent, confidentiality, power dynamics, and cultural sensitivity.

4.5 Reciprocity, Positionality, and Reflexivity

4.5.1 Reciprocity

In line with Scheyvens (2014) guidance on emphasising reciprocity in research, this study intended to share the collected data with farmers in an organised form through a user-friendly web portal in the study region's local language (Punjabi) and English. The portal was envisaged as a platform for disseminating information on sustainable agriculture, with an added feature to receive farmers' feedback, aiming to raise awareness and gather issues and solutions from a bottom-up perspective. However, as advised by my supervisor, this was beyond the scope of the current research methodology. I fully acknowledge this limitation and consider such initiatives as part of future research endeavours.

While the web portal was not created, the research succeeded in initiating meaningful discussions within some farming communities about sustainable agriculture practices. During fieldwork, whenever possible, I spent time with farmers beyond the formal survey questions—discussing day-to-day well-being and sharing tea. Farmers expressed genuine appreciation for these interactions. Many commented that it was the first time someone had come to their villages to talk about soil and crop health rather than promoting a product. They noted that it was unusual and refreshing to spend time discussing their practices with someone rather than simply sitting together and looking at their phones, as is often the case. Such feedback was incredibly encouraging and reflects the reciprocity inherent in this research. The farmers' engagement, openness, and comments provided me with valuable insight, motivation, and a sense of shared purpose.

I have maintained contact with some farmers through social media and direct communications, sharing valuable agricultural insights and continuing conversations about

farming practices. Both the farmers and I are excited to see the outcomes of this research. To honour their time and contributions, once my thesis is completed and approved, I plan to create a handout summarising the key findings in the local language to share with all participating farmers. As a researcher and part of the farming community, I will continue to maintain these connections, ensuring that the knowledge exchange extends beyond the formal research process and supports ongoing dialogue between researchers and the farming community.

4.5.2 Positionality

In this study, I approached the research from two intersecting positions: as a community member and as a student researcher.

As a community member

Being familiar with the local agricultural context and the social environment of Punjab helped me build trust with participants. Farmers were often willing to share their experiences and challenges, which provided rich qualitative insights. My background allowed me to understand local practices, variations in farming methods across regions, and socio-cultural dynamics that might not have been apparent to an outsider (Shai, 2020).

As a student researcher

My position as a student conducting research under academic supervision brought both strengths and limitations. It ensured adherence to ethical research protocols, rigorous data collection, and systematic analysis. This position also shaped how some participants perceived me during fieldwork. In a few instances, participants were cautious in sharing information, assuming that I might be affiliated with government authorities or other formal institutions.

For example, one participant declined permission to record the interview due to concerns that the information might be used to identify farmers involved in crop residue

burning. On another occasion, a participant told others present that I was “from the media” and advised them to respond as they would to media representatives. These reactions occurred during a period when farmers faced legal action and penalties for residue burning, making suspicion and hesitation understandable (Hindustan Times, 2024)

In such situations, I re-shared the participant information sheet, reiterated the purpose of the research, clarified my role as a student researcher, and emphasised confidentiality and voluntary participation. My local background played an important role in rebuilding trust, as some participants who initially expressed concern shared that this was a new experience for them, as they had not previously been approached to discuss their practices and concerns.

Maintaining reflexivity throughout the research process was therefore essential. These experiences helped me recognise farmers’ positionality within a context of regulatory pressure and uncertainty and guided me in adapting my approach while remaining aligned with ethical research principles. This reflexive and ethically grounded engagement enabled the continuation of the research while respecting participants’ concerns and perspectives.

4.5.3 Reflexivity

Throughout the research process, I maintained a reflexive approach to ensure that my positionality enhanced the quality of the study. After each interaction with participants, I recorded notes in a research journal, documenting the different insights I received. These reflections were cross-checked against the perspectives of other participants to identify patterns and recurring themes.

Coming from the same community and with prior knowledge of local agricultural practices, I trained myself to actively listen, ask clarifying questions, and engage thoughtfully with farmers’ responses. Farmers often expressed appreciation for me, with comments such as, *“It is good to see someone from our own region, especially a woman, coming to talk to us*

about our present and future agriculture practices." Such comments were motivating and reassured me that my approach was respectful and well-received.

Each survey and field interaction was a learning opportunity, revealing new aspects of practical farm work and generating additional questions for expert consultations. The research journey became an iterative process of connecting hands-on field observations with theoretical insights and controlled analyses from experts. This experience highlighted the need for a structured system that enables a bottom-up and top-down flow of information, integrating farmer-level observations with expert knowledge to build a region-specific, information-rich understanding of sustainable agriculture practices for Punjab's farming systems.

4.6 Sampling Strategy: Participant Selection

In this research, snowball and purposive sampling strategies were employed to recruit participants, ensuring representation across different landholding sizes, tenure types (owners and leaseholders), cultivation types, and a range of institutional stakeholders.

Snowball sampling is a referral-based sampling technique in which existing participants help identify and recruit additional participants who meet the study's criteria (Parker et al., 2019). This approach is beneficial in contexts where social connections are central to reaching participants and where direct recruitment via lists or random approaches may be impractical or culturally insensitive (Scheyvens, 2014). In this study, snowball sampling facilitated initial access to farming communities and enabled the identification of additional participants through trusted local networks.

Purposive sampling involves the deliberate selection of participants who possess specific characteristics or knowledge relevant to the research objectives. This technique is widely used in qualitative research as it enables researchers to focus on information-rich cases that can provide in-depth insights into the phenomena under study. Purposive sampling is not

intended to support statistical generalisation; rather, it enhances the depth and credibility of qualitative inquiry by selecting participants most likely to contribute meaningful data (Etikan et al., 2016).

This combination of snowball and purposive sampling ensured the inclusion of information-rich cases across key participant categories. Snowball sampling supported initial access and referrals within farming communities, while purposive sampling guided the selection of participants across predefined categories, including small, medium, and large landholders; owners and leaseholders; and conventional and alternative cultivators. In addition, purposive sampling was used to recruit key institutional stakeholders, including agricultural experts and representatives from relevant governmental and non-governmental organisations in Punjab. This combined approach helped achieve a diverse and representative sample for the study.

Table 4.1 presents the geographic distribution of the forty-eight farmer participants across the Malwa region districts, showing that the majority of respondents were from Ferozepur district, followed by Ludhiana and Moga.

Table 4.3: Distribution of Farmer Samples Across Malwa Region Districts

District	**Number of Farmers**
Ferozepur	32
Ludhiana	11
Moga	5
Total	**48**

All forty-eight farmer participants in this study were male. Although efforts were made to include female farmers, no female-headed households or women directly involved in farm decision-making were identified through local contacts in the sampled villages. This pattern is consistent with the broader gendered structure of Punjab's agricultural sector. As

noted in Chapter 1 (Section 1.3.1), the most recent Agricultural Census (MoAFW, 2025) remains the latest available, and it reports that only 9% of main cultivators in Punjab are women. The absence of female participants in this study, therefore, reflects the wider demographic context of the region.

Figure 4.1 illustrates the age distribution of the sampled farmers. It provides an overview of the different age groups represented in the study, helping contextualise the demographic profile of participants involved in commercial agriculture.

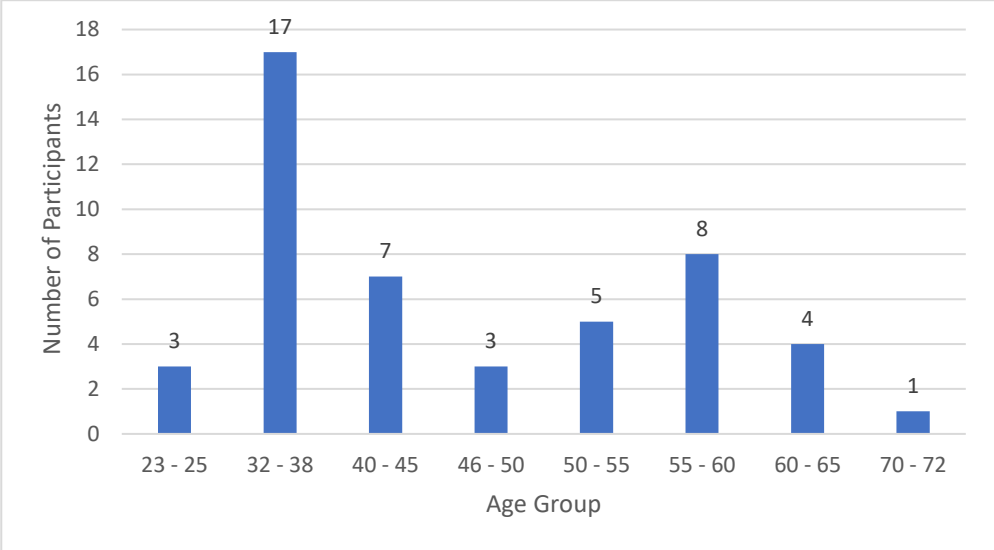


Figure 4.1: Number of Farmers Across Different Age Groups

Table 4.2 outlines the cultivation practices adopted by the sampled farmers. It categorises respondents according to conventional, mixed, organic, and natural farming systems, and includes brief notes describing the main characteristics of each cultivation type.

Table 4.2: Number of Farmers Practising Different Cultivation Types for Commercial Agriculture

Cultivation Type	**No. of Farmers**	**Note on cultivation type**
Conventional (Chemical)	43	Standard chemical-based practices with no reported adoption of sustainable or organic methods

Mixed: Chemical-Intensive + Some Sustainable Methods	2	Implement sustainable practices, such as crop residue management, direct-seeded rice on 20% of the land, and economic threshold-based pesticide application. One farmer employed an intercropping system on 33% of a large landholding, growing popular trees with sarso and some with peas. He also grows rice with an anaerobic **s**eeding rice method on 30% of the paddy cultivation.
Organic Farming	2	Full organic cultivation practices, avoiding chemical inputs.
Natural Farming	1	No chemical or bio inputs; relies on intercropping and natural plant support systems.

Table 4.3 presents the farm size classification categories used in this study. These categories were adapted from the Press Information Bureau (2019). The codes Ma, S, SM, M, and L refer to marginal, small, semi-medium, medium, and large holdings, respectively.

Table 4.3: Classification of Farm Size Categories. Source: (Press Information Bureau, 2019)

Category	**Size-Class**
Marginal (Ma)	Below 1.00 hectare
Small (S)	1.00 – 2.00 hectare
Semi-Medium (SM)	2.00 – 4.00 hectare
Medium (M)	4.00 – 10.00 hectare
Large (L)	10.00 hectares and above

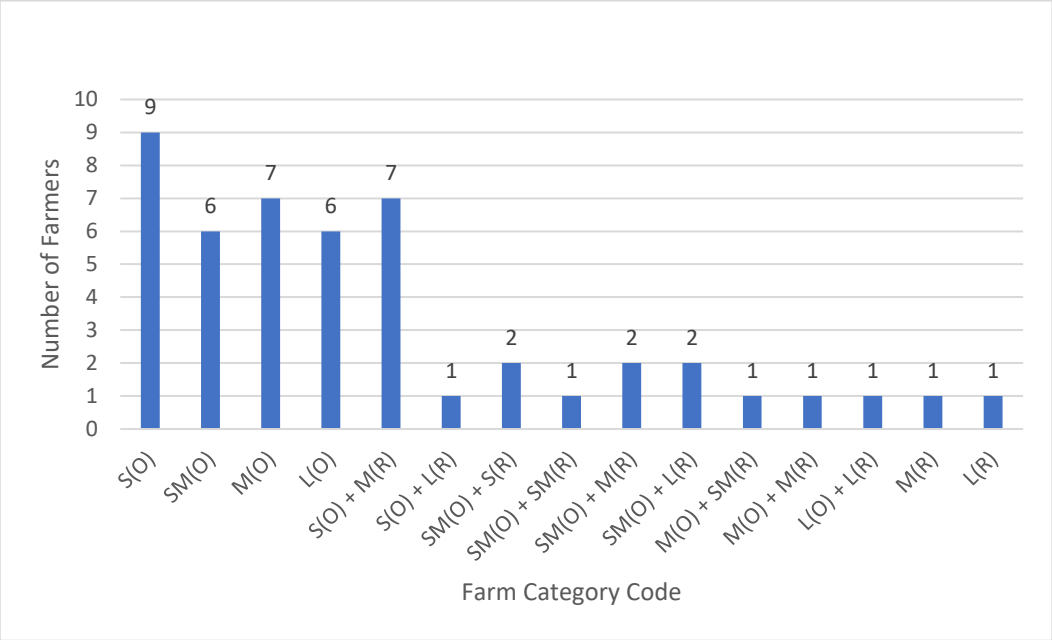


Figure 4.2 Distribution of Sampled Farmers by Combined Farm Size Categories (O = owned, R = rented)

Figure 4.2 uses the landholding codes presented in Table 4.3, along with tenure labels (O = owned; R = rented/leased), to show the distribution of sampled farmers across combined farm size categories and mixed tenure arrangements.

Table 4.4 profiles the expert participants included in the research. It summarises their positions and organisational affiliations across universities, extension agencies, cooperatives, and non-governmental organisations, highlighting the diversity of institutional perspectives represented in the study.

Table 4.4: Agricultural Expert Participants (Positions and Organisations)

No.	Position	Organization
1	Senior Agronomist, School of Organic Farming	Punjab Agricultural University
2	Assistant Professor (Agricultural Engineering),	Krishi Vigyan Kendra, Malwal
3	Assistant Professor	Farm Advisory Service Centre, Malwal

4	Director	Agriculture Technology Management Agency (ATMA), Malwal
5	Assistant Professor	Krishi Vigyan Kendra (KVK), *location was not disclosed in the interview*
6	Secretary	Co-operative Society, Sulhani, Ferozepur
7	Master Rajbir Singh, Member,	All India Pingalwara Charitable Society, Amritsar, Non-Governmental Organisation
8	Dr Avtar Singh	Good Grow Farms, Phagwara, Non-Governmental Organisation
9	Kamaljeet Singh Hayer, Organic Farmer and Founder	Sohangarh Natural Farms & Farmversity, Non-Governmental Organisation

4.7 Data Collection and Analysis

4.7.1 Data Collection

Data were collected from farmers using a survey model adapted from the SDG Indicator 2.4.1 framework (FAO, 2021), which measures the proportion of agricultural area under productive and sustainable practices. This framework provides a structured approach to assess the environmental, economic, and social dimensions of sustainability at the farm level.

The survey was structured around 11 key indicators, grouped by sustainability dimension, as shown in Table 4.5

Table 4.5: SDG 2.4.1 Sustainability Themes and Sub-Indicators Applied in This Study. Source (FAO, 2023)

No.	Sustainability dimension	Theme	Sub-indicator
1	Economic	Land productivity	Farm output value per hectare
2	Economic	Profitability	Net farm income
3	Economic	Resilience	Risk mitigation mechanisms
4	Environment	Soil health	Prevalence of soil degradation
5	Environment	Water use	Variation in water availability
6	Environment	Fertiliser pollution risk	Management of fertilizers
7	Environment	Pesticide risk	Management of pesticides

8	Environment	Biodiversity	Use of agrobiodiversity-supportive practices
9	Social	Decent employment	Wage rate in agriculture
10	Social	Food security	Food Insecurity Experience Scale (FIES)
11	Social	Land tenure	Secure tenure rights to land

Although the FAO survey is primarily designed to generate quantitative data on the proportion of land under sustainable agriculture, in this study, it was used as a reference framework to guide data collection and to explore farmers' perspectives on each indicator relative to their cultivation practices, as well as experts' perspectives on broader trends in Punjab. This approach enabled the study to capture insights into farmers' capacities and practical constraints, as well as experts' viewpoints on the strengths and limitations of existing research and extension support.

To capture region-specific information and qualitative insights additional locally relevant questions were added to the survey. Examples include:

- Irrigation practices, sources of water for irrigation, and water management efficiency (e.g., flood, drip, or sprinkler methods, monitoring of water use, and changes in water quality/availability).
- Soil management practices, including soil tests and residue management.
- Crop and product quality assessments.
- Marketing channels for crop yield and crop by-products.
- Farm-level recycling practices and management of plant protection products.

Some of these supplementary questions were informed by the Food and Agriculture Organization's (2023) guidelines on data analysis and reporting, as well as the RISE (Response-Inducing Sustainability Evaluation) framework (Bern University of Applied

Sciences, 2020), which emphasises comprehensive farm-level sustainability assessment. However, the full RISE survey could not be implemented due to software and practical constraints.

The survey was administered through face-to-face interviews, complemented by semi-structured discussions during field visits, which allowed participants to clarify responses and provide additional qualitative insights. This approach provided a rich understanding of farmers' practices, perceptions, and challenges beyond what a purely quantitative survey could capture.

The complete survey model, including all locally adapted and additional questions, is provided in the Appendix. While the collected data for this study did not quantify the proportion of land under sustainable agriculture, they provide a valuable baseline for understanding Punjab farmers' capabilities and regional resources. These insights, alongside expert perspectives, can inform future research, policymaking, and targeted interventions to facilitate a successful transition to sustainable food production systems in Punjab. A detailed explanation of and rationale for the adapted survey module is provided in Section 4.8.

4.7.2 Data Analysis

The data analysis process aimed to use the collected surveys to systematically explore farmers' and experts' perspectives on sustainable agriculture practices (SAP) in Punjab. Farmer survey responses were first organised in a matrix format to facilitate qualitative analysis. Each survey question was placed in a separate column, and each row corresponded to an individual farmer, allowing responses to be traced back to each participant while maintaining consistency across variables. Questions related to the same sustainability dimension (economic, environmental, or social) were grouped within the same worksheet to enable dimension-specific analysis.

For the farmer survey data, I used an inductive, data-driven thematic analysis (Braun & Clarke, 2006), where coding and interpretation were guided by participants' responses rather than pre-existing assumptions. This approach was well-suited to the study's structured survey, which included locally adapted questions, supplemented by semi-structured discussions with farmers and interviews with experts, providing rich, context-specific insights for analysis.

I first familiarised myself with the data by reading through all responses multiple times, noting farmers' experiences, challenges, motivations, and support needs. Summary notes were prepared for each question to highlight areas where farmers shared similar views and where opinions differed, capturing both agreement and variation within the sample. Representative quotes from farmers were also incorporated to preserve their voices and illustrate key perspectives.

Next, related responses were grouped to identify patterns across questions and sustainability indicators. From this, key enablers and barriers for each indicator were extracted, drawing on both recurring ideas and unique perspectives. Expert interviews were transcribed to capture their perspectives on the need for transitioning to sustainable agriculture in Punjab, including the availability of resources and support, and to document their responses to concerns raised by farmers. These transcriptions are presented in chapter eight.

Finally, findings from both farmers and experts were integrated to produce a comprehensive understanding of the factors influencing the transition to sustainable agriculture in Punjab. By combining manual coding, summary tables, and thematic grouping, this process ensured that the analysis remained grounded in the data while providing a structured way to translate qualitative inputs into meaningful insights for each sustainability indicator.

4.8 SDG Target 2.4 and Indicator 2.4.1: Application in This Study

Sustainable Development Goal (SDG) Target 2.4 aims to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity, maintain ecosystems, and progressively improve land and soil quality. SDG Indicator 2.4.1 measures progress toward this target by assessing the proportion of agricultural area under productive and sustainable agriculture (FAO, 2020c).

The FAO approach assesses SDG 2.4.1 through a dashboard of sub-indicators across economic, environmental, and social dimensions. Together, these sub-indicators support a structured assessment of productivity, economic viability, and resilience. The framework recognises that high output alone does not necessarily indicate sustainability, particularly when it is associated with high risk, the degradation of natural resources, or weak livelihood outcomes.

In this study, consistent with the overall qualitative design, most indicators were explored through farmers' narratives and descriptive evidence. Limited quantitative estimates were used for selected economic indicators, such as farm output value per hectare and net farm income, to provide contextual insight into the relative economic position of different farming systems. These figures were interpreted against locally observed ranges within the sample (rather than formal national benchmarks) to support comparative interpretation across the sampled farming systems and to complement qualitative analysis of income stability, perceived risk, and resource constraints.

Table 4.6 illustrates how the FAO SDG 2.4.1 survey module was adapted for the Punjab context by comparing the types of data typically collected under the FAO framework with the locally specific data captured in this study. This demonstrates that the SDG 2.4.1 structure was retained while adapting the module to capture locally meaningful insights into the

transition towards sustainable agricultural practices in Punjab. The complete survey instrument is provided in the Appendix.

Table 4.6: Alignment Between FAO SDG 2.4.1 Survey Data Requirements and the Locally Adapted Data Captured in This Study. Source: (FAO, 2021)

Dimension	**Sub-Indicator**	**FAO data requirement (FAO survey module)**	**Data captured in this study (adapted survey module)**
Economic	Farm output value per hectare	Agricultural output value per unit area (yields * prices)	Farmer-reported cropping patterns, approximate yields, selling prices, and/or Minimum Support Prices to estimate farm output value/ha
Economic	Net farm income	Farm-level income: production value minus costs	Self-reported gross income, recurring input costs, and lease costs to estimate net income
Economic	Risk mitigation mechanisms	Practices used to reduce exposure to economic and climatic risks	Farmers' narratives on diversification, responses to price and weather shocks
Environment	Prevalence of soil degradation	Evidence/indicator of soil condition and degradation	Perceived soil compaction and yield decline; soil and water testing practices (including awareness of the national initiatives for soil and water management), residue management, and perceived soil health changes
Environment	Management of fertilisers	Fertiliser use practices and nutrient management	Fertiliser application decisions, awareness of dosage recommendations, and perceived impacts on soil and water
Environment	Use of agro-biodiversity-supportive practices	Crop diversity/rotations, and ecosystem-supporting practices	Crop rotations, intercropping, tree planting, and other diversified cropping practices

Social	Wage rate in agriculture	Labour conditions and remuneration in agricultural employment	Reported daily wage rates, labour availability, and seasonal labour constraints
Social	Food Insecurity Experience Scale (FIES)	Household food insecurity experience	Self-reported food availability/affordability; seasonal food security experiences
Social	Secure tenure rights to land	Security of land tenure rights (legal/perceived)	Perceived tenure security, lease duration, and lease costs

4.9 Limitations of the Study

Despite the methodological rigour of this study, several limitations should be acknowledged to contextualise the findings. First, as noted in Section 4.7, the study adapted the FAO SDG Indicator 2.4.1 framework (FAO, 2021), which is primarily designed to generate quantitative measures of land under sustainable agriculture, so as to be able to collect qualitative insights from farmers and experts. As a result, the findings provide rich contextual understanding of farmers' experiences, decision-making, and practical constraints, rather than statistically generalizable measurements.

Second, farmers were often hesitant to report land size in precise hectares, instead providing ranges (e.g., "8–10 acres"). To standardise the data, land size was coded in accordance with official classifications used in the Indian Agricultural Census, where operational holdings are categorised as marginal (below 1.00 ha), small (1.00–2.00 ha), semi-medium (2.00–4.00 ha), medium (4.00–10.00 ha), and large (10.00 ha and above) (Press Information Bureau, 2019). This approach captured meaningful information about farm scale while respecting farmers' privacy and comfort in sharing sensitive information.

Third, although the research initially aimed to include farmers from all three regions of Punjab, data collection was ultimately concentrated in the Malwa region due to practical and access constraints. While Malwa is the largest of Punjab's three regions and has been central to the Green Revolution and regional political dynamics (Gill, 2026) this

concentration may not fully capture the diversity of production systems, farm sizes, and socio-economic conditions across the state; the findings should therefore be interpreted as indicative rather than exhaustive. Finally, time and resource constraints limited the ability to conduct follow-up interviews with farmers after incorporating experts' perspectives, which may have provided further clarification and additional insights. This could be pursued in future research.

4.10 Conclusion

This chapter outlined the methodological approach used to investigate the enablers and barriers shaping the transition towards sustainable agricultural practices in Punjab. A predominantly qualitative, bottom-up research design was adopted to ensure that farmers' voices and lived experiences were central to the study, while expert interviews provided broader contextual and institutional perspectives. The FAO SDG Indicator 2.4.1 (2021) framework was used as a guiding structure for data collection, enabling a systematic exploration of sustainability across economic, environmental, and social dimensions while remaining adaptable to local conditions.

The use of inductive thematic analysis ensured that insights emerged directly from participants' responses (Braun & Clarke, 2006). Ethical considerations, reciprocity, and reflexivity guided the research process and informed both data collection and analysis. Although the study was subject to limitations of time and scope, the chosen methodology provides a credible, context-sensitive foundation for understanding the challenges and opportunities for transitions towards sustainable agriculture in Punjab.

Chapter Five – Farmers' Perspectives on Economic Indicators of Sustainable Agriculture

5.1 Introduction

Economic outcomes significantly influence farmers' decisions regarding crop selection, farming practices, and their capacity to adopt or sustain alternative agricultural practices. Farmers face multiple pressures, including fluctuating market prices, rising input costs, land tenure challenges, and exposure to climate and production risks. These pressures directly influence not only farm profitability but also farmers' willingness and ability to diversify crops, reduce chemical inputs, or experiment with more sustainable practices (Chawla & Aggarwal, 2025).

Chapters 5–8 collectively address Objectives 2.1 and 2.2 by presenting farmers' and agricultural experts' perspectives and identifying the key barriers and enablers shaping the adoption of sustainable agricultural practices (SAP) in Punjab. This chapter begins by focusing on farmers' perspectives on the economic dimensions of sustainable agriculture.

In this study, farmers provided inputs on their current farming practices, crop selection, production levels, input use, and income through a structured survey. These self-reported data were mapped to key economic indicators of sustainable agriculture, as outlined in the FAO SDG 2.4.1 farmer survey module (FAO, 2021), namely:

(i) farm output value per hectare,

(ii) net farm income, and

(iii) risk mitigation mechanisms

Consistent with the qualitative design of the research, the FAO SDG 2.4.1 framework is not applied as a formal statistical classification tool. Instead, it is used as an analytical lens to interpret farmers' experiences of productivity, profitability, and economic resilience.

Quantitative estimates are used descriptively to support interpretation, while primary emphasis is placed on farmers' narratives, perceptions, and lived realities.

For each economic indicator, findings are presented in three parts:

1. A summary of farmers' reported practices and outcomes.
2. Some quotations illustrating farmers' perspectives; and
3. Identified key enablers and barriers influencing transitions towards more economically sustainable farming systems.

This structure allows the chapter to highlight how prevailing economic conditions both enable and constrain farmers' capacity to diversify production systems and strengthen resilience in the Punjab agricultural system.

5.2 Indicator 1: Land Productivity- Farm Output Value per Hectare (FOVH)

5.2.1 Summary of Farmers' Responses on Farm Output Value per Hectare

Farmers' responses indicate that FOVH largely depends on two factors:

a) the type of crop cultivated, and

b) the cultivation approach (chemical vs. non-chemical), provided that seed quality is good, and weather conditions remain favourable to crop requirements.

Among the forty-eight farmers surveyed, forty-five practised chemical cultivation, while three had adopted non-chemical cultivation. Among chemical cultivation farms, thirty-seven grew wheat; six combined wheat and potatoes; one replaced wheat entirely with potatoes; one combined potatoes with other vegetables. In the summer season**,** all chemical farmers cultivated paddy. Only three farmers engaged in allied activities, including poplar cultivation, poultry, and vermicomposting. The farmer practising poplar tree intercropping did not sell any trees during the survey year; hence, income from this activity is not included in the farm output values.

The three non-chemical cultivation farmers reported more diversified cropping patterns across the year, including wheat, pulses, vegetables, sugarcane, and summer moong. Summer moong, also known as green gram, helps reduce the fertiliser needs of the following crop, particularly nitrogen, because of its nitrogen-fixing properties(Hayat & Ali, 2010; Tripathi et al., 2024). None of these farmers cultivated paddy.

Table 5.1 presents the cropping pattern followed by the sampled farmers, disaggregated by land tenure type and cultivation type. Table 5.2 summarises farmer-reported production levels and indicative gross income per hectare for major crops.

Table 5.4: Cropping Pattern and Cultivation Type Across Sampled Farmers by Land Tenure Type

Cropping Pattern	**Landowners only n (%)**	**Landowners leasing additional land n (%)**	**Leaseholders only n (%)**	**Cultivation Type**
Wheat, Paddy	22 (46%)	14 (29%)	1(2%)-	Chemical
Wheat + Potato, Moong, Maize, Paddy	-	4 (8%)	1 (2%)	Chemical
Wheat + Potato, Moong, Mint, Paddy	1(2%)	-		Chemical
Potato, Mint, Moong, Maize, Paddy	1 (2%)	-	-	Chemical
Vegetables+ Maize+ Paddy	-	1 (2%)	-	Chemical
Popular Tree intercropping with Sarso and Matar, Wheat, and Paddy	1 (2%)	-	-	Chemical
Wheat, Pulses	1 (2%)	-	-	Organic
Wheat, Vegetables, Pulses	1 (2%)	-	-	Organic

Wheat, Vegetables, Pulses	1 (2%)	-	-	Natural

Table 5.1 indicates that the dominant cropping pattern among the sampled farmers in Punjab remains the conventional wheat–paddy rotation, followed by 77% (37 of 48) farmers. Only 16% (8 of 48) reported integrating higher-value winter crops, such as potatoes and other vegetables, either alongside wheat or replacing wheat during the winter season. A notable finding is that, among chemical cultivation farmers, paddy remained the only crop, indicating limited diversification in the kharif [22] season. Farmers explained that cultivating potatoes or vegetables in winter often creates a longer window before paddy transplantation, allowing some farmers to include short-duration crops such as maize, moong, or mint. In contrast, farmers who cultivate only winter wheat reported that growing paddy was the most feasible option for them, leading to a continued shift back to paddy cultivation.

Table 5.2 presents farmer-reported estimates of crop production per hectare and associated gross income. Across the three study districts, farmers reported broadly comparable ranges of production and prices for major crops. Farmers cultivating potatoes in winter have higher earnings potential than those growing wheat. The selling price of potatoes fluctuates with market demand, but farmers noted that even if prices decline, they can still earn some income from a second crop, such as maize, moong, or mint. Mint was grown only by farmers located near a mint processing facility, while others mainly grew maize and moong

.

[22]Kharif refers to the monsoon cropping season in India (June–September) (United States Department of Agriculture, 2015)

Table 5.2: Farmer-Reported Crop Production and Estimated Gross Income Per Hectare (ha) (Author's own compilation based on field data)

Chemical Cultivation			
Crop	Production (tonnes/litres per ha)	Unit Price (INR per tonne)	Gross Income (INR/ha)
Wheat	5.0 - 5.5+	22,750 (MSP[23], 2024)	1,13,750-1,25,125+
Potato	30 – 45+ (depends on seed brand and quality)	~10,000	3,00,000-4,50,000+ (market dependent)
Moong	2 - 2.5+	~50,000	1,00,000-1,25,000+
Maize	8 – 10+	~18000 - 22000	1,44,000-2,20,000+
Mint	50 – 62+ (litres) (processed to oil)	~2700 per litre	1,35,000-1,67,400+
Vegetables	Varies by crop (e.g., Onion:24+, Peas:14.8, Cauliflower: 49.4	Not reported	1,25,000 – 10,000,00+ (market and crop dependent)
Paddy	7.4 - 7.9+	23,000 (MSP, 2024)	1,70,200-1,81,700+
Organic and Natural Cultivation			
Wheat	2 - 2.5+	~40,000 - 50,000	80,000-1,25,000+
Vegetables	Varied by type	No figure was provided	No figure was provided
Moong	1 to 1.25+	No figure was provided	No figure was provided

Note: Production and prices are indicative; values may vary by location, input use, and market conditions

Farmers cultivating moong highlighted that although the minimum support price for moong was set at 70,000 INR per tonne, the actual market price they received was around 50,000

[23] MSP: Minimum Support Price. Details of MSP for all years are provided at Department of Food and Public Distribution. (2024). *MSP for wheat and rice*. Retrieved from https://dfpd.gov.in/msp-for-wheat-and-rice/en

INR. This discrepancy reflects the limited effectiveness of set minimum support prices in ensuring fair returns for farmers.

The one vegetable grower, on the other hand, noted that, under favourable weather conditions, diverse vegetable cultivation can generate up to five times higher income per hectare compared to wheat. However, he also explained that vegetable farming is highly sensitive to both market prices and weather conditions. In unfavourable seasons, he was unable to make enough to recover the cost of growing vegetables. Despite these fluctuations and risks, he chose to continue vegetable farming, noting that profits from favourable seasons were sufficient to offset losses from poor seasons and still provided higher average returns than conventional wheat-paddy rotations.

For non-chemical farming production values, all three farmers surveyed expressed hesitation in providing quantitative production data for year-round crops, as they were still in the early stages of transitioning to an alternative cultivation system. The reasons for not providing the figures and their perspectives on non-chemical cultivation are presented below in Section 5.2.2, Farmers' Perspectives.

5.2.2 Farmers' Perspectives on the Farm Output Value

This section presents quotes from both chemical and non-chemical cultivation farmers, highlighting their perspectives, experiences, challenges, and motivations regarding crop production, cultivation practices and the value of different farm outputs.

Quotes from farmers practising chemical cultivation

> *"This season, for the first time, we struggled to sell our main crop, paddy, which assured us at least the minimum support price. The State Government recommended growing PR-126, a short-duration paddy variety. Almost everyone grew it. When it comes to selling, the seller refused to buy it, saying it is a 'tota' (broken) rice and has moisture problems. We waited so many days, and then they agreed to buy it with some*

cuts, not giving the full price. We did what was recommended by the government, but where was the government when we were facing problems selling the recommended crop? Why didn't they come then? Earlier, we also used to make some extra income by selling wheat residue (toodhi), around ₹8,000 per acre. But now, with the paddy residue management system, companies are getting enough paddy residue to burn in factories; they no longer purchase wheat residue. Under the current system, our land productivity is declining day by day. We have no system here."

"Land productivity can be increased by growing a potato crop in the wheat season. If we grow only wheat, then rice is the only option to sow after wheat. But if we grow potatoes on some land, we get three more options for the next crop before the paddy season. Potatoes are costly to grow, require high labour, and are not easy to sell. Private buyers decide the rates depending on market production. Potato does not give us profit every year, but the crops after potato and before paddy, such as moong, maize, help us to generate more income."

"Lease rates keep increasing every year. Earlier, one crop's income was enough to cover the lease rent, but now it cannot. I am trying to control my farm's input costs by using fewer bags of urea. And cost is not just market inputs—there are many thieves stealing cables[24] from farms, and we farmers bear that loss too."

"To get some income out of the land, we have to use every inch of land we can. We cannot afford to keep any part free to rest. We are not getting good prices for our products. If we can get a good income from what our land can grow sustainably,

[24] Here, "cables" refers to electrical wiring connected to tube well motors used for irrigation in Punjab. These cables are commonly targeted for theft due to their scrap value.

why would we spend extra money on fertilisers?" Currently, we have to use a lot of fertilisers for a good production to meet the costs and generate some income."

"Last year, one company was promoting to grow beetroot, so I took a risk and grew them on leased land. I liked working with company people. Every week, they used to come to our farm to check crop health and provide the insecticides needed for spraying. They gave us credit money to spend on growing the produce. They even came to help us during harvest time. The only issue with them was a payment delay. They took months to process the income. We, like everyone else, need money to pay our bills or loans, but if the income comes late, it is of no use to us. We could not pay our bills and loans on time, so we were charged higher interest rates. It was good to try that crop, but if there can be a policy that the company must pay on time, on the day of selling, to farmers, I think then everyone would love to work on these different productions."

"Not all farms are the same—some perform well, some do not—but on average, most of them are seeing a decline. Paddy varieties like Dogar and Pusa were yielding well, but the government does not want them grown due to water constraints. With rice not sold on time this year, our wheat sowing got delayed; now our wheat is also going to suffer."

"*A small change in temperature affects crop health. Over the past three years, yields have been declining. This year, rice yield was 10% below average***.** *In 2021–2022, wheat yield was half of what we usually get. For those farming on leased land, this loss was quite big to bear. Landowners can still manage, but for others, it was tough. Even potatoes were affected in some places; in some areas, they did*

not even form tubers due to extreme heat in the early stages, when they needed cold temperatures. Universities should carefully look at crop scheduling again; climate change is affecting the crops grown in the normal schedules we follow."

Quotes from farmers practising non-chemical cultivation

"For income from the farm, I do not go into much detail, because if I account for it all, it could break my heart and demotivate me. I am taking quality as my motivator, not profit."

"This is my first year trying farming. It costs a lot to prepare land for organic crop production, and yields are also lower. My focus is to set up a marketing firm that can help sell the organic produce for all the organic farmers."

"I am fortunate that I do not have any loans on me. My brother earns, my father gets his pension, and I also make money from other work. That is why I can afford to take some risk and try a non-chemical method, which other farmers may not. The yield from this method is almost half that of chemical cultivation. It is labour-intensive. To prepare the land, we need cow manure, poultry manure, and vermicompost. All of these are more expensive than chemical urea. One trolley of cow manure costs 4 times as much as 2 bags of urea. If a person cannot produce organic fertilisers on their farm, transitioning to organic farming is very costly. There is a demand for organic produce. But the challenge is how to reach it. If you are growing crops organically on just half an acre, you can use it for personal use. But if you are growing it on more than three acres, then you need to think carefully, as it is costly and reaching the market is hard."

5.2.3 Key Enablers and Barriers

This section identifies the key factors enabling farmers to transition to sustainable food production systems, as well as the barriers currently limiting their adoption.

Key Enablers

1) **Presence of other income sources**: A significant enabler for farmers transitioning to sustainable practices is the availability of alternative income sources. Farmers with other earnings, such as off-farm work or financial support from family members, were able to bear the higher costs and take the risks associated with non-chemical cultivation or diversified cropping systems. This financial stability allows them to invest in labour-intensive practices, organic inputs, and experimentation with alternative crops without facing immediate economic pressure.
2) **Land tenure type**: Farmers cultivating on owned land were able to diversify cropping systems and experiment with non-chemical methods in some areas without the fear of losing income to cover high lease payments

Key Barriers

1) **Guaranteed Minimum Support Price limited to wheat and paddy:** Farmers reported that although a Minimum Support Price (MSP) is officially set for certain crops, in practice, they only receive it for wheat and paddy, while other crops do not have assured procurement or guaranteed prices. A lack of price assurance discourages most farmers from transitioning to other crops and more sustainable agriculture.
2) **Lack of Reliable Marketing Platforms:** Farmers who cultivated the crops without chemicals highlighted challenges in selling their crops. They had to reach consumers directly through social media or other platforms, an unreliable process.
3) **Climate Vulnerability and Crop Sensitivity**: Farmers indicated that extreme weather conditions and climate variability affect crop yields. Crops such as potatoes, peas,

cauliflower and other vegetables are sensitive to temperature fluctuations. Without appropriate technological support, such as protected cultivation of vegetables, for example, in a polyhouse[25], the risk of adopting alternative cultivation systems increases.

4) **Lease Tenure Constraints:** Land leases typically last for one year, which makes it difficult for farmers to experiment with crops other than wheat and paddy, which at least offer an assured minimum support price return.
5) **Weak accountability in contract arrangements and delayed payments:** Farmers who engaged in contract farming reported that such arrangements often provided technical guidance and input support. However, delayed payments emerged as a significant concern, creating cash-flow constraints, increasing reliance on short-term borrowing, and adding to interest burdens. These experiences reduced farmers' willingness to repeat or scale up diversified or contract-based cropping. Farmers suggested that timely payments and enforceable contract terms would make private partnerships more viable and trustworthy.

5.3 Indicator 2: Profitability- Net Farm Income (NFI)

5.3.1 Summary of Farmers' Responses Regarding Net Farm Income

All landowner farmers reported earning a positive income over the past three years, whereas some leasehold farmers experienced losses in one or more years. Among the forty-five chemical cultivation farmers surveyed, seven reported that their yields have been declining each year. Conversely, two farmers reported increased profits due to updated agronomic knowledge, modified farming practices, and the adoption of modern machinery. The remaining thirty-six farmers experienced year-to-year fluctuations in income, largely influenced by weather conditions and market demand.

[25] Polyhouse farming uses a structure made of polyethylene film to grow crops Mhade, R., Jadhav, H., & Malathi, A. (2024). A comprehensive review of low-cost polyhouses: Innovations and impacts on horticultural produce. *Agricultural Research Journal*, *61*(3), 322-331.

Net farm income (NFI) is also closely linked to land ownership. Leaseholding farmers reported facing higher financial risk, as rising lease rates directly reduce NFI compared to landowners. High-value winter crops such as potato, mint, and moong can increase income potential, but their profitability depends heavily on market access, market demand, and weather conditions. Organic farmers highlighted that during the initial years of transition, net income is considerably lower due to reduced yields and higher establishment costs, though NFI improves as the system stabilises and as it reaches potential customers over time. In the case of wheat grown without using chemicals, farmers mentioned that although wheat yield is reduced to about 50% of what is obtained under chemical farming, when they are able to reach customers willing to pay premium prices- usually double those of chemically grown wheat, they can earn income per hectare close to that of chemical farming. Table 5.3 provides an overview of the NFI for different crops and associated cultivation types.

Table 5.3: Estimated Net Income per Hectare. (Author's own compilation based on field data)

Chemical Cultivation			
Crop	Gross Income (INR/ha)	Recurring Cost of Production (INR/ha)*	Net Income (INR/ha)
Wheat	1,13,750-1,25,125+	~26000	87750 – 99125+
Potato	3,00,000-4,50,000+ (market dependent)	~102000 (incl. seed cost)	1,98,000 -3,48,000+
Moong	1,00,000-1,25,000+	~37000	63000 – 88000+
Maize	144000-220000+	~45000	99000 – 175000+
Mint	1,35,000-1,67400+	~49500	85,500 - 117,900+
Vegetables	1,25,000 –10,000,00+	~74000 – 1,10,000	51000 – 8,90,000
Paddy	1,70,200-1,81,700+	~35,800	134400 - 145900+
Non-Chemical Cultivation			
Wheat	80,000 -1,25,000+ (customer dependent)	~10,000 (without bio inputs) |~30,000	70,000

		(with bio inputs)	– 95,000+
Potato, Vegetables, Pulses and Beans, Medicinal plants, Sugarcane	No figure was provided	No figure was provided, but a comment, "It is costly to transition and set up the requirements."	Comment from Organic Farmers: "Earnings are very low during the first three years, and yields are almost 50% lower than conventional farming in the initial years of transition from chemical to organic practices."

*Note: Costs are indicative and vary by region, input use, and labour availability.

Table 5.4 presents the comparison of NFI per hectare for landowners and leaseholders. Leaseholder net income was calculated after deducting an average lease cost of approximately INR 1,68,000 per hectare (reported by farmers). The results highlight the significant disadvantage faced by leaseholders; for instance, in wheat-paddy cropping, a leaseholder earns approximately one-fourth of the net income of a landowner, indicating that they would need to lease roughly four hectares to match the income from one hectare of owned land.

Table 5.4: Comparison of Net Farm Income per Hectare Between Owner and Lease-holding Farmers (Author's own compilation based on field data)

Chemical Cultivation			
Cropping Pattern	Net Income (INR/ha) Landowner	Net Income (INR/ha) Leaseholder	Lease Cost as % of Gross Income
Wheat + Paddy	2,22,150 – 2,45,025+	54,190 – 77,065+	68% - 76%
Potato+ Moong+ Paddy	3,95,400 – 4,93,900+	2,27,400 – 3,25,900+	34% - 42%
Potato+ Maize+ Paddy	4,31,400 – 6,68,900+ 4,17,900 – 6,11,800+	2,63,400 – 500,900+ 2,49,900 – 4,43,800+	25% - 39% 27% - 40%
Potato+ Mint+ Paddy			

Vegetables+ Maize+ Paddy	2,84,400 – 12,10,900+	1,16,400 – 10,42,900+	14% - 59%

Note: Leaseholder net income is calculated after deducting an average lease cost of approximately INR 1,68,000 per hectare)

5.3.2 Farmers' Perspectives on Net Farm Income

Quotes from Some Farmers on Net Farm Income

"Profit does increase every year, but not by much, because when minimum support price increases slightly, all input costs – such as on seeds, fertilisers, diesel, and labour also increase, leaving no real savings for farmers. For instance, PR-126 paddy variety grows faster and has lower input costs. The government promoted PR-126 on every channel, encouraging farmers to grow it, but when we did, and buyers were not buying it, the government did not say anything."

"Crops are getting affected at their ripening stage. However, I think we should not blame the weather alone. Fake pesticides could be a reason, too. There is no testing, no control, and no lab to check the effects of pesticides on our crops. The government should step in. If we are losing 10 sacks per acre, someone should investigate. At present, there is no monitoring of fake and real pesticides. This is something the government needs to check and fix."

"I have done my education in the agriculture field. I try to follow the tools I learned during my studies to farm effectively, such as using the leaf chart for fertiliser application. However, with rising temperatures, crops are not receiving the right temperatures at the right times for their growth and health. Climate issues, lack of

proper marketing channels, and unsupportive government policies are all making farming risky."

"In my area, I have observed that for some years, wheat has not had any pest attacks. I do not spray any pesticides on wheat crop, and if I must, in a rare case, I spray once. If the seed treatment is done properly, we can also save on fungicide costs. For me, wheat cultivation costs around five to six thousand rupees per acre, but for some farmers, it costs double or even triple. Many farmers, especially those farming on leased land, spray pesticides at regular intervals rather than monitoring the crop and spraying only when needed. This is mostly done out of fear that if an attack happens, they may earn nothing. Pesticide costs keep increasing every year, while crop prices increase only a little. So, farmers who cannot control the input cost end up earning the same or even less income every year."

"We have learned that the only way to earn more is by taking our own initiatives—like growing different or high-value crops. It is all on our own. We take the risk; we either make a profit or lose everything."

5.3.3 Key Enablers and Barriers

This section identifies the key factors enabling farmers to maintain or increase profitability through their cropping systems, as well as the barriers that limit their ability to increase net farm income.

Key Enablers

1) **Use of Need-Based Inputs**: Some landowning farmers reported using chemical inputs such as fertilisers and pesticides based on actual crop needs rather than at fixed intervals. This helped them to control some market input costs and secure higher net

income. Farmers also highlighted that such knowledge was acquired by seeking expert advice and learning from agricultural content on social media platforms.

Key Barriers

1) **High Lease Rates**: All leasehold farmers reported that lease rates have been rising each year**.** To pay high lease payments and earn a small margin, farmers apply chemical fertilisers and pesticides at frequent intervals rather than on a need-based application, mainly out of fear of crop loss. This limits farmers' ability to reduce input costs and improve net farm income.
2) **Cost–Price Squeeze and Limited Price Gains:** Farmers highlighted a persistent cost–price squeeze. Even when market prices or the Minimum Support Price (MSP) increase, input costs, including land lease rates, fertilisers, pesticides, and labour, also rise each year, leaving only a slight improvement in net returns. As a result, many farmers reported that their earnings remain essentially unchanged despite nominal price increases.

5.4. Indicator 3. Resilience- Risk Mitigation Mechanisms

This indicator measures whether farmers have access to the following risk-mitigation mechanisms:

- Access to or availed of credit (i.e. formal and/or informal) for protection against external shocks.
- Access to or availed of insurance for protection against external shocks.
- On farm diversification (share of a single agricultural commodity not greater than 66% in the total value of production of the holding)

5.4.1 Summary of Farmers' Responses on Risk Mitigation Mechanisms

All farmers reported having access to credit, which they refer to as a “limit”—money available at interest from cooperative societies or banks. This credit helps them pay for

market inputs and is repaid with interest after the harvest. However, this credit is not available to cover external shocks. According to the farmers, in the event of external shocks, they are mainly on their own. They may receive some support from friends, relatives or private lenders, but lending money is not easy. Farmers sometimes struggle to repay the principal, as the current predominant wheat–rice crop system provides only enough income to meet basic family needs. Repaying loans with interest becomes challenging, particularly for those farming on leased land.

Regarding access to crop insurance, farmers reported limited awareness of available schemes and indicated that they had not received information through official channels. Some farmers noted that private agents and lenders had approached them with insurance offers; however, they remained reluctant to engage with these providers. This hesitation was linked to broader concerns about fraud and low trust in private intermediaries, as well as uncertainty about contract terms and farmers' ability to resolve disputes if problems occurred. In contrast, farmers expressed greater willingness to consider insurance if it were offered through government schemes or officially recognised institutions, which they associated with greater institutional credibility than private providers.

With respect to the FAO on-farm diversification criterion (i.e., no single commodity exceeds 66% of total production value), farmers' estimates for the wheat–paddy system suggest a relatively balanced split overall; wheat, on average, contributes about 40% and paddy about 60%. In diversified systems, potato is often the most significant winter contributor, but its share remains below 66% because farmers typically grow another crop before paddy and then paddy itself. In the vegetables–maize–paddy cropping pattern, farmers reported a significant seasonal shift in crop value due to price and yield variability, and they linked this uncertainty to reluctance to adopt vegetable-led rotations despite higher profits in favourable seasons.

5.4.2 Farmers' Perspectives on Risk Mitigation Mechanisms

Quotes from some farmers

"*For other jobs except farming, we get fixed wages for our work. We know exactly how much we will get paid for the number of hours we work. On top of that, we get retirement savings schemes and life and health insurance. Farmers do the hard work out in the fields, yet still have no guarantee of income or savings schemes. Only wheat and rice give us some assurance of income, and that is what we grow. There must be a system where farmers are also assured that they will get a fair and stable return for their efforts.*"

"People think farmers receive a lot of subsidies, but that is just for show. A Super Seeder costs Rs. 2.5 lakh, while the subsidy is only Rs. 70,000–80,000. If we get that, a machine built by a local mechanic would still be much cheaper. Subsidies are not for farmers; they are for industries. We are paying the same money. We humbly request that, if possible, please pass our message to the government to stop these subsidies and spend the money on much-needed other things in farming, give assured MSP on other crops"

"We are not aware of any insurance policies, if they exist at all. Sometimes, during a natural disaster, farmers may receive some help. For example, when wheat is destroyed by fire. Farmers lose income worth ₹50,000 and receive only ₹5,000 in compensation—what can anyone do with that?"

"Government credit is only available for cultivating wheat and rice. There is no credit available to support farmers who want to grow different crops or transition to a

sustainable agricultural system. The lack of support makes it too risky for small to medium farmers to adopt different practices than conventional."

"I think some mistake is of the government and some is of us as well. The Kisan Credit Card (KCC) scheme was brought to support farmers with agricultural expenses. However, we do not use it solely for that purpose. Medium to large landholders have been able to secure loans of ₹10 to ₹15 lakhs. Instead of using the loan for farming, some have spent it on buying cars, building large houses, sending their children abroad, or having big weddings. Even some small landholding farmers take loans under the KCC scheme to purchase expensive machinery, such as tractors, without fully assessing how they will repay the large amounts. Farmers should be provided with better financial management knowledge."

"We can also grow vegetables, but that requires good labour. Labour shortage is an issue. However, with machinery and technology available to handle many tasks, labour issues can be managed. What we really need is assured procurement, a minimum support price, and proper marketing channels. If we grow moongi, we have to travel all the way to Ferozepur or Jagraon to sell it. That makes it difficult and not worth the effort. If we had a guarantee of how much we would earn from what we grow, we would definitely do it. We feel like the government wants to push farming out of our hands—that is why they do not give us stable income or good opportunities."

5.4.3 Key Enablers and Barriers

This section identifies the key enablers that help farmers mitigate risk and sustain their livelihoods, as well as the barriers that constrain their capacity to cope with shocks and to diversify their cropping systems.

Key Enablers

1) Seasonal Variation: Punjab's distinct climatic seasons enable farmers to cultivate at least two crops per year. If one crop fails, farmers can rely on the next season's crop. Those cultivating potatoes or vegetables can even produce additional crops within a year, enabling them to diversify their income and explore alternative cropping systems beyond the conventional wheat-paddy system.

2) Proximity to agri-processing facilities: Farmers identified proximity to agri-processing units as an important enabler for crop diversification. Local processing facilities reduce transport costs, post-harvest losses, and marketing uncertainty, while improving the timeliness of sales and payments. In contrast, farmers located farther from such facilities reported higher logistical risks and fewer incentives to adopt high-value or perishable crops.

Key Barriers

1) Access to Institutional Credits just for the Wheat-Paddy Cropping System: All farmers reported access to credit facilities through cooperative societies or banks under schemes such as the Kisan Credit Card (KCC). While this system supports the purchase of essential inputs for wheat–paddy cultivation, it is less effective for other crops, where payments can be delayed. Since the scheme is not linked to farmers' income cycles, interest begins to accumulate if repayments are not made by the due date.

2) Subsidy design constraints: Farmers argued that the current subsidy model does not sufficiently reduce financial risk because it requires substantial upfront payment and often involves delays in reimbursement. They suggested that, rather than expecting farmers to purchase expensive machinery first and then wait for subsidy disbursement, the government could reduce the purchase price at the source. In their view, lowering the upfront cost would make equipment adoption more feasible and could improve the adoption of residue-management equipment, especially among small and leaseholding farmers.

3) Absence of a trusted crop insurance system: Farmers reported no awareness of government crop insurance schemes and limited trust in private providers, citing concerns about scams, unclear legal terms, and uncertainty about complaint resolution if problems arose. However, participants expressed a strong willingness to adopt crop insurance if it were delivered through government or officially recognised institutions, with transparent conditions and affordable premiums that farmers can realistically sustain. Farmers viewed such coverage as important for reducing risk and enabling greater crop diversification.

4) Limited quality regulation and price recognition: Farmers expressed concern that quality assessment at markets is primarily limited to moisture content, with little or no testing for pesticide residues or other quality parameters. In the absence of accessible testing facilities and effective enforcement mechanisms, farmers perceived no price advantage for producing higher-quality or chemical-free crops. This lack of quality-based price differentiation was seen as discouraging efforts to adopt less chemical-intensive production systems.

5.5 Conclusion

This chapter analysed farmers' perspectives on the economic dimensions of sustainable agriculture in Punjab using the FAO SDG 2.4.1 framework as an interpretive guide. The findings show that economic security, assured procurement, predictable returns, and access to institutional credit play a key role in informing farmers' cultivation choices and practices. Although diversified and non-chemical systems offer higher income potential under favourable conditions, their adoption is constrained by market volatility, lack of enforcement of minimum support price, climate risk, high upfront costs for machinery, and limited access to effective risk-mitigation mechanisms.

Overall, the chapter highlights that farmers' reluctance to diversify is not due to resistance to change, but to structural economic constraints that increase financial risk, particularly for small and leaseholding farmers. Enablers such as land ownership, seasonal

cropping opportunities, and proximity to processing facilities indicate potential pathways for strengthening economic resilience. These insights provide a foundation for the subsequent chapters, which explore how environmental and social factors further shape farmers' capacity to transition towards sustainable agriculture in Punjab.

Chapter Six- Farmers' Perspectives on Environment Indicators of Sustainable Agriculture

6.1 Introduction

This chapter presents an analysis of the survey data on the environmental impact of the farm's agricultural activities. Farmers' inputs were collected on five environmental indicators: prevalence of soil degradation threats; adoption of soil health management practices; pesticide management; fertiliser management; variation in water availability; and adoption of biodiversity-supportive practices. These indicators are based on the FAO SDG Indicator 2.4.1 survey module (2021) used in this study.

For each indicator, the findings are presented in three sections: the first provides a summary of farmers' inputs; the second presents quotations from some farmers; and the third identifies key enablers and barriers from farmers' viewpoints for transitioning toward sustainable agricultural practices. Together, these sections highlight both the environmental pressures farmers associate with prevailing production systems and the practical constraints shaping their ability to transition toward more sustainable practices.

6.2 Indicator 1 Soil Health- Prevalence of Soil Degradation Threats

6.2.1 Summary of Farmers' Responses on the Prevalence of Soil Degradation Threats

The primary threats to soil degradation reported by farmers were soil compaction and poor irrigation water quality. While no farmer reported permanent land loss due to soil degradation, all expressed concern about losing some area in the near future if they continue the conventional practices, which are causing the farm soil to become increasingly compacted each year. Farmers attributed soil compaction to prolonged standing water conditions under flooded paddy cultivation.

One farmer reported that for the past two seasons, wheat failed to grow on three acres of his land. Although he was able to obtain some yield from paddy, wheat cultivation was a complete failure. Subsequent soil and water testing revealed that the issue was linked to irrigation water quality. The groundwater pH was reported to be around 8, indicating alkaline water (Brunton, 2011), which had adversely affected soil health. After installing a new bore at a different location to access better-quality water, the land is gradually recovering and can now support crop production.

Farmers were also asked whether they test their farm soil regularly to inform fertilisation and cultivation planning. Of the 48 farmers surveyed, only 4 reported testing the soil every 2 or 3 years, depending on when they had time available to visit the laboratory. Three farmers had tested their farm soil twice in the past decade, while five had never tested it. The remaining thirty-six farmers indicated that they conduct soil tests only when they experience issues with land productivity. When asked whether farmers possessed a soil health card, issued under the Government of India's Soil Health Card Scheme, launched in 2015 to provide farmers with information on soil nutrient status and recommendations on nutrient application to improve soil health and productivity (Press Information Bureau, 2025) - all farmers responded "no". None of the surveyed farmers was aware of the scheme.

Regarding paddy residue management, twelve (25%) of forty-eight farmers surveyed reported incorporating crop residue into the soil. Twenty (42%) farmers burn part of the residue, mainly the standing lines left by rice cutting machines. Sixteen (33%) farmers reported having to burn all residue, as no other options were feasible for them. Figure 6.1(a & b) shows example photographs of these paddy residue management techniques taken during the field visit.



Figure 6.1(a): Paddy residue is burned to prepare the field for wheat sowing. Source (Author's Photograph)



Figure 6.1(b): Paddy Residue managed by incorporating it into the soil. Source (Author's Photograph)

6.2.2 Farmers' Perspectives on the Prevalence of Soil Degradation Threats

Quotes from farmers on the prevalence of soil degradation threats

"With flooded rice cultivation, our soil is becoming very hard. Over the past five to seven years, soil compaction has been increasing. We used to think that rice was very profitable for us to grow; however, it is damaging our environment. Flooded cultivation produces humus during the summer, and we also apply pesticides and fertilisers in the standing water, which doubles the impact. You can only feel some relief if you are sitting in an air-conditioned room; outside, it becomes very hot and humid."

"*Every year, we have to increase the dose of fertiliser; if we do not increase it, the land does not produce the same yield. I feel the soil has now become dependent on chemicals. We used to use one bag of fertiliser, but now we use more than three, and the amount keeps increasing rather than decreasing or staying the same. This is not just me; every farmer in my village follows the same practice. Only one or two people may differ, but the rest follow the same."*

"I noticed water quality contributes significantly to soil degradation. Good-quality water in my area is available below 170 - 190 ft; water above that level is also considered harmful to the crop, as it seems oily. Water can both damage and improve soil health. The problems with soil health caused by the overuse of chemicals can be solved by applying good-quality water. If we start getting canal water, the soil compaction issue can be easily resolved; at present, ploughing is helping to manage it."

"*Over the past three years, after I harvest wheat from the seven acres of land I lease, the soil turns like stone. Water does not penetrate, and seeds do not germinate. We used to grow potatoes on this land without any problems. I am not*

sure about the reasons for this; maybe increased use of urea or DAP is causing it, or the flooded irrigation for paddy. I do understand that paddy residue can help maintain soil health, which we have been burning for many years. However, when we are already facing losses under the current cropping system, how can we, who are leasing land at increasing rates, afford to spend an additional Rs. 5000 - 7000 per acre on diesel and machine rentals to manage the residue? Simple matchsticks cost nothing. Ninety per cent of the challenges in our farming practices are due to unsupportive government policies. This year, the government deployed many police officers to monitor incidents of residue burning using satellite imagery. The government must be paying salaries and covering diesel costs for these officers to check every farm. Instead of spending money on such monitoring, the government could have provided Rs. 1500 per acre incentives to farmers to manage paddy residue, and no farmer would have burned it."

Quotes from some farmers on soil testing

"We do not have the facility here. We would have to go to Ludhiana, but nobody goes there. There is one nearby, but I have never gone there either. This is our land; we have lived here since childhood, so we know how it is and what it needs."

"*Lab technicians and agriculture officers want farmers to bring the soil samples to them, but most people cannot do that. It is not about the money; it is about the time. Earlier, families had more children; we were four or five brothers, and one elder brother usually handled tasks like gathering information and handling external work. Now, most families have only one child who handles everything on their own. Expecting that person to leave a day's work and travel to a distant lab is*

unreasonable. The easiest solution would be to assign one extension officer per village, who would visit farms to collect samples and send reports to each farmer. We are even willing to pay for their petrol cost if they can come."

"Schemes do not reach the village level. Agriculture experts rarely visit the village. I have never seen a practical demonstration in my village. Only during the two-day Ludhiana Agriculture Fair do they showcase the machines, but how can anyone understand everything in just two days, with lakhs of people present? Every agriculture expert should adopt a village. They should visit regularly and educate farmers, explaining the advantages and disadvantages of each method. Practical training is essential."

"I did the test yesterday. The lab people told me there is low nitrogen, but everything else is fine. They said one bag of urea is enough, but we do not stop there—we use four bags because our hearts fear we might not get a good yield. Those who farm on their own land can try using only the recommended amount, because they do not have to pay high lease amounts. As leaseholders who depend on the earnings after paying the lease, we cannot rely solely on the recommendations."

"I recently did the soil test, and the result was good. The lab technician advised me not to broadcast urea directly onto the soil, as it will reduce the efficiency, and will not benefit wheat sown in the mulched field, but to apply it with irrigation water. The report showed that the soil has high phosphorus and a deficiency of micronutrients. I am applying the suggested solutions to address it. I am soon going to Australia and plan to buy my own soil-testing machine there, so I will not need to depend on the lab

for testing. Here in Punjab, the officers do listen; they are from the local area and help farmers. However, it depends on how you approach them. If you show respect, they respond. When they are busy, they tell you when to come. It is not like in developed countries, where you book an appointment. If farmers are respectful and flexible with meeting times, they can get the information they need."

Quotes from some farmers on Paddy Residue Management

"To manage residue, we need big machinery, a high-horsepower tractor. Small landholders cannot afford to buy these, so burning becomes a necessity for us. Nobody burns residue happily — we have to do it because we do not have the resources. No cooperative society helps us. Machines are usually given to large or medium-sized landowners or to those with connections to the society's head. If the government truly wants to solve this issue, it should create a system that ensures machinery is available to all farmers. Instead, the government sends the police to charge us for burning. Burning cannot be stopped by sending police officers — that only adds to the farmers' struggle. We are willing to rent machines and follow alternative systems wholeheartedly if resources are made available to all of us in time."

"Sometimes machines are available in our area. The problem is time. People responded well to state government announcement to start sowing rice from June 10 this year, but that leaves a very short gap between harvesting paddy and sowing wheat. Farmers growing potatoes or peas do not even have three days after the paddy harvest to sow their crop. Properly managing residue requires at least 15 days. If we can start sowing paddy on 1 June instead of 10 June, farmers will have more time to access and use machines."

"To manage residue, we struggle with three main problems: machines, time, and human resources. I bought all the machinery, and it was expensive. Now, I need a well-trained driver to run it. Labourers are untrained and cause significant damage to the machines. We need trained drivers to operate these heavy machines. Not only that, but I also used a recommended Super Straw Management System with a combine harvester on some acres; there was a lot of residue to incorporate. I do not know how I would have managed if I had used a Super Straw Management System[26] on all the acres, given the labour shortage. If farmers do not use SMS, at least they can burn the residue and start sowing wheat"

"Since 2018, I have not been burning residue. I used the Happy Seeder to sow wheat in standing paddy stubble in 2018, then the surface seeder from 2019. My method is much cheaper for residue management and wheat cultivation than other available methods, which are expensive. However, nobody in the village has followed it yet. After harvesting paddy, I broadcast wheat seed, level the field using a ripper, and spread the residue evenly across the surface. I then apply light irrigation either on the same day or the following day to initiate seed germination. The excess water must drain or dry within 24 hours; otherwise, it can cause seed rot. The mulch layer helps retain adequate soil moisture. After five to six days, wheat seedlings emerge. With this method, wheat yields are good, and more clean, soil-free wheat straw is produced for animal feed because the seed is placed close to the soil surface in direct contact with moist soil and protected by a residue mulch, rather than being deeply drilled into the

[26] The Super Straw Management System is a device attached to a combine harvester that cuts and evenly spreads crop residue across the field Kaur, A., Kaur, P., & Kumar, P. (2021). Status of paddy straw management technologies in Punjab. *Indian Journal of Extension Education*, *57*(1), 78-83. .

soil. For five to six years, my wheat crop has not fallen in bad weather either. One farmer tried following my method, but applied heavy irrigation. I told him to remove the excess water on the same day. He did so the next day, but it was late, and the wheat did not grow. He did not try the method again. People often do not accept their own mistakes and instead conclude that the method is not right, without considering whether the guidelines were followed properly."

"This year, the pollution got worse with all the burning — breathing became difficult for everyone. Many people are suffering from respiratory issues, and it is affecting all age groups. The best time to burn residue is in the afternoon, when the smoke does not spread much. However, this year, the police were fining farmers for burning. So, farmers had to wait until the officers were not around and burn in the evening. This made the pollution worse because, in the evening, the residue is wet, and the smoke stays low and spreads rather than rising as it does during the daytime. Also, I want to ask one question to the government, bailers provide residue to factories, and then the factory people burn it; where does that smoke go? Does it not contribute to pollution? Why are the factories not being questioned? We burn during the day and get fined; factories burn the same residue during the day, and there is no problem. We do not want to burn, but we are forced to because we can not afford the cost. The government calls us 'annadata' (food providers), but they do not treat us as such. We have more knowledge about farming than they do, if they are willing to listen."

"I am a common farmer like others in my village. I requested the head of our village Gurdwara Sahib (Sikh temple) to play an audio recording about the side effects of baling paddy residue. After hearing it, no one on my farm gave the residue to the

bailer. If they had listened to my advice, why would they not listen to the officers' advice? Our village is very far from major cities, and no officer comes here. I am even willing to lend my tractor and machinery free of charge if the Deputy Commissioner organises a training camp in our village. Many generous people are willing to lend tractors. If any mishap occurs, we all contribute. This is our virsa (heritage), our soil — why will we not do something to protect it?"

6.2.3 Key Enablers and Barriers

This section identifies the key factors that enable or limit farmers' ability to maintain soil health and manage threats to soil degradation, as seen from the farmers' perspectives.

Key Enablers

1) **Knowledge and Experience with Cost-Effective Residue Management Practices:** Some farmers reported using inexpensive residue management methods, such as a surface seeder, and observed improved wheat yields and better soil health after incorporating residue for more than three years. They noted that the soil became more porous than it was under the compacted condition it had when residue was burned on the land. Farmers gained this knowledge from non-governmental organisations; one in particular mentioned learning from Dr Avtar Singh, Founder of Good Grow Farms, Phagwara.
2) **Buying Residue Management Machinery or Access to Shared Machinery:** Farmers who could afford to purchase expensive residue management machinery or rent equipment such as a smart seeder or high-horsepower tractors from a co-operative society on nominal rent rates were able to incorporate crop residue into the soil, as one of the effective methods to maintain soil health.

Key Barriers

1) **Lack of Awareness and Access to Government Schemes:** Surveyed farmers were unaware of initiatives such as the Soil Health Card Scheme, which provides information on soil nutrient status and fertiliser recommendations. This limited awareness prevents farmers from leveraging government support to improve soil health and adopt sustainable practices.
2) **Limited Extension Support and Practical Training:** Farmers highlighted the absence of regular visits from agriculture officers and practical demonstrations in their villages. Without hands-on guidance and training, farmers often struggle to understand and effectively implement soil health management and improvement practices.
3) **Cost and Resource Constraints:** Many farmers, particularly smallholders and leaseholders, reported not being able to afford to purchase or rent expensive residue-management machinery or the high-horsepower tractors required to operate it. Labour shortages and limited access to shared machinery further restrict the timely adoption of alternative residue management practices, often leaving farmers with little practical option but to continue burning crop residue.
4) **Low Perceived Need for Soil Testing:** Some farmers perceived their long-term, experiential knowledge of the land as sufficient for making soil management decisions. As a result, even when testing facilities were available, farmers showed low motivation to access them, especially when services required travelling to distant centres. This combination of experiential reliance and logistical constraints represents a significant barrier to the adoption of scientific soil assessment tools, even though such tools could improve input efficiency and support more informed decisions regarding soil health.

5) **Reluctance to Try New Practices**: Even when cost-effective and technically successful methods exist, many farmers are hesitant to adopt them. Factors such as uncertainty about the method, fear of crop failure, or previous unsuccessful attempts discourage farmers from experimenting. For example, based on the farmers' perspectives presented above, one farmer who tried a new residue management technique experienced failure and did not attempt it again. Such experiences make other farmers cautious, and they may prefer to continue with familiar practices rather than risk new approaches. This barrier highlights how perceived risk and caution can limit the uptake of improved or alternative agricultural practices.

6.3 Indicator 2: Water Use- Variation in Water Availability

This indicator assesses farmers' awareness of water availability issues on their farms, including whether they have observed a reduction in water resources over time. It also assesses the presence of organisations responsible for allocating water among farmers, and the extent to which these organisations are working effectively.

6.3.1 Summary of Farmers' Responses on Variation in Water Availability

All forty-eight farmers surveyed reported irrigating 100% of their cropped area. The sources of irrigation varied: twelve farmers (26%) relied equally on canal water and groundwater. Within this group, three farmers used canal water exclusively during most of the paddy season but switched to tubewell water at the final stage of rice cultivation. Farmers perceived canal water as denser, sediment-laden, and more conducive to disease development at the final stage, particularly rice blast[27] and false smut[28], both fungal diseases. In contrast,

[27] Rice blast is a fungal disease that causes spots on rice leaves at maximum tillering, and can damage the panicle, reducing grain yield Punjab Agricultural University. (2024). Package of Practices for Crops of Punjab. *Kharif 2024*, 15. https://pau.edu/content/ccil/pf/pp_kharif.pdf .

[28] False smut is a fungal disease in which some rice grains turn into yellowish or greenish ball-like structures ibid..

tubewell water was preferred, as it was considered to be cleaner and more suitable for maintaining crop health and grain quality at the final stage .

The remaining 36 farmers (74%) depended entirely on groundwater from electrically operated tubewells. Across the sample, many farmers expressed a strong preference for accessing canal water, particularly during the early stages of paddy cultivation. At the same time, some farmers voiced concerns about using canal water due to the possibility of industrial effluents and chemical residues entering canal systems, which they feared could contaminate irrigation water and affect food crop safety. This highlights an important area for further research, as farmers prefer canal water for its availability but remain concerned about potential contamination. Addressing this dilemma would require targeted research to better understand water quality issues, alongside appropriate government interventions to ensure safe and reliable irrigation.

Flood irrigation was the predominant practice for both wheat and paddy crops. Only two vegetable-growing farmers reported adopting drip irrigation systems for nursery and potato cultivation, while flood irrigation remained the primary method for all other crops. Water use was generally estimated on a time basis, with a common belief that one acre could be irrigated in approximately four hours. None of the farmers had a system in place to monitor the actual volume of water applied, nor were they aware of the optimal amount for different crops. Two farmers reported experimenting with alternative paddy cultivation methods, such as direct-seeded rice and anaerobic-seeded rice, primarily to reduce water use compared with conventional flood irrigation.

All farmers were aware of the issue of water scarcity and expressed concern about its availability, particularly those entirely dependent on groundwater and had no access to canal water. Fifteen farmers expressed serious concern because they were required to lower their

submersible pumps each year by adding approximately 10 feet of pipe to access water. A further eleven farmers reported needing to extend their pumps every three years.

Farmers with access to canal water reported no major challenge in water availability. In areas without canal access, groundwater quality at depths of 170–190 ft was considered suitable for agriculture. As a safeguard against future depletion and to delay the need for new installations, most new borewells are now drilled to depths of more than 600 feet. The cost of constructing a new borewell was reported to be around INR 200,000, a considerable financial burden for small- to medium-sized landholders.

In response to these water-related challenges, one farmer transitioning towards natural farming practices described an individual initiative to construct an artificial canal on his farm to address the water issue. According to the farmer, the primary source of water for this artificial canal would be diverted canal water and rainwater. He explained that canal water is not required continuously for all crops or at all stages of crop growth, and surplus canal water during allotted irrigation often goes unused. An artificial canal can be used to store this surplus water, which can later be pumped to the fields using a solar-powered pump when needed. The farmer also planned to use the canal to store rainwater and excess drainage during periods of heavy rainfall by diverting surplus field water into it, thereby reducing at least some crop damage from waterlogging. Additionally, the canal floor was tiled rather than lined with cement concrete, allowing gradual seepage to support groundwater recharge. The project had already cost the farmer approximately INR 700,000, and at the time of the survey, the canal was still under construction and had not yet been filled with water. Figure 6.2 presents a photograph of this artificial canal taken during the field visit.



Figure 6.2: Artificial canal on the farm of a natural farming practitioner. Source (Author's photograph)

Regarding the role of organisations in canal water allocation, farmers generally reported that the system functions adequately. They mentioned that the water schedule for each farm is fixed, which reduces the need for frequent organisational involvement. However, one major concern raised was that the schedule had remained largely unchanged since the early establishment of the canal irrigation system, despite changes in crop patterns and water requirements over time. In addition, farmers highlighted the deteriorating condition of traditional field water channels through which canal water is distributed. These channels are very old and require reconstruction. Some areas had recently received pipeline replacements for the water channels, and others are still awaiting such improvements.

6.3.2 Farmers' Perspectives on Variation in Water Availability

Quotes from Some Farmers on Variation in Water Availability

"Borewells at 120–140 feet give oily water, which harms crops. Good water now only comes from around 170-190 feet. We need to go two layers deeper. For the past three

years, we had to go 10 ft deeper every year. If paddy could be stopped, it would help a lot — the number of problems would reduce. It will enable farmers who own land to protect it from damage, and those renting land would be able to earn a little more if the Minimum Support Price (MSP) is provided for other crops. I do not want to grow paddy anymore — it is destroying the environment."

"When I was a child in the late 1980s, water could be accessed at 60–70 ft. In my father's childhood, it was at just 20 ft. However, the last borewell we drilled was 620 ft deep to access water at 180 ft. You can imagine where we have reached. If someone has two to three acres of land, the maximum income they can earn is around ₹100,000, but a borewell costs over ₹200,000. How can someone survive on that? Loans are available, but they come with interest. That is why we do not have many small farmers anymore. Earlier, there used to be many, but now it is too expensive to farm."

"We are near Harike, so we do not have water problems. Our water is at 25 ft. But in nearby areas of Ferozepur, the water level drops every year. That area needs to cultivate different crops besides rice — maybe legumes or others. Before the Green Revolution, we had more crop diversity. I believe people need to let go of their obsession with rice. We could grow arhar (pigeon pea) or other crops and earn well. I want to try, but my father does not agree—he says there is no guarantee of a sale. If I get a stable job, I might take the risk. People are scared. With growing paddy and wheat, farmers can earn some assured income to pay for children's education or other essentials. But if they grow other crops, there is no guarantee — and with financial weakness, that fear becomes even stronger."

"I am building an artificial canal on my land. Growing Basmati rice feels like compromising my conscience — it is not sustainable. I believe rain-fed crops are better. We used to get canal water, but then it stopped. One reason was that landowners migrated abroad, and farmers who rent land do not need to worry about arranging canal water access for the landowner's land, because renting is usually done annually without any guarantee, so investing time in the process is not worth the effort. I took the initiative to apply for canal water access, but the elections delayed it. It is still under consideration. I am also considering renewable energy, though getting subsidies is a headache — the process is long and difficult."

Quotes of farmers on alternative rice cultivation methods

"Direct-seeded rice does not work properly — there are too many weeds and waste plants. If someone wants to try it, the farmer has to stay in the field all the time to manage and remove the waste plants. Also, it does not work on sandy soil, just on hard soil."

"*I do direct-seeded rice (DSR) on 30%–40% of my land, but it is still in practice — I have only been doing it for two to three years. With the conventional method, one acre used to take about four hours to irrigate, but with direct seeding, it takes 2.5 to 3 hours. The reason for this is that ground levelling is not disturbed; we level the land first, then direct seed. In the conventional method, with puddling, levelling gets disturbed, and more water is used. Overall, per season, we can save 20–30% of water. Yield with this method is the same, sometimes even more, but never less, and there is no reason for it to be less. During the rice-growing stage, proper air circulation*

reduces disease compared with conventional methods. Flood irrigation creates a humid environment that promotes fungal growth, forcing farmers to use expensive fungicides. But DSR is more resistant to fungus, so we do not need the expensive fungicides; normal, less costly ones work fine. I plan to do direct seeding on all my land, but we cannot do it everywhere. We need to run the conventional method in parallel, even on a small scale, because plots that get more dirt from storms or are near roads or dust mounds have more rat problems. At the initial stage, when very little water is applied, rats pull the plants out. Considering this, we have to keep some area under the conventional method, but the majority can be direct seeded."

"We grow rice on 10 acres using the anaerobic seeding *method (ASR) of Good Grow Avtar Singh. I used to grow sugarcane, but I stopped four to five years ago because there is no sugar mill nearby. Fungus has less effect with this method. Yield is about 1 to 1.5 quintals more. We use protective measures to control weeds. If weeds still grow, we spray herbicide. We grow PUSA 44, a good seed variety for the direct-seeded and anaerobic-seeded methods, which gave higher yields. PR 126 and 31 are less likely to grow well with this method due to their thin stems. PUSA 44 has better growth and length; it just takes an extra week to mature. If we give water in a controlled manner, it gives the same yield as other seeds. If we give more water, it will take longer to grow."*

6.3.3 Key Enablers and Barriers

This section identifies the key enablers and barriers currently impacting farmers' adoption of sustainable water management practices, based on the surveys and material above. Enablers present the supportive conditions that support the sustainable use of water

resources. Barriers outline obstacles that prevent the adoption of water-efficient farming methods.

Key Enablers

1) **Access to Canal Water and Water-Use Efficiency:** Farmers with access to canal water reported not facing challenges related to water availability and therefore did not need to rely heavily on groundwater to cultivate water-intensive crops such as paddy. In some areas, traditional open irrigation channels have been replaced with underground piped irrigation systems to improve the efficiency and reliability of water delivery at the farm level. Many farmers also perceive canal water as beneficial for restoring and maintaining soil health.

   However, research on agricultural water productivity indicates that improvements in water conveyance efficiency alone do not necessarily result in real water savings at the basin scale. Real water savings are achieved through reductions in consumptive water use (Giordano et al., 2017), consistent with the objectives of SDG 6.4.1 (to substantially increase water-use efficiency across all sectors). While piped irrigation systems may generate apparent (or local) water savings, achieving real water savings requires systemic policies and complementary interventions that support effective on-farm water management and address total water consumption.

2) **Connected to and learned from NGOs promoting sustainable agricultural practices:** Only two farmers from the forty-eight surveyed experimented with alternative paddy cultivation techniques: one with Direct Seeded Rice (DSR) and another with Anaerobic Seeded Rice (ASR). They reported benefits such as improved soil structure, reduced fungal infections, decreased dependence on expensive fungicides, and, notably, savings in irrigation water. Empirical studies further support the water-saving potential of DSR compared with conventional puddled transplanted

rice (PTR). For example, Bhardwaj and Sidana (2019) collected field data from Faridkot and Ferozepur and reported that DSR reduced irrigation water use by approximately 28.10% in basmati and 25.33% in non-basmati fields, with water use under DSR at 4,639 m^3/ha (basmati) and 5,549 m^3/ha (non-basmati) compared with 6,452 m^3/ha and 7,432 m^3/ha under PTR, respectively.

Another field study (Kaur et al., 2023) conducted in the districts of Mansa and Sri Muktsar Sahib - the district with the highest adoption of DSR technology - found that DSR reduced irrigation water use by approximately 23% compared with conventional practices. These findings across multiple districts indicate that DSR's water savings result from avoiding continuous flooding and reducing irrigation frequency. Similarly, ASR has been promoted as a water-efficient alternative, with practical demonstrations by organisations such as Good Grow Farm showing that this method can contribute to real water savings by reducing irrigation requirements (Good Grow Farms, 2022). Together, this evidence suggests that water-efficient practices, supported by knowledge and practical experience, can ease pressure on groundwater resources and serve as effective enablers of sustainable water use in Punjab.

Key Barriers

1) **Inequitable Access and Infrastructure Challenges in Canal Water Allocation:** Some farmers reported not having access to canal water, which limits their ability to reduce reliance on groundwater. Most of the surveyed farmers indicated that, if canal infrastructure were restored and canal water made available to their fields at least at the initial stage of cropping, it could help prevent the over-extraction of groundwater associated with conventional high-water-use practices, at least until proper marketing and procurement systems are established for alternative, less water-intensive crop options.

2) **Operational Challenges in Adopting Water-Efficient Rice Cultivation Methods:** Despite the reported benefits of direct-seeded rice and anaerobic-seeded rice methods, many farmers remain hesitant to adopt them due to challenges such as weed management, unsuitability for sandy soils, and pest issues, including rats pulling out the rice stems. The lack of targeted training and technical support further restricts the large-scale adoption of these methods.

6.4 Indicator 3: Fertiliser Pollution Risk- Management of Fertilisers

This indicator collects information from farmers on chemical fertiliser application. It assesses whether farmers follow recommended fertiliser use guidelines or protocols, and whether they combine chemical fertilisers with organic sources such as cow manure, incorporate legumes as a cover crop or within multi-cropping systems to reduce fertiliser inputs, or follow other practices to mitigate fertiliser pollution risk.

6.4.1 Summary of Farmers' Responses on Fertiliser Management

All farmers, except for three who practised non-chemical cultivation, reported using chemical fertilisers. None of the farmers used the soil testing report to guide fertiliser application. When compared with PAU's recommended dosages in the Appendices 1–3, farmers' reported practices show limited alignment. Most wheat growers applied 3–3.5 bags of urea per acre, which is 135–157.5 kg, one bag weighs 45 kg, plus one 50 kg bag of DAP, which is approximately 25–47.5 kg urea per acre higher than PAU's indicative wheat guidance (~110 kg urea/acre). Only one farmer reported using inputs consistent with PAU recommendations, while two farmers indicated they planned to reduce urea by about half a bag in the following season.

For rice, farmers applied similar urea rates (135–157.5 kg/acre), which is 45–90 kg higher than PAU's variety-specific recommendations. Potato cultivation involved

substantially higher DAP use—around four times that of wheat—while urea use remained similar. Although PAU provides crop- and deficiency-specific guidance, fertiliser decisions were largely based on peer advice and social media due to limited soil testing. (Punjab Agricultural University, 2025).

All farmers except one reported that they apply the fertiliser as guided by the shopkeeper, rather than reading the instructions on the packaging, as those were mostly written in English. A few farmers who had incorporated crop residues into their fields observed that, after some years of incorporating residue, they were able to reduce the dosage of both urea and DAP compared with previous years. One farmer, who followed the recommended fertiliser application practices issued by Punjab Agricultural University (PAU), applied fertilisers according to crop growth stages. He emphasised that he was the only farmer in his locality to do so, owing to the knowledge he had gained through his agricultural degree. In contrast, most farmers acknowledged that their application rates exceeded recommended levels and had been increasing each year.

Organic sources of nutrients, such as cow manure, vermicompost, and green manuring, were rarely used. Farmers mentioned that one reason is the decline in livestock ownership. Every farming household used to own some cows, but now only a few in the village have them. Even when organic sources such as cow manure are available to purchase, these inputs were described as expensive compared to the relatively low cost and easy availability of urea. In contrast, farmers adopting non-chemical cultivation methods reported purchasing expensive cow manure and vermicompost to enrich the soil with natural microbes.

6.4.2 Farmers' Perspectives on Fertiliser Management

Quotes from Farmers on Fertiliser Management

"*Earlier, we used to apply five to six bags of urea, but now I have reduced it straight to three bags. Next, I will reduce one more bag and see what happens to the yield. We sometimes use neem fertiliser as well. The only thing we are still using in the same way is pesticides, because at the moment we do not know any other alternative."*

"*I used to use six bags of urea, but this year I used around three bags of urea on my farm I own. On the farm we rent, we use 7 to 8 bags of urea because we sometimes lease land for only 1 year. Sometimes we get land that has not received cow manure or green manure for 7 years. Now in the 8th year, if I try to make it better, it costs at least five trolleys of cow manure — 1,500 per trolley plus 600 for labour. We know from experience that this kind of land can only yield 50,000 in production, but the lender is asking for 70,000. What can we do then? The lender never says that you take the land on a five-year lease and keep it as your own. So, we also then apply as much fertiliser as we can to get enough production to earn some income for us and repay the lease rates."*

"A crop does not grow if we do not apply nitrogen. Bio-fertiliser is not available in our area — it is available about 100 km away, at a cost of ₹40,000 for 10 acres. We put organic manure only in pasture areas — that is all we have."

"I have been using the recommended dose for three years, never putting even one kg more than what is advised. I get good crops with less input. I know, based on my knowledge, that if I give twenty kg of urea, the crop will only use what it needs, so applying eighty kg is just a waste and damages the soil. Young people who are studying or have studied agriculture should be appointed as farmer advisors in

villages. Nobody listens to free advice. The government should spend resources on these initiatives."

6.4.3 Key Enablers and Barriers

This section identifies the key factors currently influencing or limiting farmers' adoption of sustainable fertiliser-use practices that help mitigate fertiliser pollution risk, based on the survey results and farmer interviews..

Key Enablers

1) **Land Ownership:** Farmers who owned land were more interested in following recommended fertiliser application practices and investing in soil health. Ownership reduced the pressure to maximise short-term yields, allowing them to adopt sustainable practices and avoid excessive fertiliser use.
2) **Access to Agricultural Knowledge and Training**: Farmers with formal agricultural education or those who actively sought guidance (e.g., from Punjab Agricultural University or Non-Governmental Organisations) mentioned following recommended fertiliser dosages according to crop growth stages. This support helped them reduce over-application and minimise potential fertiliser pollution.

Key Barriers

1. **Lack of official guidance:** Most farmers did not use soil testing reports, and very few followed the Punjab Agricultural University (PAU)–recommended fertiliser dosages. Instead, they relied on shopkeeper or neighbour guidance, as packaging instructions mentioned were mostly in English, limiting farmers' ability to follow official recommendations.
2. **Leasehold Pressure:** Short-term leases discourage investment in soil health (e.g., green manuring), pushing farmers to maximise yield through higher fertiliser use to recover high input costs.

3. **Expensive organic inputs and limited access**: Organic nutrient sources, such as cow manure, vermicompost, and biofertilizers, were rarely used due to high costs, limited local availability, and the decline in livestock ownership. This created a barrier for farmers in combining chemical and organic inputs to minimise the risk of fertiliser pollution.

6.5 Indicator 4: Pesticide Risk- Management of Pesticides

The indicator assesses the use of pesticides on farms, including the type of pesticides used, and the measures adopted to mitigate associated health and environmental risks. Regarding health, the survey assesses whether farmers follow label recommendations, use personal protective equipment (PPE), and dispose of pesticide waste safely. Regarding environmental factors, the survey explored whether farmers adjust planting times or intercrop to disrupt pest cycles. It also assessed the use of biological pest control methods, adherence to the economic threshold concept for pesticide application, and regular cleaning of machinery and equipment to prevent the dissemination of pests. The discussion below draws on the survey results and farmer responses.

6.5.1 Summary of Farmers' Responses on Pesticide Management

All farmers practising chemical cultivation reported using pesticides as a preventive measure against potential pest attacks, except one farmer who followed the economic threshold level (PAU , 2023), applying pesticides only when the pest population seemed to exceed the threshold level.

Moreover, none of the farmers reported using personal protective equipment (PPE), such as gloves or the masks provided with pesticide packaging. Instead, some farmers mentioned occasionally covering their faces with a cloth while spraying. The reason provided was that they did not use red-labelled, highly hazardous pesticides and therefore believed PPE was not

needed. Protective equipment was used only when shopkeepers explicitly recommended it for specific products.

Overall, pesticides other than red-labelled were generally perceived by farmers as not harmful to human health; however, this perception does not necessarily reflect the actual risk. All pesticides can pose risks to humans, animals, and other living organisms when not handled correctly, particularly in the absence of appropriate safety measures such as personal protective equipment (Kumar et al., 2012). Pesticide exposure has been associated with a range of adverse health effects, including both acute and chronic illnesses, depending on the level and duration of exposure (Kaur et al., 2018; Mittal et al., 2014).

Both chemical and non-chemical cultivation farmers reported following the recommended pesticide dosages. A commonly expressed statement was: *"We are mostly growing wheat and rice, and since we ourselves also consume this produce, there is no reason to overuse pesticides. We do apply fertilisers in higher quantities sometimes to increase production, but not pesticides."* However, pesticides were generally applied at regular intervals, regardless of whether pests were present.

A widespread concern among farmers was the uncertainty regarding the authenticity of pesticides. Many expressed doubts about whether the products they purchased were genuine, as receipts were often not provided at the time of purchase. Farmers also reported being pressured by shopkeepers and even cooperative societies to purchase additional products beyond their needs to meet company sales targets. Several farmers noted they were not informed about the purpose or necessity of these additional products. Chemical cultivation farmers strongly emphasised the need for accountability and transparency in pesticide sales. They demanded that all pesticide shops and cooperatives be held responsible for ensuring product integrity and that farmers be provided with reliable systems to verify the authenticity of agricultural inputs. This concern is supported by a study conducted by the Federation of

Indian Chambers of Commerce & Industry (FICCI) in 2015, which found that approximately 30% of the agrochemical market in India consisted of adulterated, counterfeit, or substandard pesticides, and such incidents were occurring at an alarming rate (FICCI, 2015). In response to these challenges, the Government of India introduced the draft Pesticides Management Bill, 2025, to strengthen regulatory and administrative control and impose stricter penalties for counterfeit pesticides (MoAFW, 2026).

In contrast, waste management practices were broadly similar across the sample. Fertiliser sacks were either given to waste collectors or reused for other purposes after cleaning, while emptied pesticide bottles were buried in the waste area on the farm – small, non-cultivated spaces used by farmers to accumulate and dispose of waste, either by burning or burial. Farmers reported burying pesticide containers in these areas, as waste collectors did not accept them; cardboard boxes were generally burnt.

However, FAO/WHO (2008) guidelines on pesticide waste management emphasise that the burial or burning of pesticide packaging at the place of use should be prohibited. Burning may generate environmentally persistent toxic emissions, while plastic containers do not biodegrade and can remain intact indefinitely when buried. Furthermore, FAO's assessment of agricultural plastics and their sustainability notes that only a small fraction of agricultural plastics are collected and recycled, with the majority being burned, buried, or landfilled. The report emphasises the urgent need for coordinated and decisive action to manage agricultural plastic waste effectively (FAO, 2021).

Non-chemical cultivation farmers followed similar waste disposal practices for bio-pesticide containers. However, they also reported exploring additional non-chemical pest management measures recommended by the institutions they were associated with or by relatives with some agricultural qualifications. These included intercropping and the use of traditional practices such as spraying fermented buttermilk as a fungicidal treatment.

6.5.2 Farmers' Perspectives on Pesticide Management

Quotes from Farmers on Pesticide Management

"I use green-label pesticides. It has been many years since I sprayed anything for aphid attack on wheat. Some farmers spray out of fear. I think when you apply more urea, you get more problems. I only spray one fungicide and one pesticide in rice. There is no need to spray on wheat — rarely, if ever, one spray is enough. Once, I had a leaf folder and stem borer attack on rice, which scared me a lot, but from experience, I knew it would not cause much damage. I followed economic thresholds. I cannot go fully organic because it yields less, and it is a struggle to sell organic produce. Why should I put so much effort and not use any chemicals when I do not get any price difference for the quality, and struggle to sell?"

"Pesticide has no fixed rate. You go to one shop — the same medicine, same salt, just a different box — and it is ₹50 less. Another shop also has it for ₹50 less again. For example, Coragen costs ₹700, but a shopkeeper called me to take it for ₹250. There is no control on price, and we know nothing about the authenticity of the products."

"We have one community from outside Punjab living in our village. They take land on lease for one lakh per acre – it is quite a large amount. They use a lot of cow manure on the land. They grow vegetables, sell them to the big mandi, and make good profits. Looking at what they do on our leased farms, I think vegetables can be grown in our area, but we do not know the right method. They do intercrop with different types of vegetables. They are a big family, all of whom work on the farm, and they have a lot of machinery. However, they spray a lot of pesticides, which is why nobody from the village buys vegetables from them. Farmers who grow paddy on that land after vegetables get lower yields of poor quality. No officers from the agricultural university

or government officials have come to our village to talk to farmers about such alternative cropping methods and about our concerns related to fertiliser and pesticide usage, or our future with the current farming system."

"*People do not know what is good to eat and what is not. They do not buy from farmers in their own village but from intermediaries. The suggestions people give to farmers about doing our own packaging or branding are just fake ideas. We, farmers, are just breathing - living is tough"*

"I follow the guidance of Punjab Agricultural University scientists and extension officers to use or prepare biopesticides on my farm. I prepare biopesticides using neem leaves, jaggery, Calotropis Procera leaves, and other plants recognised for their pest-control properties. The officers are very dedicated to their work, but since only one or two of them serve many villages, it sometimes takes more time to receive their advice, which is understandable. This is my third year following their recommendations, and since the real results of using biopesticides start to show by the third year, I expect to see better yields soon."

"Pests become resistant to chemical pesticides — if chemicals can stop working, how will biopesticides work? Biopesticides exist only in books. We know that chemical pesticide companies are private and work for profit, but they support us a lot by providing timely information and visiting our farms whenever we face problems. I have not seen such efforts for bio methods. Farmers need to see a lot of practical demonstrations before even thinking of taking the risk to transition; it cannot be done just by talks."

6.5.3 Key Enablers and Barriers

This section identifies the key factors currently supporting and limiting farmers' adoption of sustainable pesticide management practices to mitigate pesticide risks to human health and the environment.

Key Enablers

1. Access to Expert Guidance and Training: Farmers connected with agricultural institutes such as Punjab Agricultural University (PAU) scientists or extension officers, or NGOs, and through social media channels of agriculture experts, gained knowledge on economic threshold concepts and biopesticide preparation. This shows that access to expert guidance enables judicious pesticide use.

Key Barriers

1. **Limited Outreach and Institutional Support**: Farmers expressed willingness to adopt alternative pest management methods if they received the same timely support from biopesticide suppliers as they currently receive from chemical pesticide sellers. Delays in guidance and the lack of practical demonstrations from official agricultural institutions in farmers' local areas limit farmers' trust and the adoption of sustainable practices.

2. Market Barriers: Farmers face challenges in fully adopting biopesticides due to the perception that these methods require more monitoring and frequent applications. Uncertainty around yield, produce sales, and market prices for quality crops increases financial risk. Due to these risks, farmers are currently avoiding a complete switch to biopesticide use.

3) Lack of Awareness of "Sustainable Agriculture" and Recommended Dosages: The farm survey highlighted the absence of a middle path in transitioning from conventional chemical-based farming to fully organic systems. When asked about alternative or sustainable practices, most farmers referred exclusively to organic farming. Only one out of forty-eight farmers reported using the recommended chemical dosages provided by Punjab Agricultural University for wheat and paddy. The remaining farmers applied chemicals based on

experiential knowledge, peer advice, or personal judgment, rather than conducting soil tests or consulting agricultural scientists.

6.6 Indicator 5: Biodiversity- Use of Biodiversity-Supportive Practices

This indicator assesses farmers' adoption of biodiversity-supportive practices. It includes:

1) Maintaining natural vegetation, including the number of trees on the farm.
2) Incorporating components into farm production, such as tree or tree products, fish, poultry, or other allied activities.
3) Practising crop rotation involving at least three crops on at least 80% of the farm area

6.6.1 Summary of Farmers' Responses on Biodiversity-Supportive Practices

Among the 48 farmers surveyed, most reported having 1 to 3 trees per acre, except 4 who reported 10 to 15 trees per acre. Land leased generally had only one tree per two acres. One farmer explicitly stated the reason for having fewer trees on leased land as, *"We will have less profit on leased land if we grow shady trees there, more problems to handle, such as insect and pest growth. We only keep one small kind of tree near the motor; we do not let that tree grow big."*

Another farmer suggested a way to encourage tree planting, saying, *"Suppose if we have five acres, we should have at least five trees on our farm. Otherwise, the subsidy or other facilities should stop for that farmer. That is how farmers can become aware of the importance of growing trees."*

Overall, farmers considered trees, especially shady trees, to cause problems for pest and insect growth. Tree cover in and around farm areas was very minimal. Seasonal crop production was the primary contributor to farm output for the majority of farms surveyed, except for three farms: one integrated poultry farming alongside crop production, one had a

vermicompost plant, and another had poplar trees contributing to farm production. Figure 6.3 shows the poplar tree farm photograph taken during the field visit.



Figure 6.3: Mustard intercropped with poplar trees on one of the participants' farms. Source (Author's Photograph)

Only farmers who grew potatoes in the winter season, vegetable growers, and those practising non-chemical cultivation reported growing three different crops in a year. For example, potato → moong or/and maize, mint→ paddy. All other farms cultivated only two crops, wheat and paddy. As a result, only holdings growing potatoes or vegetables in the winter season met the condition of practising crop rotation involving at least three crops on at least 80% of the farm area.

6.6.2 Farmers' Perspectives on Biodiversity Supportive Practices

Quotes from Farmers on Biodiversity-Supportive Practices

"Farmers sow those crops that can be sold in the nearby market. Unless a crop can be sold within 5–10 km, it is difficult for farmers to grow and sell that cop. The Doaba belt grows maize and potatoes because they have proper markets for these crops. Lack of infrastructure is a problem."

"We are concerned about the environment and water. We want to stop growing paddy, but the rents are too high to pay. Only paddy provides enough income to cover those costs. We are in a trap. Farmers, like me, who rent land are not able to save anything; they are just managing their daily expenses."

6.6.3 Key Enablers and Barriers

This section identifies the key enablers that support farmers in adopting biodiversity-friendly practices, including tree integration, crop diversification, and residue management, as well as the factors that limit their wider adoption.

Key Enablers

1. Land Ownership: During farm visits, it was observed that farmers farming on their own land had more trees around their farms, with some having twelve or more trees per acre. The common reason given was that, if shaded trees slightly reduce yield in some areas, they still receive yield from most of their land and do not face the pressure of paying high lease amounts.

Key Barriers

1. Trees perceived as a liability, particularly on leased land: Trees, particularly large or shady species, were widely perceived by farmers as contributing to increased pest and insect populations, which in turn affect crop yields. Studies by Li et al. (2024) and Laub et al. (2022) highlight that shading can alter microclimatic conditions - such as humidity, temperature, and light availability - in ways that may negatively affect grain crops like wheat and rice. While

these studies do not directly link tree shade to increased pest incidence, the reported ecological effects provide a plausible explanation for farmers' perceptions of higher pest pressure and reduced yields under shaded conditions.

Leaseholding farmers indicated that although they were willing to grow and maintain trees on land they owned, they were reluctant to do so on leased land due to the risk of reducing the effective cultivable area and increasing pest pressure, which could further affect already narrow profit margins under high lease payments. Farmers further emphasised that minimising environmental risks and adopting biodiversity-supportive practices, including tree integration, should not be the sole responsibility of leaseholding farmers but also of landowners and the government. They argued that the government should introduce supportive policies on lease arrangements, crop insurance schemes, and regulations or incentives to encourage tree retention on agricultural land.

2. Limited Institutional Support and Guidance: Farmers from remote villages expressed concern about the minimal visits from agricultural officers and the lack of guidance on biodiversity-friendly practices. They emphasised that with proper knowledge, timely training, and consistent local support from officers, the community would willingly support their efforts and adopt sustainable practices. However, since such support is currently not available, transitioning to potentially risky practices is too great a risk for individuals whose livelihoods depend entirely on farming.

3. **Limited Market Access for Diversified Crops:** Farmers reported that they largely grow crops that can be sold within a 5–10 km radius. The lack of local markets, storage facilities, and reliable procurement systems limits farmers' ability to cultivate other crops such as pulses, oilseeds, and vegetables. Even with potatoes, which some farmers cultivated as a second major crop instead of wheat, farmers noted that medium- to large-scale landholders were more likely to benefit from potato cultivation, as private buyers preferred bulk purchases

from larger farms rather than smaller quantities from smallholders. As a result, small landholding farmers faced greater difficulty in experimenting with alternative crops due to limited access to local private buyers and the absence of supportive government procurement policies.

6.7 Conclusion

Overall, farmers' accounts indicate that environmental sustainability challenges in the study area are closely tied to the dominant wheat–paddy system, limited marketing platform, guaranteed minimum support prices for alternative crops, rising input costs, limited advisory support, and high dependence on groundwater. In relation to soil health, farmers widely reported increasing soil compaction and linked degradation risks to prolonged flooded paddy cultivation, growing chemical dependence, and constrained residue management options. The low uptake of soil testing was shaped by limited access, time constraints, and reliance on experiential knowledge, compounded by near-zero awareness of formal support schemes. Crop residue burning emerged as a practical and economic decision rather than a preference, driven by short turnaround times between crops, machinery and labour constraints, and limited incentives that would make alternatives feasible, especially for smallholders and leaseholders.

Water-related concerns were widespread, with many farmers describing declining groundwater levels, increasing pumping depths, and the high financial burden of constructing new borewells. While canal water was viewed by some as beneficial, especially during early crop stages, others expressed concerns about potential contamination from industrial effluents entering canal systems, which may affect crop health. These findings highlight the need for improved irrigation infrastructure, effective regulation of industrial discharge, and stronger institutional oversight to support safe and sustainable food production.

Across fertiliser, pesticide, and biodiversity indicators, farmers described practices shaped more by risk management and market pressures than by scientific guidance, alongside concerns about pesticide authenticity and limited institutional monitoring. Together, the findings suggest that enabling a transition toward environmentally sustainable agriculture in Punjab requires not only technical solutions but also strengthened governance, accessible local advisory systems, and supportive market and policy mechanisms that reduce financial risk and make sustainable practices practically viable for diverse farmer groups.

Chapter Seven- Farmers' Perspectives on Social Indicators of Sustainable Agriculture

7.1 Introduction

This chapter presents findings from a farmer survey on the social aspects of sustainable agriculture, focusing on three indicators: decent employment, food security, and land tenure. These Indicators are based on the FAO SDG Indicator 2.4.1 survey module (2021) used in this study. Farmers responded by describing their day-to-day farming duties and household realities, such as labour conditions and wage rates, access to food across seasons, and land tenure arrangements, which are analysed here in relation to the social requirements of sustainable agriculture.

The chapter is organised into three sections corresponding to these indicators. The first section reports farmers' perspectives on decent employment, including farm labour wage rates, and broader perceptions of farm work and well-being. The second section presents findings related to food security among farming households. The third section reports farmers' perceptions of land tenure arrangements and tenure security. Within each section, key enablers and barriers relevant to the respective social indicator are identified. Together, these findings highlight social factors that influence farmers' capacity to engage in and transition towards sustainable agricultural systems.

7.2 Indicator 1 Decent Employment- Wage Rate in Agriculture

This indicator assesses whether the daily wage rate paid to unskilled farm labour meets, exceeds, or falls below the minimum wage rate in the agricultural sector. In addition, farmers' broader perceptions of farm work as decent employment are explored, including its effects on physical, mental, and social well-being.

7.2.1 Summary of Farmers' Responses on Decent Employment

Across all surveyed farms, farmers reported that routine agricultural tasks are generally undertaken by farmers themselves and their family members. Migrant and local labour are

primarily employed during peak labour seasons, such as sowing and harvesting periods. Wage rates for farm labourers in all surveyed farms were reported to be fixed as per the local fixed rate of the village and the surrounding villages. All farmers highlighted that migrant workers often agreed to work for ten to fifteen per cent lower wages than local workers, as many local workers prefer other employment opportunities, such as driving jobs or work provided under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA)[29]. It is important to note that this study collected data only from farmers; labourers' own perceptions of wages and work conditions were not assessed directly.

Farmers often described that agricultural work contributes to physical fitness. While the increased use of modern machinery has reduced the physical workload, working in hot and humid conditions during paddy cultivation remains physically demanding. At the same time, all farmers reported experiencing mental stress due to time pressures during sowing and marketing the produce, labour shortages, crop health, weather conditions, and social expectations. Peer judgment regarding crop yields also contributes to mental strain. One farmer in particular stated:

"*Sometimes, I lie about the yield I get, because when you tell the actual number, other farmers judge and assume that the farmer must not have done the work properly. The farmer continues the best he can in the hope of achieving the expected yield next year. It is not just me; most farmers feel that pressure*."

Several farmers—particularly those farming on leased land or a mix of owned and leased land reported that farming provides only enough income to meet basic household needs, leaving them with little to no money left to invest in improvements. They described saving "every penny" to cover expenses such as children's education, which also helps

[29] Details of MGNREGA scheme are available here: Ministry of Rural Development. (n.d.). *Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)* https://nrega.dord.gov.in/MGNREGA_new/Nrega_home.aspx

explain why many continue with wheat–paddy and hesitate to spend on costly residue-management machinery. A smallholder group from Ferozepur, in particular, noted that they are fortunate that their children had secured government jobs - if children also pursued farming on that small land, it would have been difficult to afford even two meals a day for a family from farming alone. By contrast, medium- to large-scale landholders did not describe farming as financially unviable, but emphasised labour shortages and the lack of reliable marketing and procurement systems as the main constraints to shifting to alternative crops.

In addition, all farmers expressed concern about declining community engagement and collaboration compared to the past, attributing this to widening educational gaps and youth emigrating abroad. Farmers highlighted that they support each other during peak seasons with machinery and labour, but discussions about transitioning to better agricultural systems or the impacts of conventional farming methods on the environment and wider society do not often occur. Despite these challenges, many farmers valued the autonomy of agricultural work while acknowledging the financial, physical, and mental pressures it entails.

7.2.2 Farmers' Perspectives on Decent Employment

Quotes from Farmers on Decent Employment

> "*Nobody wants to work here, whether rich or poor. Most want to go abroad. We manage with what we know, but to transition to new crops and carry out administrative tasks, such as soil testing recommended by universities, we need youth- our children, to understand the reports and the changes required in our current practice. People like me, who are the only person responsible for the farm, cannot manage all the changes and associated administrative work. But due to stagnant incomes and no guaranteed minimum support prices for alternative or chemical-free*

crops, youth are migrating abroad. During the season, it gets very hard. We get labour from other states. Earlier, we used to work together with neighbours; no shyness about it. Now it is just individualistic; community bonding is declining. We are connected on WhatsApp to get information about new pesticides and seeds, but if somebody asks, "Come and help me with spraying," no one will come. It is the era of machinery; everybody is becoming individualistic."

"Labour shortage is real. Only elderly local labourers are working on the farm. The younger generation from labourer families does not participate. In our neighbouring village, farmers had to pay more to secure labour to get the work done."
"In every village, if you are trying to shift to better agricultural practices, you get harsh comments such as, 'He has lost his mind, he will fail miserably.' If you have not mentally prepared yourself to stand up to these comments, it is hard to do anything. There is no motivation from anyone, not even from your own family. My parents did not support me when I started, but now they do — looking at the quality of my crop, they can see the difference. Perhaps, one day, others will also understand my concerns and agricultural methods."

"God gave me this body to work—the more I use it, the better it becomes. I have no problem doing physical tasks. But spraying urea and pesticides affects my health. Agriculture provides a unique sense of mental calm; we have no boss. Other jobs require constant subservience to others."

"Physical health working in hot weather gets affected. Undoubtedly, more labour is needed during paddy cultivation. Mental stress arises when labour is unavailable, and

securing a combine harvester on time is challenging. Small landholders face even greater difficulties managing these tasks. Everyone is under stress and depression. Previously, we used to socialise, play, and discuss various topics, but that sense of community has gone."

7.2.3 Key Enablers and Barriers

Key Enablers

1) Autonomy and Psychological Satisfaction: Farmers value working independently on their own lands. Farm work provides exercise and engagement with nature, which farmers perceive as beneficial.

2) Income predictability for labourers: Locally fixed wage rates provide some predictability for income during peak periods, especially for migrant labourers.

Key Barriers

1) Low Wage Rates May Discourage Timely Availability of Local Labour: Farmers reported that local workers often prefer non-farm employment, such as factory work, which offers higher wages than farm labour, while migrant workers tend to accept the lower rates. This has resulted in shortages of local labour and a growing reliance on migrant workers to meet seasonal labour demands, while also limiting the availability of local human resources needed to support more labour-intensive and diversified cropping systems beyond the wheat–paddy seasonal cycle.

2) Youth Emigration: Many young individuals from farming families reported leaving agriculture and migrating abroad or to other cities in search of better income opportunities. As a result, many farms were managed by a single adult, who struggled to balance labour, upskilling, and the administrative tasks required to implement changes in farming practices. This trend disrupts the continuity of knowledge and skills transfer in agriculture, creating a

void in the experimentation and implementation of the latest agricultural technologies on farms.

To address this challenge nationwide, initiatives such as the *Attracting and Retaining Youth in Agriculture (ARYA) project* by the Indian Council of Agricultural Research (2015) and the *Skill Development Centre* at Punjab Agricultural University (2015) were launched to empower youth through practical skill development and entrepreneurship skills in agriculture. These programs aim to enhance farm productivity, income, and employment opportunities. However, all surveyed farmers perceived these programs as ineffective in improving farm income or business outcomes. Only one organic cultivator reported receiving useful guidance from the Skill Development Centre, but no support in marketing. An interview with a senior agronomist at Punjab Agricultural University (PAU) confirmed that, while skill development centres provide technical and practical training, the institutional capacity to support marketing and income generation is currently insufficient. Further perspectives on the transition to sustainable agriculture, as shared by the PAU senior agronomist, are provided in the next chapter.

4) **Lack of Social Support and Distrust in the Organic Farming Label:** One organic farmer reported adopting organic practices five years ago on his eight-acre farm, knowing it would take three years to yield fully organic produce. However, he faced ridicule from other farmers, who often consider organic farming ineffective or "fake," believing that soil accustomed to chemicals cannot produce crops without any chemical. Discouraged by peer perceptions and initially low output, he reverted to chemical cultivation for most of his land, maintaining only two acres for family-consumption organic farming. According to the farmer, over five years, his organic wheat yields gradually improved, though they still did not match those of chemically grown wheat. Based on this experience, he stated that a successful transition requires knowledge support, mental resilience, and strong financial backing. The issue of trust

in organic labels is echoed in a recent Better India article that describes a young farmer in Punjab starting an urban-oriented organic farming venture. Families are allocated portions of land where vegetables are grown on their behalf, with the opportunity to monitor and harvest produce directly. The farmer explained:

> "The core focus of this initiative is to create a robust system that bridges the gap between the demand and supply of organic food while instilling **trust** in the largely misused term 'organic'." (Gupta, 2024)

These cases emphasise that transitioning from conventional chemical systems to alternative or organic systems requires not only awareness and access to resources but also trust-building interventions and social support.

7.3 Indicator 2: Food Security- Food Insecurity Experience Scale (FIES)

This indicator assesses the severity of food insecurity experienced by farming households. The analysis, therefore, focuses on farmers' perspectives on food security within their households.

7.3.1 Summary of Farmers' Responses on Food Insecurity Experience Scale

All farmers consistently reported that food insecurity is not an issue for them — they always had food to eat. However, they noted that their incomes are not increasing in proportion to inflation. Farmers mentioned that they face financial instability but not food insecurity, because the minimum Support Price (MSP) rises slightly, whereas inflation increases significantly.

7.3.2 Farmers' Perspectives on Food Insecurity

Quotes from Farmers on Food Insecurity

"*We have not faced food insecurity, but we have faced income insecurity. MSP has increased a little, but inflation has increased for everything else. If we get a good yield and a good price,*

we can meet our needs. But when, due to market shocks or environmental shocks, the yield gets affected, we face financial insecurity, though not food insecurity for our household."

7.3.3 Key Enabler and Barrier

Key Enabler

1) **Reliable Access to Food:** Farming households consistently reported having sufficient food throughout the year, ensuring basic food security despite financial fluctuations. This reflects that farm production itself provides a safety net for households.

Key Barriers

1) **Financial Instability:** Although farming households reported being food-secure, their incomes are not keeping pace with inflation. Farmers rely on slightly rising Minimum Support Prices (MSPs), but rising costs of living, increasing lease rates, and market input costs every year reduce their real purchasing power, limiting their resources to adopt improved agricultural practices.

7.4 Indicator 3: Land Tenure- Secure Tenure Rights to Land

This indicator assesses ownership or secure rights to the use of agricultural land.

7.4.1 Summary of Farmers' Responses to Secure Tenure Rights to Land

All farmers reported that landowners have registration of their land. Lease agreements were generally verbal, based on mutual trust or a sense of brotherhood. However, when parties are not well known to each other, written agreements are sometimes used, although verbal agreements are generally more common.

Most agreements last for only one year and are renewed annually. Due to the uncertainty of renewal and the lack of long-term security, leaseholders often prioritise maximising short-term returns, sometimes through increased use of chemical fertilisers without assessing actual need through soil testing.

Leaseholder farmers indicated that longer-term lease arrangements (for example, around five years), along with clear communication – ideally in a written form – and some support from landowners to follow sustainable practices, such as contributing to the cost of crop residue machinery, could help encourage a more sustainable form of farming. They emphasised that maintaining soil health within tenure arrangements should be a shared responsibility, not only of leaseholders.

7.4.2 Farmers' Perspectives on Secure Tenure Rights to Land

Quotes from Farmers on Secure Tenure Rights to Land

"*Getting a lease on land is mostly done verbally and based on brotherhood. The land we own is legally registered."*

"If the person is totally unknown or from another village, we sometimes use a written agreement, but this is rare; generally, agreements are verbal."

"The main problem with lease agreements is that they are only for one year. We know the owner may give the land to someone else next year if they offer more money, as lease rates are increasing every year. Following sustainable practices should also be the responsibility of the landowner, as it is their land. If they provide longer-term agreements and communicate with us to treat the land as our own, we are willing to collaborate. Honestly, we tend to use more fertilisers and pesticides on leased land because there is no certainty of retaining it next year. It becomes about income for both the owner and the farmer, and soil health is often neglected by both parties."

7.4.3 Key Enabler and Barrier

Key Enabler

1) **Registered Land Ownership:** All surveyed landowners reported having legal registration of their land, which provides formal recognition of ownership and contributes to security in land use.

Key Barrier

1) **Reliance on Verbal Lease Agreements:** All lease agreements in this study were reported to be verbal, based on mutual trust or social relationships. This aligns with previous research in Punjab, where a large proportion of 120 sampled farmers in Moga and Amritsar districts had verbal lease arrangements (86.66% and 91.66%, respectively), while written agreements were much less common (13.33% and 8.33%, respectively) (Singh, 2017).

   Verbal agreements, while flexible, can create uncertainty or disputes when farmers want to try new practices, if the expected produce is not guaranteed. Singh (2017)also noted that legal restrictions on land leasing markets can act as safeguards, providing tenants security through clearly fixed terms such as fair rent and tenancy duration.

   Leaseholder farmers in this study were also reluctant to invest in soil conservation practices on rented land, such as the use of organic manure or fertiliser based on soil testing. One key reason was the lack of assurance that they would retain access to the land in subsequent years and therefore benefit from such investments, which are often more costly than conventional inputs. Leaseholder farmers further emphasised that landowners should also share responsibility for maintaining soil health. This aligns with findings by (Leonhardt et al., 2019), which highlights that insecure tenure discourages long-term investment

Furthermore, as farmers in this study reported limited understanding of formal reports, written agreements in the local language could help clarify roles, rights, and responsibilities, enabling more confident experimentation with sustainable practices. Conversely, reliance on verbal agreements may limit risk-taking due to fear of disputes or misunderstandings.

7.5 Conclusion

This chapter has presented farmers' perspectives on key social indicators of sustainable agriculture: decent employment, food security, and land tenure. Overall, farmers reported that farm work provides both physical and mental benefits, though challenges such as labour shortages stemming from low farm wages and youth migration create barriers to consistent, reliable employment. While households generally experience food security, financial instability, and incomes that do not keep pace with inflation may limit resources for adopting improved agricultural practices. Land tenure is largely secure through registered ownership; however, reliance on verbal lease agreements introduces uncertainty and can discourage experimentation with sustainable agricultural practices.

Collectively, these findings highlight that social factors, including labour availability, income stability, knowledge transfer, community support, regulation of lease rates, and tenure security and shared responsibility between landowner and leaseholders, play a critical role in shaping farmers' capacity to engage in sustainable agriculture. Strengthening enabling conditions while addressing the identified barriers can support farmers in adopting innovative, environmentally sustainable practices that also enhance household livelihoods and financial resilience.

Chapter Eight: Agricultural Experts' Perspectives on Transitioning to Sustainable Agriculture in Punjab, India

8.1 Introduction

This chapter presents insights from nine agricultural experts engaged in agricultural research, extension, cooperative governance, and alternative farming initiatives across Punjab. While previous chapters explored farmers' perspectives on the economic, environmental, and social dimensions of sustainable agriculture, this chapter introduces the institutional and agricultural experts' viewpoints that help contextualise the opportunities and constraints influencing the transition to sustainable agriculture in Punjab. This approach helps in highlighting how sustainability is understood, promoted, and debated across different knowledge systems and governance structures.

The experts interviewed include a Senior Agronomist from Punjab Agricultural University (PAU), two extension professionals from Krishi Vigyan Kendra (KVK), an official from Farm Advisory Service Centre (FASC), and a representative from the Agricultural Technology Management Agency (ATMA), a cooperative society, and a representative from non-governmental organisations working on natural and organic farming models. Together, these participants offer insights into institutional priorities, extension challenges, farmer engagement, and emerging alternative approaches to agriculture.

In addition to outlining expert perspectives, the chapter also responds directly to concerns raised by farmers on the farm survey, providing an institutional lens to the barriers and enablers associated with the transition. Overall, this chapter contributes to the thesis by situating farmers' lived experiences within broader institutional and ideological debates about sustainable agriculture in Punjab. These insights lay the foundation for the integrative discussion presented in Chapter Nine, where farmers' and experts' perspectives are brought together to identify potential bottom-up pathways for sustainability transitions.

As outlined previously in Chapter 4, Section 4.6, the study draws on insights from nine agricultural experts working across Punjab's research, extension, cooperative, and non-governmental institutions. Table 8.1 restates these participants, with the organisational roles of their affiliated institutions included, to contextualise the institutional support discussed in Section 8.2

Table 8.1: Agricultural Expert Participants (Positions, Organisations, and Organisation Role)

No.	**Position**	**Organisation**	**Organisation Role**
1	Senior Agronomist, School of Organic Farming	Punjab Agricultural University (PAU)	State agricultural research, education, and extension institution
2	Assistant Professor (Agricultural Engineering),	Krishi Vigyan Kendra (KVK) Malwal	District-level extension centre providing training, demonstrations, and technical support
3	Assistant Professor	Krishi Vigyan Kendra (KVK), the *location was not disclosed in the interview*	
4	Assistant Professor	Farm Advisory Service Centre (FASC), Malwal	Field-level advisory services on pest, nutrient, and residue management
5	Director	Agriculture Technology Management Agency (ATMA), Malwal	Participatory extension, technology promotion, and capacity building
6	Secretary	Co-operative Society, Sulhani, Ferozepur	Provision of credit, inputs, and cooperative governance at the village level
7	Master Rajbir Singh, Member,	All India Pingalwara Charitable Society, Amritsar (NGO)	Large-scale natural farming model, training, and demonstrations
8	Dr Avtar Singh	Good Grow Farms, Phagwara (NGO)	Natural farming, crop biodiversity, ASR rice cultivation technique

9	Kamaljeet Singh Hayer, Organic Farmer and Founder	Sohangarh Natural Farms & Farmversity (NGO)	Natural farming training, nutrient-cycle restoration, and experiential learning

8.2 Institutional Support for Transition: Insights from Experts

Experts described a wide range of institutional efforts supporting sustainable agriculture in Punjab. Their insights reveal both the strengths of existing systems and the persistent gaps that constrain large-scale transition.

8.2.1 Punjab Agricultural University (PAU) - Research, Training, and Long-Term Sustainability Efforts

The Senior Agronomist from PAU emphasised that sustainable agriculture practices have been embedded in the university's research agenda since the Green Revolution. For decades, PAU's *Packages of Practices* have offered farmers multiple options, including the use of farmyard manure, balanced fertiliser application, residue management, and resource conservation techniques.

To strengthen capacity building, PAU established Krishi Vigyan Kendras (KVKs) in every district to make the agricultural training services accessible to farmers in their own district. Additionally, Farm Advisory Service Centres (FASCs) have been established in 15 districts to provide field-level solutions to farmers' challenges. Despite these efforts, participation in training programmes remains low. As the Agronomist explained:

> "We have used chemicals for a long time; an immediate shift to organic farming is not possible. The transition will be gradual, considering marketing avenues and food security issues."

He stressed that sustainability requires both mindset change and economic security, encouraging farmers to begin with small organic plots and adopt integrated models such as beekeeping, mushroom cultivation, and vegetable production. The PAU expert further

highlighted that although PAU has the capacity to host large numbers of trainees, sometimes fewer than 20 farmers attend training sessions, particularly those related to organic farming. He noted that only recently have people begun to show concern about their health and agricultural practices, leading to increasing awareness. Consumers, especially in urban areas, are now demanding products grown without chemicals. However, without assured income and access to consumers willing to pay premium prices, it remains difficult for farmers to take such risks.

8.2.2 Krishi Vigyan Kendras (KVKs)- Village Adoption, Machinery Banks, and Demonstrations

KVKs serve as district-level hubs that bring PAU recommendations closer to farmers through village camps on crop production, plant protection, horticulture, soil science, and home science.

A KVK Assistant Professor described the Crop Residue Management Project, under which four high "paddy residue burning[30]" villages were adopted in 2024. Each adopted village received five days of intensive training and free access to machinery, such as happy seeders, smart seeders, rotavators, mulchers, reversible ploughs, and zero drills. The adoption period typically lasts one season, enabling experts to establish a direct connection with farmers. This connection encourages farmers to approach experts freely with queries. Officials also collect feedback on farmers' experiences with machinery and its performance in real field conditions. This feedback enables experts to better understand on-ground challenges and assess the effectiveness of the technologies being promoted.

KVKs also operate machinery banks, allowing adopted villages to borrow high-cost equipment free of charge and enabling farmers from other villages to rent machinery at

[30] Here, "paddy residue burning" refers to the open field burning of rice straw left after paddy harvest, commonly done to clear fields quickly before the next cropping season. The implications of paddy residue burning for air quality and environmental health are discussed in Chapter Six.

nominal rates. Soil testing services are also available; however, these are limited by laboratory capacity.

8.2.3 Farm Advisory Service Centres (FASCs)- Field-Level Problem Solving

Farm Advisory Service Centres (FASCs) operate as frontline extension units to provide field-level problem-solving and technical guidance to farmers. Their primary role is to translate Punjab Agricultural University (PAU) recommendations into practical, on-farm support. FASCs also conduct village-level demonstrations and advisory services on integrated pest management, integrated nutrient management, crop residue management, and water-saving technologies. They also appoint Kheti Doots - trained farmers who disseminate PAU-recommended practices within villages.

Example photos from FASC Centre, Ferozepur (Author's photographs)



Figure 8.1: Tensiometer

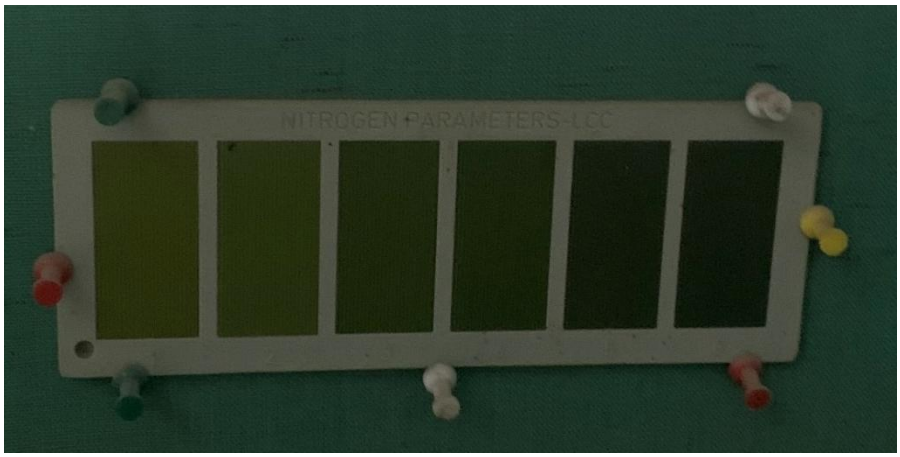


Figure 8.2: Leaf Colour Chart

8.2.4 Agricultural Technology Management Agency (ATMA)- Participatory Extension and Technology Promotion

ATMA promotes participatory extension through monthly village sessions and block-level training programmes. However, the Project Director highlighted a critical challenge:

> "The success rate of the training is very low, hardly 5 to 7 %. The low success rate is due to the lack of assured market returns for diversified crops, such as moong, maize, pulses, and oilseeds. Training farmers to adopt technology for different crops goes to waste without assurance of fair prices. In some countries, the agriculture sector uses drone technology and remote sensing, but here, many farmers have not even heard of the use of these tools in agriculture. We are far behind in adopting advanced technologies. We need campaigning to create awareness, but we also need more extensive research in this area so these technologies can genuinely support the transition."

Both ATMA and PAU experts observed consistently low participation in trainings on organic farming, intercropping, and integrated management practices. They attributed this to

farmers' financial insecurity and limited access to premium markets for chemical-free produce.

8.2.5 Cooperative Societies- Credit, Inputs, and Structural Limitations

The Secretary of a Cooperative Society explained that cooperatives provide credit at lower interest rates, but only for wheat–paddy systems. No special loans exist for diversification, making alternative crops financially risky. He further highlighted that timely repayment of loans can sometimes reduce interest rates to 3–4%, whereas delayed repayment may increase interest rates to 9.5%. Farmers also access fertiliser and diesel through cooperative systems.

However, the Secretary acknowledged instances of corruption, including:

- Secretaries selling subsidised inputs to their own associates
- Uneven distribution of fertiliser and diesel
- Farmers being overcharged or held liable for incorrect entries

To address these issues, the state government introduced a digital monitoring system. Secretaries are now required to record all transactions on an online platform, which automatically notifies farmers. This digitisation is expected to improve transparency and accountability within cooperative operations.

8.2.6 Non-Governmental Organisations- Experiential Learning and Alternative Models

NGOs such as Pingalwara Organic Farm, Sohangarh Farmversity, and Good Grow Farm contribute through experiential learning, farm visits, and training camps.

- **Good Grow Farm** hosts weekly *Kheti Satsang* (Agriculture discussion) sessions and promotes crop biodiversity and naturalisation of agriculture through raised bed farming[31] and intercropping[32].
- **Pingalwara Organic Farm** practices chemical-free natural farming on 55 acres, using bed planting, intercropping, and biofertilisers such as Jeev Amrit. Training sessions are typically conducted during April–May after wheat harvesting and are advertised through social media and newspapers.
- **Sohangarh Farmversity** conducts three-day training programmes focusing on nutrient cycles and natural farming practices.

Despite these initiatives, participation from farmers remains low, as a Good Grow expert noted:

> "We are practising what we teach. However, many people form quick impressions; if they do not see good results within a year, they discontinue - this is one of the major challenges."

Another expert from Sohangarh Farmversity explained that their training programmes typically include around 20 participants per session, with 3–4 sessions conducted annually. However, most participants are professionals such as doctors, engineers, and professors rather than farmers who rely on agriculture as their primary livelihood. This is largely because farmers face heavy loan burdens and high input costs under conventional agriculture, making them less willing to take risks associated with alternative practices

[31] The method involved planting crops on raised beds.Sahu, R., Sohane, R., & Kumar, R. (2024). Raised bed plantingA proven technology under climate change scenario.

[32] In an intercropping system, two or more crops are grown simultaneously on the same area of land Fordham, R. (1983). Intercropping–-what are the advantages? *Outlook on Agriculture*, *12*(3), 142-146.

8.3 Experts' Perspectives on the Economic, Environmental, and Social Dimensions of the Transition

8.3.1 Experts' Perspectives on the Economic Viability of the Transition

Across all interviews, experts consistently identified economic viability as the most significant barrier to transitioning towards sustainable agriculture in Punjab. Farmers face income uncertainty, high input costs, and a lack of assured markets for alternative crops. These constraints make it difficult for farmers to transition from established conventional practices, even when they are aware of the long-term benefits of sustainable agriculture

The PAU expert explained:

> "Farmers are reluctant to change their practices because of income uncertainty. Farmers earn income on season basis, after six months of the crop, but other professions earn a salary every month. When farmers observe pests in the field, fear often drives them to follow shopkeepers' advice of using chemicals rather than PAU recommendations."

As a result, even when institutional recommendations are available, farmers often prioritise immediate risk mitigation over long-term sustainability. Despite these challenges, the PAU expert emphasised the urgent need for change, arguing that:

> "The traditional saying, "ਦੱਬ ਕੇ ਵਾਹ, ਤੇ ਰੱਜ ਕੇ ਖਾ," meaning "Work hard to produce enough food," no longer applies these days. The mindset has to change to "ਅਕਲ ਨਾਲ ਵਾਹ ਤੇ ਰੱਜ ਕੇ ਖਾ," meaning "Work wisely and thoughtfully to produce enough food."

In line with this, the PAU expert recommended a gradual and practical approach to transition. Farmers can begin by allocating a small portion of their land, such as one acre, to organic farming based on local demand, and exploring projects such as value addition and processing, along with subsidiary occupations like beekeeping, mushroom farming, and vegetable cultivation, as a way to reduce economic risk while experimenting with alternative

practices. He also presented the Integrated Farming System (IFS) model developed by PAU, which demonstrates the potential to earn a net return of approximately INR 4.5 lakhs per hectare—nearly double the net return[33] from the conventional wheat–paddy system per hectare.

Example of PAU Research and Recommendations (Author Photograph, January 2025)

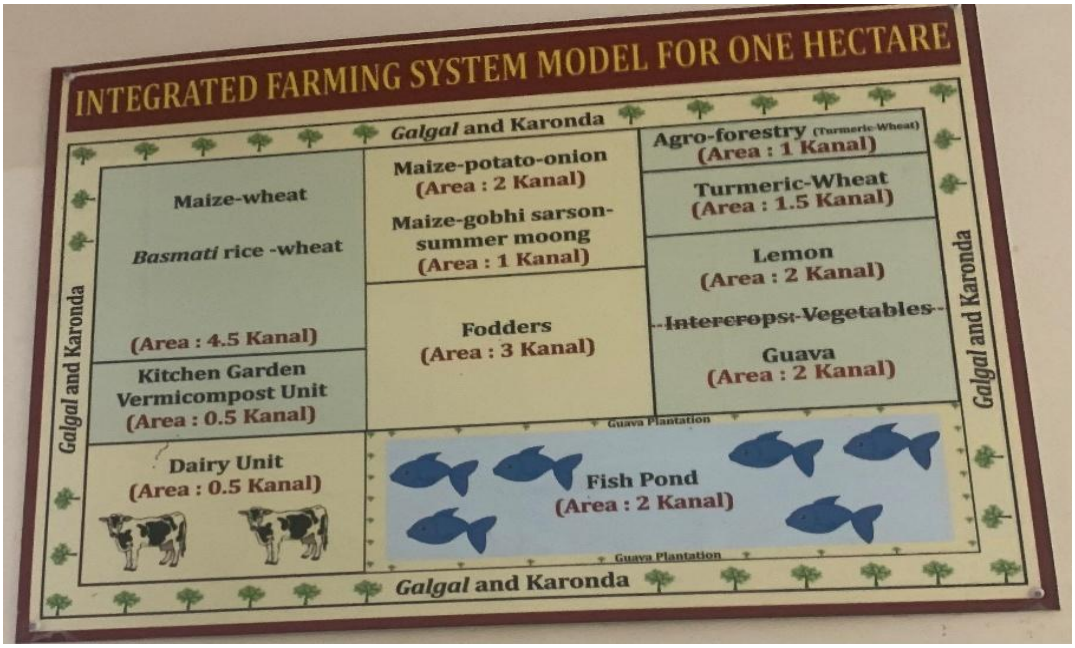
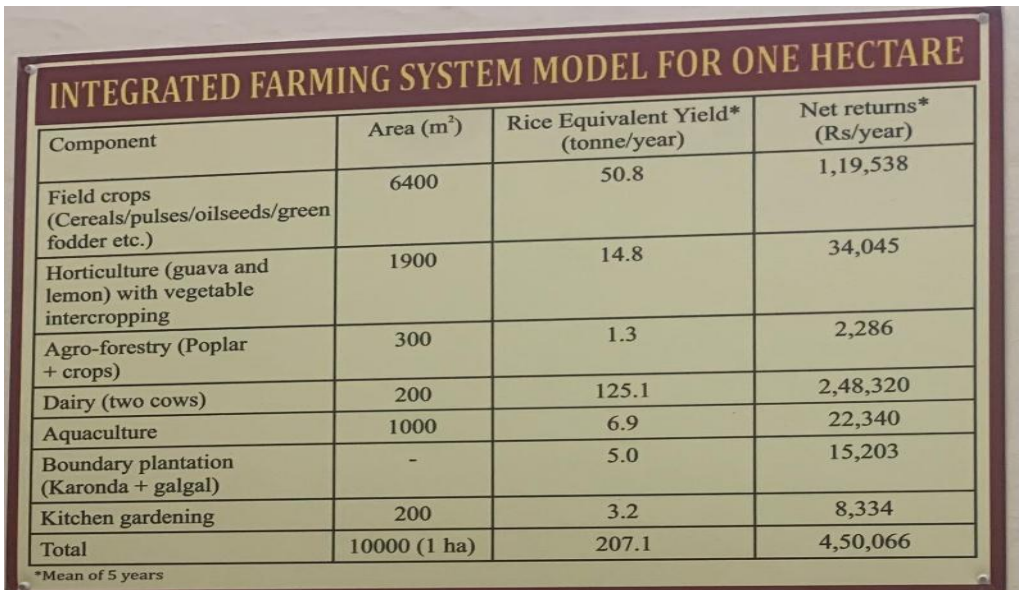


Figure 8.3(a): Integrated Farming System Model for one hectare



INTEGRATED FARMING SYSTEM MODEL FOR ONE HECTARE

Component	Area (m^2)	Rice Equivalent Yield* (tonne/year)	Net returns* (Rs/year)
Field crops (Cereals/pulses/oilseeds/green fodder etc.)	6400	50.8	1,19,538
Horticulture (guava and lemon) with vegetable intercropping	1900	14.8	34,045
Agro-forestry (Poplar + crops)	300	1.3	2,286
Dairy (two cows)	200	125.1	2,48,320
Aquaculture	1000	6.9	22,340
Boundary plantation (Karonda + galgal)	-	5.0	15,203
Kitchen gardening	200	3.2	8,334
Total	10000 (1 ha)	207.1	4,50,066

*Mean of 5 years

Figure 8.3(b): Integrated Farming System Model for one hectare

[33] Net Return of wheat-paddy system presented in Table 5.3

While experts from PAU emphasised gradual, risk-managed transitions, some NGO practitioners also demonstrated that ecological farming methods can deliver strong economic outcomes when implemented effectively. At the All India Pingalwara Charitable Society[34] farm, natural farming practices such as bed planting, intercropping, and diversified vegetable cultivation have transformed previously barren land into productive fields and now generate production equivalent to approximately 2.5 acres of conventional farming from just one acre. Although the produce is not sold commercially due to the organisation's charitable mandate, the model illustrates how diversified natural farming can enhance per-acre productivity while reducing input costs.

Similarly, Dr. Avtar Singh from Good Grow Farm explained that natural farming, specifically through bed plantation, significantly reduces production costs by eliminating chemical fertilisers and minimising water use, allowing him to sell produce at the same market price as conventional farmers while still earning a stable income. For Dr. Singh, crop biodiversity is essential for making agriculture both profitable and sustainable, particularly for farmers with one or two acres of land.

Dr. Singh emphasised that by cultivating a variety of crops, farmers can keep one crop as "secure crop"—such as sugarcane in some regions or cotton in the cotton belt—to cover household and farm expenses, while other crops contribute to income diversification. He provides detailed guidance on biodiversity practices through his YouTube channels[35] and stressed the importance of demonstrations to build farmer confidence. However, he noted that government and university support for such initiatives remains limited. He also noted that

[34] Pingalwara Cheritable Society provides care and support to the homeless, disabled, and elderly, running facilities like homes, rehabilitation centers, and schools.
[35] www.youtube.com/@goodgrowfarms859

while natural calamities or failed germination can affect crop yield, these setbacks are part of the learning process and can be overcome with patience and understanding.

Example of NGO Models Demonstrating Economic Potential

All India Pingalwara Charitable Society Natural Farming Model

Master Rajbir Singh from All India Pingalwara Charitable Society, Amritsar**,** presented a natural farming model implemented on 55 acres of land. The system includes:

a) Bed farming with intercropping of sugarcane, poplar trees, and a wide range of vegetables such as cauliflower, coriander, onion, spinach, broccoli, turmeric, carrots, green chilli, turnip, radish, gourd, and eggplant
b) Cultivation of fruit trees and fodder crops
c) Experimental plantation of trees such as sandalwood and agarwood
d) Wheat planted on raised beds

Some Pesticide and Fertiliser management methods include:

a) Jeev Amrit- a natural fertiliser using cow dung mixed with canal and groundwater in a wetland pond.
b) Agni Asthar -A natural pesticide made from cow urine, neem leaves (or neem seed kernel), green chilli, and garlic, used to control pests
c) Cow milk and sour buttermilk sprays for fungal disease control.

Master Rajbir Singh emphasised that beneficial insects play a crucial role in soil health, and chemical pesticides kill both harmful and beneficial species, disrupting ecological processes. Jeev Amrit supports microbial activity, improving soil fertility without additional inputs. Master Rajbir Singh emphasised that People want to eat quality food. Wheat and rice cultivation are not sustainable in the long run.

Figures 8.4 (a–f) show examples of work on the All India Pingalwara Charitable Society farm, photographed during field visits. The photos show intercropping with sugarcane and

poplar trees, wheat grown on raised beds, preparation of a bio-fertiliser mix, and machinery such as a bed planter and a robotic weeder used to remove weeds mechanically.



Figure 8.4(a): Intercropping crops with Sugarcane, Poplar Trees



Figure 8.4(b): Wheat planted on a bed



Figure 8.4(c):Intercropping with Poplar Trees



Figure 8.4(d): Jeev Amrit Method – Bio Fertiliser



Figure 8.4(e): Soil Hackers Robotics is used for removing weeds mechanically



Figure 8.4(f): Bed Planter used on the farm

Overall, experts agreed that while sustainable agriculture offers long-term economic and ecological benefits, the transition pathway must be financially secure, gradual, and

supported by reliable markets. Without these enabling conditions, farmers, particularly those with small landholdings and high debt burdens, remain understandably risk-averse.

8.3.2 Experts' Perspectives on Environmental Sustainability and Resource Constraints

Experts consistently highlighted that Punjab's current agricultural system is environmentally unsustainable. They pointed to multiple interrelated challenges, including soil degradation, groundwater depletion, air pollution, and the declining nutrient content of food.

PAU and FASC experts traced these challenges to the chemical-intensive practices introduced during the Green Revolution. While they acknowledged that chemical fertilisers are not inherently harmful when used judiciously, they stressed that the near-complete abandonment of organic manures has destabilised soil health. According to the PAU expert, farmers should ideally apply cow manure or green manure in combination with chemical fertilisers to maintain soil fertility, but such balanced practices are rarely followed. The PAU expert further noted that interest in organic farming only began to re-emerge in the 21st century, driven largely by rising health consciousness among consumers. Although shifting all farmers away from established practices remains difficult, he observed that Punjab's agriculture is now in a "transformation stage," with growing awareness of environmental decline.

The ATMA Project Director strongly emphasised the severity of environmental degradation. He stated:

> "It is true that we are achieving good yields from wheat and rice, but the overuse of fertilisers and pesticides is degrading our soil and water resources and polluting the air. Air, water, and soil are essential resources; if all three are polluted, how will current and future generations survive?"

He stressed that while extension agencies can provide training, only the government can create the financial platforms needed to support farmers to transition to sustainable agriculture. Without a transparent system that ensures fair prices, timely payments, and accessible markets—at least for crops consumed within Punjab—meeting the Sustainable Development Goals for agriculture by 2030 seems far from reality.

An expert from Co-operative Society highlighted that even when farmers are aware of the environmental and health impacts of excessive fertiliser use, peer pressure—particularly the desire to outperform neighbours—drives them to apply more fertiliser than recommended. Changing such habits and mindsets, he argued, "takes a very long time."

On the other hand, Kamaljeet Singh Hayer from Sohangarh Farmversity (NGO) stressed that the concept of sustainability is widely misunderstood and is often confused with *self-sustainability*. According to him, the two are fundamentally different. Sustainability, in its true ecological sense, is rooted in the closed nutrient cycle, not merely the avoidance of external inputs. He presented a model aimed at ensuring nutrient-rich food security at both farm and village levels. He emphasised:

> "The true essence of sustainable agriculture is to understand, protect, and restore the nutrient cycle. If you farm five acres, continue conventional farming on four acres, but dedicate one acre to a food bank model. Grow all produce there without external inputs, consume it on-site, and return all waste to the land. This acre will maintain its nutrients indefinitely."

Dr. Avtar Singh from Good Grow Farm (NGO) employs a similar set of natural farming practices but applies them for commercial purposes. He frames agriculture as the judicious management of nature's five elements—earth, water, fire, air, and space. Understanding these natural processes, he argued, makes natural farming intuitive and self-sustaining. Both the

Sohangarh and Good Grow models offer ecologically grounded approaches to sustainable agriculture, which are presented below:

Example of NGO Models Demonstrating Ecologically Sustainable Models

Good Grow Farm – Natural Farming Model and Anaerobic Seeding of Rice Method

Dr. Avtar Singh explained that healthy crops require an uninterrupted air supply to the root zone. Over-irrigation suffocates beneficial microbes and disrupts physiological processes. For example, wheat may turn yellow in early stages due to excess water. Farmers often respond by consulting chemical suppliers, who recommend urea, which temporarily restores growth but disrupts the natural nutrient cycle and contributes to "hidden hunger" in crops. Dr. Singh described conventional farming as "legalised and scientific adulteration," noting that while traders are punished for adulteration, farmers receive subsidies for chemical inputs like urea and DAP that ultimately compromise food quality.

He described bed farming as a highly effective method for producing nutrient-rich crops. In this system, crops are planted on raised beds, allowing water to flow downward and supply both moisture and oxygen through centrifugal movement of nutrients[36]. These nutrients are naturally carried upward to the plant. He emphasised that almost any crop can be grown using this method, though rice requires specific adjustments.

Although Dr. Singh does not grow rice himself, he developed the Phagwara Technique, also known as the Anaerobic Seeding of Rice (ASR) method, for farmers who cultivate paddy. He argued that paddy cultivation is highly damaging to Punjab's environment due to continuous flooding, which compacts soil and destroys microbial life. While farmers face legal penalties for burning residue, he noted that the environmental damage caused by flooded irrigation is rarely discussed, despite being "far more destructive."

[36] The participant uses the term "centrifugal" to describe the outward movement of nutrients through water and moisture within the raised-bed system.

The ASR[37] method eliminates the need for ploughing or levelling after wheat harvest if the field is already laser-levelled. After pre-sowing irrigation (rauni), a levelling plank weighted on both sides is run crosswise across the field at least six times to remove oxygen from the soil. Rice seed is then drilled at a depth of 0.75–1.25 inches, followed by two additional rounds of levelling. The first irrigation is applied after 21 days—"the later, the better"—and no seed treatment is required. Typically, the monsoon arrives after the first watering, reducing the need for further irrigation. Moisture is required at the tillering stage, but standing water is unnecessary. If rainfall is insufficient, irrigation may be applied after 15 days.

Dr. Singh contrasted ASR with Direct Seeding of Rice,[38] arguing that DSR failed because it attempted to grow rice like wheat, ignoring rice's natural requirement for anaerobic conditions. ASR, by contrast, aligns with rice physiology and avoids the pitfalls of puddling, which destroys soil structure and microbial life. He emphasised that crops require moist soil rather than excessive water, and that efficient water management naturally reduces the need for chemical fertilisers:

"Save from water, and you will automatically save yourself from chemical fertilisers (ਪਾਣੀ ਤੋਂ ਬਚੋ, ਰਸਾਇਣਕ ਖਾਦਾ ਤੋਂ ਆਪੇ ਬਚ ਜਾਓਗੇ)"

While some farmers expressed concern that the heavy compression used in the ASR method might compact the soil, Dr. Singh acknowledged this risk. He clarified that long-term soil health may indeed be affected by repeated compression, which is why he does not personally recommend cultivating paddy. However, he stressed that if farmers must grow rice, the ASR method is still *significantly better* than traditional puddling. Compression, he explained, maintains soil porosity and supports beneficial microorganisms, whereas standing

[37] Definition of ASR is provided in Chapter 1, Section 1.5
[38] Definition of DSR is provided in Chapter 1, Section 1.5

water forces out oxygen, kills aerobic decomposers, and prevents plants from absorbing nutrients.

At present, Good Grow Farm sells its produce in the open market. According to Dr. Singh, the production costs under natural farming are substantially lower, allowing him to sell at the same price as conventional farmers while still earning a good income. He concluded by situating agriculture within the broader climate crisis. Agriculture, he argued, is both a contributor to and a victim of global warming. Although other sectors also contribute to environmental degradation, he asserted that the naturalisation of farming offers a viable and necessary pathway for reducing agriculture's ecological footprint.

Although Dr. Singh's and Master Rajbir's farming approach is rooted in experiential learning and ecological principles, similar practices are also reflected—though in a more formalised manner—in institutional guidelines. Punjab Agricultural University has developed recommendations on bed planting, organic cropping systems, and approved bio-pesticides, indicating that elements of natural and organic farming are increasingly being incorporated into mainstream research and extension frameworks. Figures 8.5 (a-c) illustrate examples of PAU's technical guidance on organic management and bed-planted wheat.

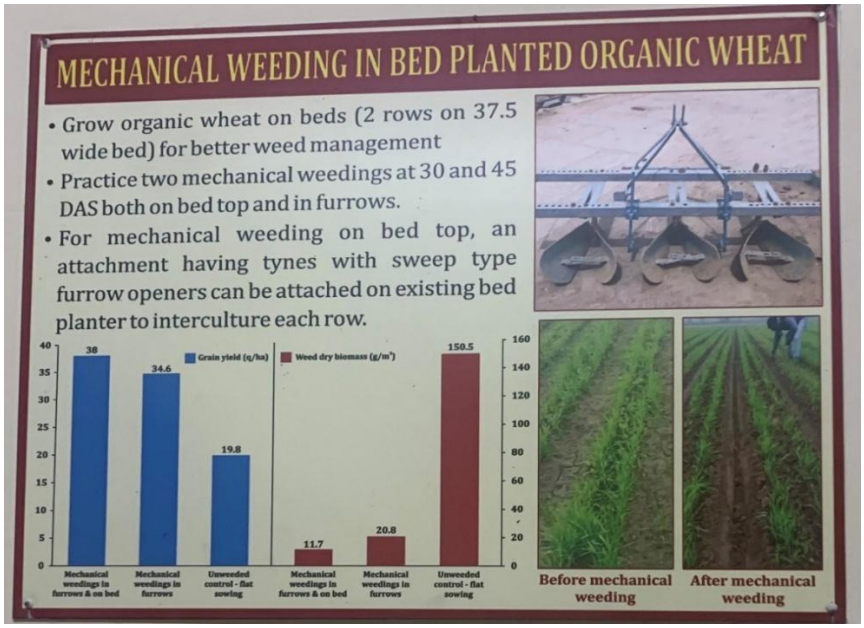


Figure 8.5(a): Mechanical Weeding in Bed Planted Organic Wheat. Source (Author's Photograph)

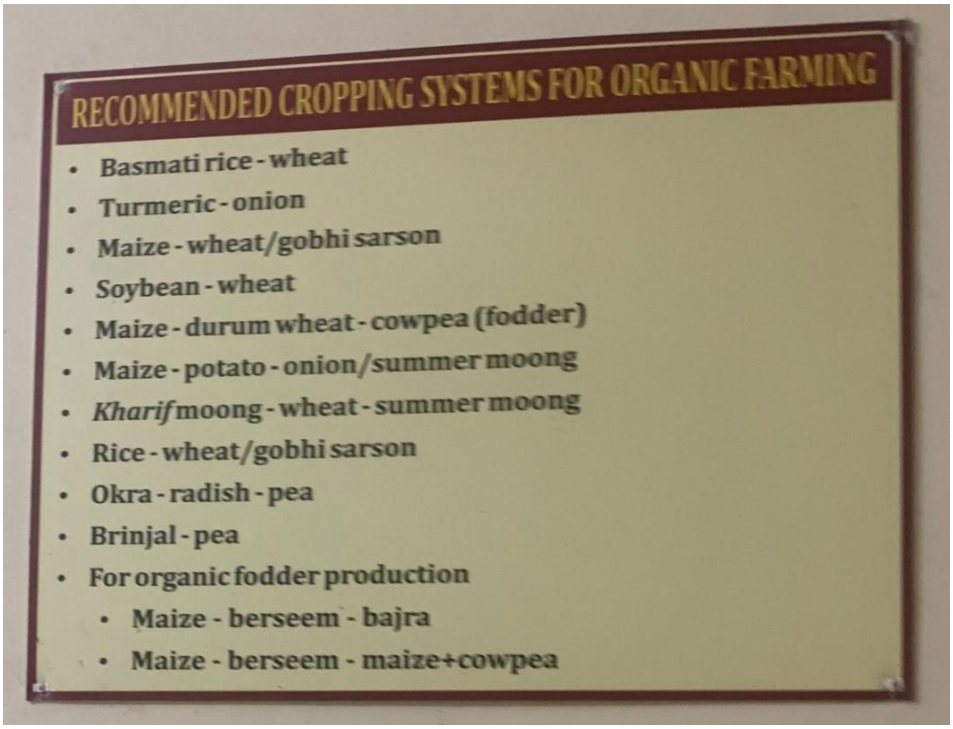
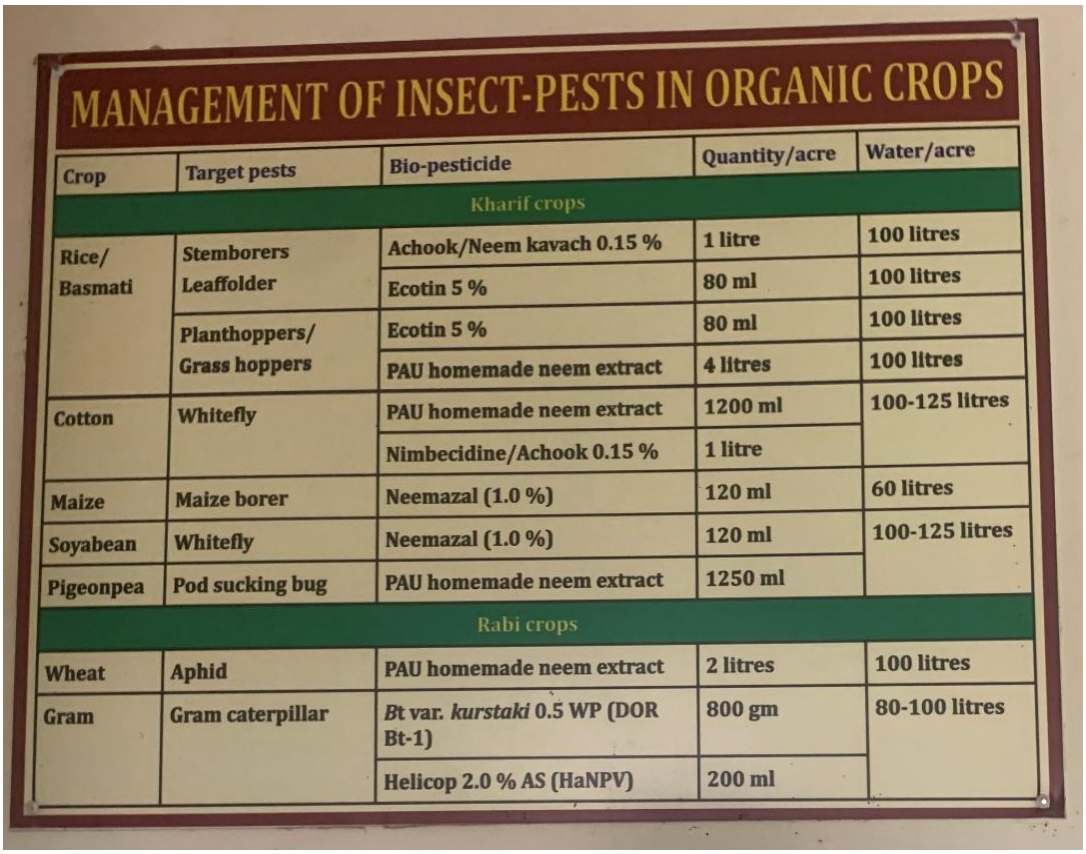


Figure 8.5(b): Recommended Cropping Systems for Organic Farming. Source (Author's Photograph)



MANAGEMENT OF INSECT-PESTS IN ORGANIC CROPS

Crop	Target pests	Bio-pesticide	Quantity/acre	Water/acre
Kharif crops				
Rice/ Basmati	Stemborers Leaffolder	Achook/Neem kavach 0.15 %	1 litre	100 litres
		Ecotin 5 %	80 ml	100 litres
	Planthoppers/ Grass hoppers	Ecotin 5 %	80 ml	100 litres
		PAU homemade neem extract	4 litres	100 litres
Cotton	Whitefly	PAU homemade neem extract	1200 ml	100-125 litres
		Nimbecidine/Achook 0.15 %	1 litre	
Maize	Maize borer	Neemazal (1.0 %)	120 ml	60 litres
Soyabean	Whitefly	Neemazal (1.0 %)	120 ml	100-125 litres
Pigeonpea	Pod sucking bug	PAU homemade neem extract	1250 ml	
Rabi crops				
Wheat	Aphid	PAU homemade neem extract	2 litres	100 litres
Gram	Gram caterpillar	*Bt* var. *kurstaki* 0.5 WP (DOR Bt-1)	800 gm	80-100 litres
		Helicop 2.0 % AS (HaNPV)	200 ml	

Figure 8.5(c): Management of Insect-Pests in Organic Crops. Source(Author's Photograph)

Sustainable Agriculture Model as defined by Kamaljeet Singh Hayer, Organic Farmer and Founder of Sohangarh Natural Farms & Farmversity

For Kamaljeet Singh Hayer, sustainability is rooted in the closed nutrient cycle, not merely the avoidance of external inputs. Hayer explained that in the earliest stages of human existence, people lived within forests, consuming food and returning all waste to the soil. This continuous return of nutrients maintained a natural nutrition cycle. Even after the transition from forests to settled village life, the nutrient cycle remained largely intact: crops were grown and consumed locally, and both human and animal waste returned to the fields.

However, the shift to urban settlement disrupted this cycle. Nutrients began to flow from agricultural land to residential areas, where food is consumed but waste is not returned to farmland. In the conventional agricultural model, crops such as wheat and paddy are harvested and transported for sale, but the nutrients extracted from the soil never return. Hayer described this as nutrient mining, a process that gradually depletes soil fertility. He also noted that current food quality assessments focus on pesticide residues or adulteration, but rarely on nutrient content—an omission that masks the deeper ecological crisis.

Hayer outlined four distinct agricultural models:

1. **Conventional agriculture** — high yields achieved through chemical inputs..
2. **Organic farming** — an improved model, but reliant on organic inputs purchased from markets.
3. **Natural farming** — producing biofertilisers and biopesticides on the farm itself; a system he practised for over ten years.
4. **Sustainable agriculture** – maintaining a closed nutrient cycle so that nutrients removed from the soil are returned to it.

One of the biggest challenges, Hayer argued, is **population centralisation**. The problem is not population growth itself, but the concentration of people in urban centres. This requires

large-scale food transport, consumes more energy, and results in significant nutrient loss. Much of the food transported to cities is wasted in landfills or oceans, and these nutrients never return to farmland. He emphasised that this is not only a problem for Punjab but a global issue.

Hayer defined sustainable agriculture as a system in which:

- food is consumed directly on the farm, and
- all waste is returned to the soil,
- thereby maintaining a closed nutrient cycle.

He stressed that sustainability should not be reduced to self-sustainability, which simply implies growing food without external inputs. True sustainability requires stopping nutrient mining and preserving soil nutrients for future generations. When he fully understood this concept, Hayer stopped selling his produce altogether. However, this raised practical questions: *How would he sustain himself? How would he pay workers?* These questions led him to explore alternative livelihood models that preserve the nutrient cycle without compromising economic viability.

To address this challenge, Hayer developed two innovative models:

1. **Farm Tourism** Visitors stay on the farm for one or two days, consume food grown on-site, rest, and return home. They pay only for accommodation. This ensures that no produce leaves the farm, preserving the nutrient cycle.
2. **Natural Healing Centre** The first of its kind in Punjab, this centre allows individuals suffering from illness to stay close to nature, walk barefoot on the soil, and eat food grown on-site. Different packages are offered depending on the length of stay.

These models allow Hayer to maintain a closed nutrient cycle while generating income.

Hayer emphasised that transitioning to sustainable agriculture is not easy; it requires a complete shift in approach. Soil that has been depleted through decades of nutrient mining will take many years to restore without chemicals—far longer than the commonly cited three-year transition period.

8.3.3 Experts' Perspectives on the Role of Social Structures for the Transition

Experts highlighted that the transition to sustainable agriculture in Punjab is shaped not only by economic and environmental factors but also by deeply embedded social structures, labour dynamics, governance challenges, and generational aspirations. These social dimensions significantly influence farmers' willingness and ability to adopt alternative practices.

FASC expert noted that the environmental consequences of the Green Revolution—soil degradation, pest resistance, and rising input costs have also produced profound social impacts. Declining farm profitability has pushed many farmers into debt, forcing them to borrow from banks and local moneylenders to meet farm and household expenses. This cycle of indebtedness has weakened Punjab's agricultural economy and heightened social vulnerability.

A recurring theme across expert interviews was the lack of youth engagement in agriculture. Master Rajbir Singh observed that young people increasingly prefer to migrate abroad due to limited opportunities and low social prestige associated with farming. Transitioning to sustainable agriculture requires time, effort, and knowledge-building, but many youth are unwilling or unable to invest in these processes.

NGO experts and ATMA Project Director highlighted a critical social divide: those who are adopting alternative practices tend to be professionals—engineers, doctors, teachers—who own some land but are not dependent on farming for their primary income. Their financial security allows them to experiment with organic or natural farming for

household consumption. In contrast, farmers whose livelihoods depend entirely on agriculture rarely approach ATMA for advice on diversification or alternative crops. For them, the risk of crop failure or market uncertainty is too high. This creates a social inequality in the transition, where only a small percentage can afford to experiment, while the majority remain locked into conventional systems.

Social trust in institutions emerged as another major factor. A Cooperative Society expert stressed that monitoring by higher authorities is essential to ensure accountability at the village level. Although cooperative leaders are supposed to be elected by members, political influence often shapes leadership selection, undermining fairness and transparency. He argued that greater digitisation, transparent operations, and democratic selection of cooperative leadership could rebuild trust. Combined with government support for fair pricing of diverse crops and regular training in organic and sustainable practices, such reforms could motivate farmers to consider transitioning.

Experts across institutions emphasised that the transition requires structured pathways, standardised processes, and consistent support. The ATMA Director noted:

- lack of standardised lease rates
- absence of assured income
- unreliable input supply
- insufficient on-farm support staff

These gaps limit the effectiveness of training programmes and discourage farmers from adopting new practices. Without enabling conditions, he argued, farmers will continue doing “the best they can to sustain their livelihoods,” rather than experimenting with unfamiliar systems.

A further social dimension relates to labour availability and the practicality of diversified systems. The KVK expert shared his experience on his farm, managing a

diversified farming system that includes paddy, potato, moong, and a mushroom unit. He mentioned that, while mushroom cultivation can be profitable, it is highly market-dependent and labour-intensive. Seasonal mushroom production creates employment for migrant workers, but the lack of local labour remains a challenge. He noted that intercropping is a promising model for small farms, where management is easier and multiple crops can provide resilience. However, on large farms, intercropping requires mechanisation or significant labour, increasing costs. His experience illustrates how labour dynamics, farm size, and management capacity shape the feasibility of adopting diversified or sustainable practices.

Figures 8.6(a – c) show the mushroom cultivation huts, the manure preparation set-up on the KVK expert farm, and samples of the harvested produce photographed during the field visit



Figure 8.6(a): Mushroom cultivation huts. Source (Author's Photograph)



Figure 8.6(b): Manure Preparation set up. Source (Author's Photograph)



Figure 8.6(c): Sample of the harvested produce. Source (Author's Photograph)

8.4 Answers to Farmers' Concerns by Experts

This section presents experts' responses to the key concerns raised by farmers in earlier chapters. Their insights reveal both institutional constraints and ongoing efforts to address farmers' needs, while also highlighting areas where systemic improvements are required.

1) **Farmers ' Concerns on the Delay in Soil Test Reports**

   Farmers frequently expressed frustration about delays in receiving soil test results. A PAU scientist acknowledged this concern, explaining that each KVK currently operates with only one soil testing laboratory, which leads to delays during peak periods when large numbers of samples are submitted. Limited staff capacity further slows down processing and administrative work. He emphasised that expanding laboratory infrastructure and hiring additional trained personnel are essential steps to ensure the timely delivery of soil health reports.

2) **Farmers' Concern about Limited Effective Training Support**

   Farmers also reported insufficient and ineffective training opportunities from PAU. In response, the PAU expert outlined the university's existing efforts, noting that each Krishi Vigyan Kendra is required to adopt one to three villages annually and develop them as model villages for demonstrations—"seeing is believing." PAU uses multiple channels to reach farmers, including social media, farm fairs, government programmes, and private forums. However, despite these efforts, adoption remains low; out of 100 farmers who attend training, only 5–10 adopt non-chemical cultivation practices.

   The expert further highlighted PAU's one-hectare Integrated Farming System (IFS) model, which demonstrates how efficient land use can generate double returns than those from the conventional wheat–paddy system. This model illustrates how waste from one component becomes an input for another, reinforcing the idea that farming is not failing; techniques need updating. PAU has also developed area-specific models

and provides online literature for all recommended practices. While crops can receive urea at any stage, cow manure cannot be applied in the same way; to address this, PAU is working on botanical extracts and organic concoctions. He noted that PAU receives daily calls from farmers interested in organic farming, but heavy teaching, extension, and research workloads limit the time staff can dedicate to individual requests. He suggested that more consultancy services are needed to support farmers in adopting new techniques.

3) **Farmers expressed concern that PAU focuses more on wheat and rice than on other crops for seed production, and that private sellers' seeds yield more for vegetables:**

   Farmers expressed concern that PAU focuses more on wheat and rice than on other crops for seed production, and that private sellers' vegetable seeds often yield better results. The PAU expert acknowledged this, explaining that over 90% of Punjab's cultivated area is under wheat and rice, which naturally directs institutional resources toward these crops. While PAU does produce vegetable seeds, private companies have greater funding capacity and therefore dominate seed development for vegetables and other niche crops.

4) **Farmers expressed concern about introducing new machinery every year:**

   Farmers also raised concerns about PAU introducing new machinery each year. The PAU expert agreed that this issue had been observed internally as well. He explained that PAU is now shifting its focus toward improving existing machinery rather than introducing entirely new models. He emphasised that PAU does not force adoption of new machines; instead, it presents options and evidence so that farmers can choose what best suits their conditions.

5) **Farmers' Concern on Increased Input Costs Associated with Crop Residue Management (CRM)**

ATMA experts addressed farmers' concerns regarding the cost and complexity of crop residue management. They explained that systematic use of machinery can reduce diesel consumption, and that even spreading of residues reduces machine load and improves performance. While the Super Straw Management System (SMS) adds ₹300–₹400 to rental costs due to increased fuel use, it does not significantly increase operational time. Farmers often request permission to burn leftover residue lines after combine harvesting, but ATMA officials emphasised that allowing partial burning would make enforcement impossible. SMS improves soil health and enhances the efficiency of subsequent operations.

To encourage adoption, ATMA advises farmers to experiment with new techniques on a small portion of their land—about 10%—before scaling up. Poor results often stem from incorrect methodology rather than the technology itself. However, most farmers in the region own small to medium landholdings and depend heavily on wheat and rice, leaving them unable to take financial risks. Negative peer experiences also spread quickly; when a farmer misuses a machine and later reports that "it doesn't work," such statements discourage others from adopting the technology. ATMA recommends that farmers test machinery on their own fields rather than relying solely on neighbours' experiences, as differences in technique can lead to different outcomes.

6) **Farmer Concerns Regarding Limited Training Opportunities from KVK and FASCs**

Experts acknowledged that participation in training programmes is often low. Training camps are organised through village heads or committee members, but political differences within villages sometimes limit attendance. To increase participation,

announcements are also made through Gurdwara Sahibs (Sikh temples), yet turnout remains inconsistent. Farmers who cannot attend village-level sessions are encouraged to visit their district KVK, and KVK staff can also provide on-farm assistance. However, experts noted that interest in alternative practices, crop diversification, and integrated nutrient management remains limited due to the higher costs associated with these practices and the absence of financial support to compensate for potential yield losses during the three- to four-year transition period. Until a financially supported, transparent, and accountable system for transition is established, generating widespread farmer interest in alternative practices will remain challenging.

8.5 Conclusion

This chapter has presented a diverse range of expert perspectives on Punjab's transition towards sustainable agriculture, highlighting both shared concerns and differing interpretations of what sustainability entails in practice. Institutional experts from PAU, KVKs, FASCs, ATMA, and the Cooperative Society emphasised gradual transitions grounded in integrated nutrient management, need-based pesticide use, strengthened extension systems, and stronger policy support. They also pointed to several structural constraints that continue to limit adoption, including limited laboratory capacity, low participation in training, market uncertainty, and the dominance of wheat–rice procurement systems, concerns similar to those shared by farmers. From these institutional viewpoints, sustainability is understood as a long-term process requiring coordinated governance, income assurance, adequate training and resources, and incremental behavioural change rather than abrupt transformation.

In contrast, NGO practitioners and alternative farming experts promoted more transformative pathways centred on natural farming, biodiversity, nutrient cycling, and ecological regeneration. Their models illustrate what a more ecologically grounded agricultural system could look like, while also acknowledging the risks farmers face when

moving away from conventional practices. Despite these differences in approach, the nine experts noted signs progress: some farmers are experimenting with organic methods, and many more are adopting improved residue management practices, contributing to a noticeable reduction in stubble burning.

Overall, the findings show that sustainability transitions in Punjab are shaped not only by farm-level decisions but also by governance structures, extension capacity, market systems, and competing visions of agricultural development. The next chapter builds on these insights by bringing together farmers' and experts' perspectives to develop a more integrated discussion of potential pathways for sustainable agriculture in Punjab.

Chapter Nine: Discussion and Conclusions

Bottom-up pathways for advancing sustainable agriculture in Punjab, India

9.1 Introduction

This chapter discusses the study's findings by integrating the perspectives of farmers and experts. The analysis demonstrates that the transition toward sustainable agricultural practices (SAP) in Punjab is not simply a matter of farmers adopting better agricultural practices; instead, it is shaped by the conditions farmers operate within, such as governance arrangements, operational feasibility (time, labour, machinery), market prices, and the need to protect household livelihoods under growing economic pressure. This chapter contributes to objective 2.3 by identifying key gaps and proposing targeted interventions to facilitate the transition toward sustainable agricultural practices in Punjab. Although the study draws on a small sample of 48 farmers from three districts, the findings offer rich, context-specific insights into the conditions shaping agricultural decision-making in Punjab.

This thesis aims to explore the key enablers and barriers influencing the transition towards sustainable agricultural practices (SAP) in Punjab, India. By integrating farmer voices with institutional insights, the study sought to understand what sustainable agriculture requires in principle, and what makes change feasible in practice under current economic and social realities. In doing so, the study also contributes to the broader aims of the UN Sustainable Development Goals, particularly Goal 2 (Zero Hunger), Target 2.4, and Goal 13 (Climate Action), Target 13.3, by generating evidence on farmers' awareness, preparedness, and support needs for climate-resilient and sustainable agricultural transitions (United Nations, 2015a, 2015b).

The research was guided by the following research questions:

RQ1: How do the predominant agricultural practices in Punjab impact the economic, environmental and social outcomes for farmers and communities?

This question was addressed in Chapters Two and Four through a review of relevant literature, policy documents, and frameworks developed by food and agriculture organisations (FAO, n.d.-a), alongside India's National Mission for Sustainable Agriculture(Press Information Bureau, 2018).

RQ2: What perspectives do farmers and other key stakeholders hold regarding the adoption and implementation of Sustainable Agriculture Practices (SAPs) in Punjab, and how do they contribute to this process?

Chapters Five to Nine address this question. Chapters Five to Seven document farmers' experiences, current practices, and perceived risks. Chapter Eight presents the perspectives of government and non-governmental stakeholders. The present chapter Nine integrates these insights through five sustainable agriculture principles and identifies governance priorities and targeted interventions grounded in farmers' realities.

The first part of this chapter discusses the findings through five sustainable agriculture principles. Within each principle, the discussion first outlines what farmers' and experts' perspectives indicate, then identifies implications for governance actions

9.2 The Current System Farmers Operate Within

Across the findings, farmers described several structural elements of the current agricultural system in Punjab that support present farming activities, but these supports were reported as uneven, incomplete, and not well aligned with diversification and sustainability goals. The key elements of the current system that significantly impact the enabler and barrier toward transition to a more sustainable food production system are:

- **Assured procurement[39] for wheat and paddy by the State Government and Food Corporation of India**, offering relatively stable and predictable income compared with most alternative crops.
- **Seasonal credit through banks and cooperative societies** (often described as a "limit"), used mainly to purchase inputs and manage seasonal cash flow.
- **Access to mechanisation**, through ownership, rental services (private or through KVK), or shared machinery arrangements.
- **Some knowledge channels**, including peer learning, social media, and advice from private input sellers (particularly for pesticides and fertilisers).
- **Institutional advisory and training infrastructure**, including PAU-linked services, Krishi Vigyan Kendras, and NGO initiatives, although farmers reported uneven last-mile reach, especially in remote villages.

Farmers and experts consistently emphasised that sustainable agriculture in Punjab cannot rely solely on farmer initiative or local institutions. As per the latest agricultural census of 2015-16, Punjab has average operational landholdings of just 3.62 hectares (MoAFW, 2019) and only 5% of farms classified as large, compared with 34% semi-medium and 28% medium (MoAFW, 2025). Most households, therefore, operate on small to medium holdings where even a single failed crop threatens livelihood security. Experts noted that transitions to biological or reduced-chemical systems require at least three years of consistent support before stabilising, a period that small and medium farmers find extremely hard to self-finance.

Several experts also reflected that while trainings, demonstrations, and awareness camps are routinely provided, these efforts have limited practical value for farmers whose

[39] Procurement Policy of Wheat and Rice is available here, Ministry of Agriculture & Farmers Welfare. (2026). *Government invites public comments on Draft Pesticides Management Bill, 2025* https://www.pib.gov.in/PressReleasePage.aspx?PRID=2212144&reg=3&lang=1

livelihoods depend on agriculture unless accompanied by the necessary financial support and investment from the government. Farmers further stressed that diversification is not feasible without assured prices, timely payments, and reliable market infrastructure. In Section 9.3, the targeted actions required from the government, based on farmers' and experts' perspectives and organised through the FAO (2015) sustainable agriculture principles are outlined in detail.

9.3 Integrating Farmers' and Agricultural Experts' Inputs Using the Five Sustainable Agriculture Principles

This section draws on the Five Principles of Sustainable Agriculture (FAO, 2015) presented in Chapter 3, to structure the integration of farmers' and experts' perspectives and to assess how current agricultural practices and the support system for farmers in Punjab align with sustainability goals. Although the sample size of the study is limited, the clear consistency of perspectives across the three districts indicates that the themes identified reflect shared structural conditions rather than isolated experiences.

Principle 1: Improving efficiency in the use of resources

Principle 1 promotes the efficient and judicious use of key inputs (e.g., fertilisers, water, land, energy, and labour) alongside integrated pest management to minimise waste and environmental pressure while sustaining productivity.

What the findings indicate

Across the surveyed farmers, heavy chemical input was used as a response to insecurity, particularly fear of yield loss and uncontrolled pest attacks, rather than a simple preference for chemical-intensive farming. Farmers described fertiliser and pesticide use as a form of risk management: when input costs are rising, lease payments increase each year, and crop marketing is uncertain, farmers try to "protect yield" because losing production can mean losing the season's income.

Need-based input practices remain limited. Soil testing and chemical fertiliser dosage planning were underused, and farmers often relied on experiential judgment, peer advice, or recommendations from private dealers. Awareness of economic-threshold approaches to pest management, integrated strategies, and intercropping was also low. Many farmers expressed scepticism toward biological inputs due to limited local availability, variable quality, and few locally credible examples of success at the farm scale.

Resource-use efficiency constraints were also evident in water management**.** All farmers reported irrigating 100% of their cropped area, and flood irrigation remained the dominant practice for both wheat and paddy. Most farmers estimated irrigation needs based on time (e.g., "one acre in about four hours"), and none reported monitoring the volume of water applied or knowing crop-specific optimal water requirements. While awareness of groundwater decline was widespread, adoption of water-saving practices was limited: only two farmers reported experimenting with alternative rice cultivation methods.

Importantly, several farmers framed chemical and water use practices as a reluctant necessity: reducing inputs is not perceived as a technical question alone but as a livelihood risk. Without stronger market signals and trusted, timely extension support, farmers considered transitions toward reduced-chemical or non-chemical, and water-efficient systems impractical and risky for most households, particularly those leasing land.

Targeted Actions Based on Findings

The findings suggest that improving resource-use efficiency will remain constrained unless the state and central government address the structural drivers of input dependence. Key areas requiring government attention include:

1. **Price assurance beyond wheat and paddy**: Farmers repeatedly described the absence of reliable price support for alternative crops as a major constraint on diversification and on willingness to reduce yield-risk inputs.

2. **Market infrastructure near farms:** Participants emphasised the need for marketing facilities closer to farm-gates and local food-processing infrastructure so diversified crops can be sold reliably and without high transaction costs.
3. **Transparent, enforceable contracts and clear scheme communication:** Farmers emphasised that contract farming terms must be enforceable and communicated clearly in Punjabi, with strict rules on payment timing and accessible dispute-resolution pathways. They also argued that government schemes and farmers' rights and entitlements should be communicated through local media and other Punjabi-language channels.
4. **Regulation of input markets:** Monitoring counterfeit pesticides and ensuring reliable access to authentic bio-products were repeatedly reported as prerequisites for building trust in non-chemical options.
5. **Redesign of extension as a relationship-based service:** Farmers consistently compared public extension with private dealers. Dealers were described as readily reachable, able to provide farm-specific advice, and likely to maintain follow-up contact. In contrast, farmers reported that KVK engagement often reaches only a small subset of farmers and is frequently delivered through camps, with limited continuity and follow-up.
6. **Staffing and laboratory capacity:** Both farmers and experts highlighted staffing shortages in extension and soil-testing services. Strengthening staffing, improving turnaround time, and providing farmer-friendly recommendations were identified as necessary conditions for scaling need-based nutrient management.
7. **Village-level repeated contact points:** The findings support the need for practical, local advisory roles that can conduct regular farm visits, facilitate soil testing, provide tailored recommendations, and maintain two-way feedback between farmers and

institutions. Farmers' comments suggest that advisory needs extend beyond technical recommendations. Participants also highlighted the importance of support with cultivation planning and basic financial decision-making, including budgeting, credit-use choices, and navigating schemes and subsidies. This reinforces the value of village-level advisory roles that combine agronomic guidance with practical planning and financial counselling, supported by regular follow-up.

8. **Support for safe trials of water-efficient methods:** Farmers' hesitation around water-efficient rice methods and continued reliance on flood irrigation reflect operational barriers (weed pressure, soil suitability, rodent damage, and plot-level conditions) rather than simple resistance. Government support through dedicated funding and the hiring of additional trained staff at the village level enables repeated technical follow-up and field-based troubleshooting. Such ongoing, hands-on support, rather than one-off demonstrations, is essential for farmers to safely trial and adopt water-efficient practices.

Principle 2: Conserving, protecting, and enhancing natural ecosystems

Principle 2 emphasises safeguarding soil health, water quality, biodiversity, and ecosystem functions to ensure long-term agricultural sustainability and environmental balance.

What the findings indicate

Environmental pressures, such as residue burning constraints, groundwater decline, and soil degradation, were repeatedly linked to operational constraints. Farmers described crop residue management (CRM) as a sequence of time-sensitive operations within the short rice–wheat window. While the PAU Super SMS was recognised as helpful for chopping and spreading straw, farmers noted that evenly spread residue increases labour and fuel requirements for incorporation under conventional tillage. Farmers also emphasised the financial pressure associated with incorporating residue; incorporation often requires renting

multiple machines and high-horsepower tractors, making the non-burning pathway more expensive and time-consuming than burning. This helps explain why some sampled farmers preferred harvesting without SMS so that straw falls in windrows, enabling selective burning of lines or targeted removal to create sowing pathways on time.

As noted in Principle 1, water stress was widely acknowledged, yet adoption of water-saving practices remained limited, largely due to perceived operational risk and inadequate technical support. Farmers also raised concerns about canal water contamination from industrial sources, highlighting that sustainable farming outcomes are not only connected to improvements in agricultural practice but also to broader environmental governance beyond the agriculture sector.

Targeted Actions Based on Findings

The findings suggest that ecosystem protection will remain difficult unless the state and central government address both the operational feasibility and equity dimensions of residue and water management. Key areas requiring governmental attention include:

1. **Residue policy to move beyond enforcement-only approaches.** Farmers acknowledged that strict penalties may reduce burning, but emphasised that compliance depends on service readiness, timely, workable, and affordable non-burning options during the rice–wheat window.
2. **Reduce the real cost burden of crop residue management (CRM) compliance:** Farmers reported that paddy residue incorporation is not a single-step solution. It requires multiple iterations, substantial fuel use, and access to high-horsepower tractors compatible with CRM equipment. Government responses, therefore, need to reduce the full operational cost of non-burning pathways through measures such as affordable machinery services, including reliable availability in peak periods, access to

trained operators/drivers, and appropriate credit mechanisms, rather than assuming adoption is primarily an awareness issue.

3. **Treat tenancy as a central equity issue in environmental compliance:** Leaseholders cultivating the dominant wheat–paddy system reported that lease payments can account for approximately 68–76% of gross returns (varying by region), leaving income to the leaseholder around 24–32% per hectare before other input and operational costs. In this context, CRM compliance costs become an additional burden. The findings therefore support approaches that recognise shared responsibility for land stewardship, including mechanisms that encourage cost-sharing between landowners and tenants (e.g., shared machinery cost and lease clauses that reflect residue-management expectations).
4. **Strengthen canal maintenance, water quality, and equitable distribution:** Farmers' concerns about deteriorating water channels and pollution risks from industrial effluents highlight the need for cross-sector government action (including monitoring and enforcement of industrial discharges), alongside investments to improve canal infrastructure and ensure fair and reliable distribution.

Principle 3: Strengthening rural livelihoods and social well-being

Principle 3 supports fair income opportunities, decent livelihoods, and inclusive participation in agricultural systems, recognising the social dimension of sustainability

What the findings indicate

Livelihood pressures emerged as a decisive factor shaping sustainability outcomes. Farmers reported increased financial stress due to rising lease rates and input prices, and labour shortage. Many questioned the value of marginal MSP increases when production costs rise rapidly, and net margins continue to shrink. Leaseholders were particularly vulnerable, with high lease payments compressing net income and reducing the ability to invest in soil

restoration, alternative inputs, or residue management services. Labour scarcity was identified as one of the major barriers to diversification and adoption of labour-intensive practices. Farmers reported that local workers often prefer non-farm employment with higher wages or more stable income, reducing the availability of skilled farm workers.

Farmers' comments also showed that livelihood pressure is not only about low margins but also about financial decision-making capacity. Some participants reflected that credit, such as the Kisan Credit Card Scheme (MoAFW, 2022) is sometimes used for non-farm expenditures or high-cost machinery purchases without repayment planning, which can deepen debt stress. This indicates a need for practical financial advisory support, including budgeting, repayment planning, and cost–benefit assessment alongside agronomic extension.

Targeted Actions Based on Findings

The findings suggest that strengthening rural livelihoods and social well-being requires government responses that treat tenancy, labour, and income stability as structural conditions shaping farmers' capacity to sustain environmentally responsible practices.

1. **Address rising lease rates as a social well-being and equity issue (not only an economic issue):** Farmers highlighted that lease rates often rise annually alongside input inflation. At the same time, modest MSP increases do not keep pace with increasing production costs and tenancy payments. This widening cost–price squeeze reduces net income, increases financial stress and insecurity, and leaves little capacity to invest in soil restoration, residue management, or diversified cropping—particularly for leaseholders.
2. **Improve income predictability beyond wheat–paddy to reduce livelihood insecurity:** As noted in Principle (1), government attention, strengthening procurement/price assurance for additional crops and improving market access are a must to support livelihood stability and reduce the perceived risk of diversification.

3. **Create credible rural pathways for youth engagement and skilled livelihoods in agriculture:** Farmers linked labour scarcity and weak knowledge transfer to youth disengagement in agriculture. Government investment in agri-service entrepreneurship (e.g., machinery operation services, advisory support, soil/water testing services), and locally viable agri-processing/marketing work can strengthen rural livelihood options and reduce outmigration pressures.
4. **Introduce practical farm financial advisory support:** Provide accessible guidance on budgeting, repayment planning, machinery investment decisions, and subsidy navigation (e.g., via trained advisors, cooperatives, or KVK-linked outreach), so credit strengthens farm viability rather than increasing debt exposure.

Principle 4: Enhancing the resilience of people, communities, and ecosystems

Principle 4 encourages adaptive farming systems capable of withstanding climate change, market shocks, and environmental risks while maintaining stable production.

What the findings indicate

Farmers' inputs indicate that existing safety nets are insufficient to manage increasing climate variability and market uncertainty, particularly for marginal to semi-medium landholders and leaseholders. Seasonal credit was generally reported as available to finance input purchases for the wheat and paddy seasons, but no comparable support for managing major shocks (e.g., crop failure or abrupt market disruptions) or for sharing the financial risk associated with experimenting with new practices. Many farmers expressed strong interest in crop insurance as a confidence-building and risk-mitigation mechanism, but emphasised that they would only trust it if scheme conditions were explained clearly, contracts were written in the local language, and farmers had access to someone who could guide them through the

process. Farmers expressed little interest in private insurance schemes, citing concerns about complexity, limited transparency, and uncertain dispute-resolution processes.

Experts and NGO participants further suggested that transitions, particularly toward reduced-chemical or non-chemical systems, require sustained support over multiple years, often at least three years, to allow farmers to stabilise practices, observe soil responses, and build confidence. However, neither farmers nor experts indicated that such long-term transition support is currently available in practice. Participants also expressed low confidence in biological input due to limited availability and the absence of locally credible examples that farmers could observe directly.

Targeted Actions Based on Findings

The findings suggest that resilience will remain limited unless government policies and investments strengthen risk protection and transition support in ways that farmers can trust and access. Key areas requiring government attention include:

1. **Introduce a credible and accessible crop-insurance mechanism:** Farmers identified insurance as a key confidence-building and risk mitigation tool, but do not currently have access to a trusted, usable system in practice. Government action is needed to establish an insurance system that is transparent and understandable, with terms and procedures clearly written in the local language.
2. **Multi-year transition finance to support diversification and experimentation:** Current credit structures largely reinforce the wheat–paddy cycle. Farmers and experts indicated that resilience would improve only if financing and support mechanisms enable diversification and experimentation and provide multi-year backing, especially during the first three years, so farmers can stabilise practices and outcomes without threatening household livelihood security.

3. **Establish verified bio-input supply chains and stronger testing capacity.** Participants emphasised that trust in biological options will not grow without reliable availability (including in remote areas) and verification against counterfeit products through credible testing systems.
4. **Expand locally credible demonstrations and follow-up support.** The lack of visible, locally trusted examples limits farmer confidence. Institutions with government funding support need to move beyond one-off demonstrations towards repeated engagement and troubleshooting in real farm conditions.

Principle 5: Ensuring responsible and effective governance of natural and human resources

Principle 5 highlights the need for effective participation, coherent policies, institutional coordination, and transparent decision-making to guide sustainable agricultural transitions.

What the findings indicate

Governance emerged as one of the most significant foundational factors influencing the feasibility of sustainability transitions. Farmers spoke of uneven extension outreach, inconsistent enforcement of market rules such as minimum support price beyond wheat-paddy, weak oversight of input markets, and limited confidence in organic labels. Many participants were open to working with government institutions, but they emphasised that cooperation depends on reliable, transparent, and experienced support at the farm level. In this view, trust is not created by policy announcements alone; it grows through consistent service delivery, clear and local-language communication, and market practices that farmers experience as fair and accountable.

Targeted Actions Based on Findings

The findings highlight the need for governance reforms that strengthen coordination, accountability, and practical service delivery at the farm level. Key priorities include:

1. **Coordinate action across departments:** Participants emphasised that sustainable agriculture cannot be delivered by one department alone; it requires alignment across procurement/markets, water/irrigation, pollution control, and rural development so farmers receive coherent support rather than fragmented programmes.
2. **Communicate policies, rights, and scheme conditions clearly in local language:** Farmers repeatedly stressed that rules, entitlements, and scheme conditions must be communicated in local language through local channels farmers are familiar with, so information is not limited to "those who already have connections."
3. **Strengthen extension into a field advisory service:** Participants called for dedicated extension staff, primarily for supporting the transition to a better system. Farmers and experts emphasised that public extension remains uneven, partly because staff are often diverted to unrelated administrative duties and because staffing levels do not allow regular farm visits and follow-up beyond occasional camps, accountability through public service standards rather than sales-driven advice.
4. **Strengthening market and quality governance across the value chain:** Farmers emphasised the need for enforceable contracts, predictable procurement and payment timelines, and stronger market infrastructure for diversified crops so diversification does not translate into marketing failure or delayed payments. Also, strengthening verification, quality control, and enforcement against counterfeit inputs and misleading claims is therefore essential for rebuilding trust in both inputs (e.g., bio-products) and outputs (credible labels).

5. **Move from isolated pilots to co-designed, scalable implementation:** Participants emphasised collaboration among farmers, researchers, and local governance bodies so initiatives reflect field realities, expand beyond single-village demonstrations, and are evaluated through outcomes that farmers recognise as meaningful.
6. **Ensure fairness in environmental governance across tenants and sectors:** Farmers argued that environmental compliance should reflect economic realities by sharing stewardship responsibilities and residue-management costs between landowners and leaseholders, rather than placing the burden primarily on tenants. They also raised concerns about canal pollution and water quality, emphasising that sustainability governance must apply consistently across sectors—if agriculture is regulated, industrial discharge must also be monitored and addressed. Such equity in both tenancy arrangements and cross-sector accountability is central to building trust and legitimacy in sustainability governance.

9.4 Integrative Perspective

Considered together, the perspectives of farmers and experts in this study suggest that sustainable agriculture transition in Punjab cannot be achieved through isolated technology adoption or awareness campaigns alone. Rather, they require coordinated action across farm, village, and governance levels, as strongly emphasised in the FAO (FAO, 2015) *Building a Common Vision for Sustainable Food and Agriculture report*. The integrative insights presented in this chapter should be interpreted within the scope of the study's limited sample, which reflects experiences from only forty-eight farmers from three districts.

Farmers' agricultural decisions reflect concerns around income security, labour and machinery access, operational feasibility, and institutional trust. When markets reward primarily wheat–paddy systems, when lease arrangements compress margins, when risk

protection is weak, and when advisory services lack consistent farm-level reach, sustainability becomes difficult to pursue, even for farmers who recognise long-term ecological harms.

Studies on India's agricultural system, including analyses that feature Punjab prominently, highlight persistent structural challenges such as policy incoherence, weak inter-departmental coordination, and limited district-level implementation capacity, all of which continue to constrain sustainable transitions (Gupta et al., 2021; Kalkat, 2017; Sidhu et al., 2010; Srivastava et al., 2016). These findings resonate with the concerns raised by farmers and experts in this study, particularly regarding the need for institutional arrangements that respond to local ecological and economic realities, supported by credible price assurance, predictable and equitable service delivery, reliable testing and verification systems, stronger extension support, and risk-sharing mechanisms that reduce uncertainty during transition period.

Furthermore, experts interviewed in this study emphasised that in Punjab, research on advanced technologies such as precision irrigation, water-resource monitoring, and need-based fertiliser management needs to expand significantly, especially in areas such as Internet-of-Things–enabled monitoring and remote sensing, which have shown strong potential for improving resource efficiency (Khan et al., 2021). Experts stressed that such technological development must be paired with government support to ensure these innovations are accessible for farmers to test, adapt, and use confidently.

Under these conditions, incremental change, small trials, gradual reduction of unnecessary inputs, partial residue improvements, and locally tested water-saving methods can scale more fairly and effectively (Gupta et al., 2021).

The following figures visually summarise the bottom-up approach presented in this discussion chapter. Figure 9.1 integrates the relationships among farmers' needs, existing system supports, and the governance gaps that currently constrain the adoption of sustainable

agriculture practices. The diagram highlights that many challenges arise not from a lack of farmers' awareness but from structural conditions in markets, advisory systems, and service delivery. Figure 9.2 presents a bottom-up staircase model for advancing sustainable agriculture transitions in Punjab. It demonstrates that the practical changes at the farm level require coordinated support from local institutions, reliable district-level services, and broader governance actions to reduce risk and scale sustainability. The model, therefore, translates the discussion into a practical systems pathway grounded in field realities.

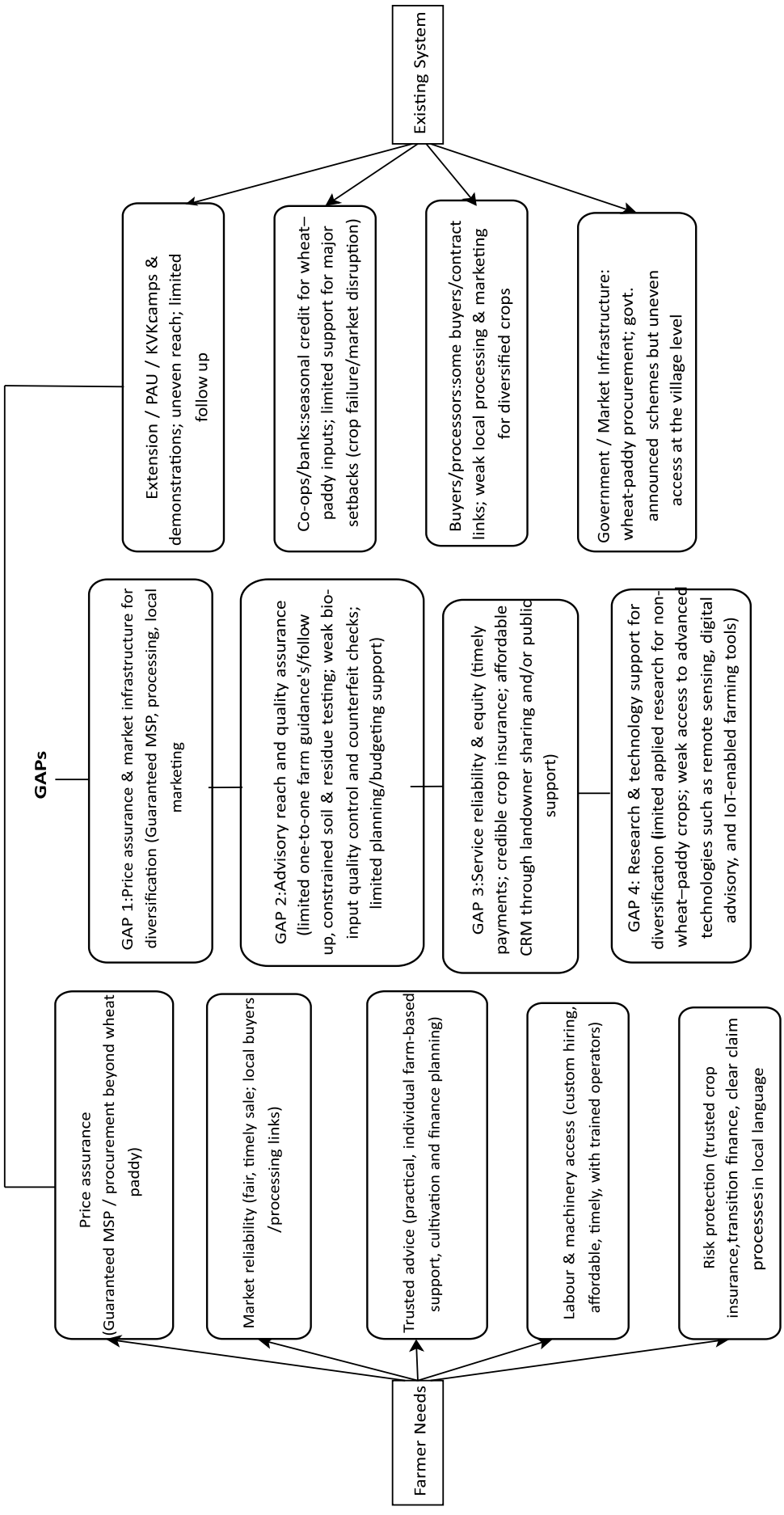


Figure 9.1 Farmer needs, existing system supports, and key governance gaps shaping the transition to sustainable agriculture in Punjab (Created by the author in draw.io)

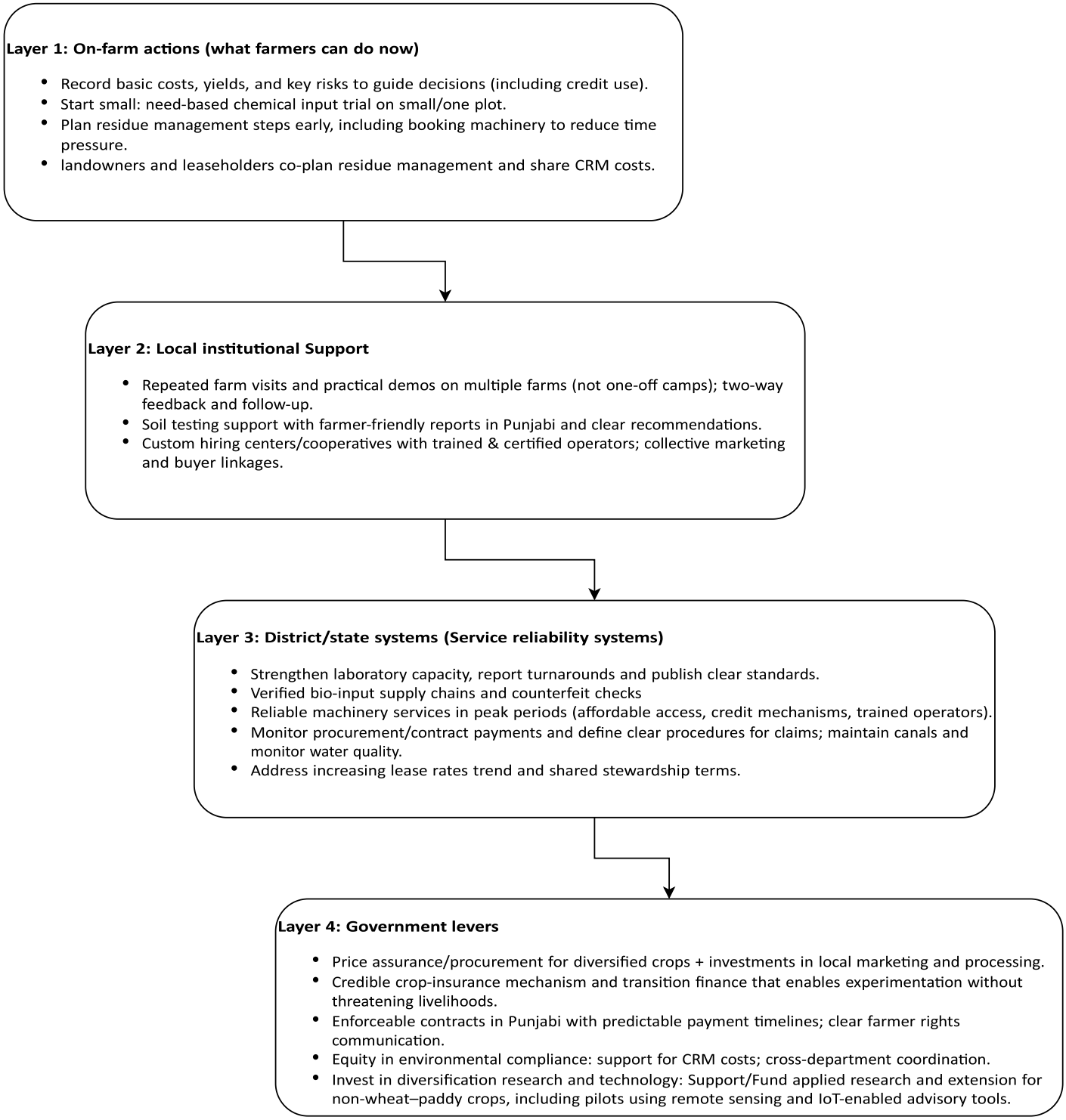


Figure 9.2 Bottom-up staircase model for advancing sustainable agriculture transitions in Punjab: Integrating farmers' and experts' perspectives (Created by the author in draw.io)

9.5 Closing Thoughts and Recommendations

The findings of this study suggest that the transition to sustainable agriculture in Punjab requires systemic changes rather than simple technology adoption. Although this qualitative-dominant pilot study draws on the experiences of forty-eight farmers from three districts, the insights it provides offer depth and contextual understanding of the conditions shaping agricultural decision-making in Punjab.

Survey responses from the sampled farmers indicated that farming decisions are shaped by income predictability, operational feasibility, and trust in institutions. Even when farmers recognise environmental challenges such as soil degradation or groundwater decline, many current practices persist because they are perceived as the least risky options within the existing system. The visual models presented in Figures 9.1 and 9.2 demonstrate that sustainability transitions depend less on individual behaviour change and more on aligning the wider agricultural system around farmers' realities. Strengthening reliable advisory services, improving testing and quality control capacity, expanding risk-protection mechanisms, and ensuring that environmental responsibilities are shared fairly among all stakeholders are central to this alignment.

A bottom-up transition pathway, therefore, requires coordinated action across multiple levels, as also emphasised by (FAO, 2015; Gupta et al., 2021; Khan et al., 2021; Pretty, 1995; Srivastava et al., 2016). As suggested by farmers and experts, at the farm level, incremental adjustments, such as small-scale trials of need-based inputs and improved residue practices, should be promoted. At the village level, advisory systems such as Krishi Vigyan Kendras and Farm Advisory Support Centres can combine agronomic guidance with cultivation planning and financial counselling to support more informed decision-making. At the state and central government levels, broader reforms related to price assurance, quality monitoring, and service reliability are necessary to make sustainable practices practical rather than risky choices.

Importantly, this study suggests that sustainability must be understood as a shared responsibility, as emphasised by (Bansal, 2019). Farmers stressed that they should not be expected to bear the burden of transition alone, given that markets reward limited crop systems, advisory reach is inconsistent, and environmental governance is uneven across sectors. Building trust in the system requires consistent service delivery, transparent communication in the local language, and policies that reflect both ecological goals and economic realities.

Beyond these empirical insights, the study contributes methodologically to ongoing efforts to operationalise SDG 2.4.1 on sustainable agriculture (FAO, 2019a). Although FAO encourages countries to adapt proxy indicators to their national contexts (FAO, n.d.-b), India did not report in its internal assessment report any inputs on the sustainable agriculture SDG 2.4 indicators (NITI Aayog, 2024). This gap is partly due to limited farm-level data (FAO, 2019b). The thesis responds by adapting elements of the FAO sustainability survey (FAO, 2021) to the Punjab context, incorporating locally relevant questions, and piloting its use with farmers. While the survey was applied only to crop farmers and did not generate nationally representative quantitative data, it provides an important step toward understanding where farmers stand, what their needs are, and how they perceive existing support systems. Combined with expert interviews, the study offers a two-way flow of insights, bottom-up and top-down, that can inform targeted interventions and future data-collection efforts.

As a pilot study, the research also demonstrates the feasibility of applying the SDG 2.4.1 framework in exploratory, qualitative-dominant research. Farmers' comments about shared practices within villages suggest that a larger district-wide application of the survey could generate deeper insights into capacity-building needs and sustainability constraints. This study, therefore, outlines a pathway for future research that can support more robust monitoring of agricultural sustainability and guide evidence-based policy design.

Overall, the findings of my research support a gradual, equity-sensitive transition pathway grounded in farmers' lived experiences. Although it is an ambitious aim, my research indicates that by aligning governance systems with on-farm realities, bottom-up knowledge, and the research and innovation efforts of agricultural experts, supported by coordinated public investment, rigorous field trials, and accountable policy action, can help Punjab move toward more resilient and sustainable outcomes without undermining household livelihoods.

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