

**EXPLORING THE RELATIONSHIP BETWEEN FARM
SIZE, PRODUCTIVITY, AND PROFITABILITY IN
PUNJAB AGRICULTURE**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

**IN
ECONOMICS**

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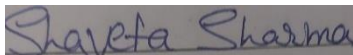


LOVELY PROFESSIONAL UNIVERSITY

2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Exploring the relationship between farm size, productivity, and profitability in Punjab Agriculture**” in fulfilment of degree of Doctor of Philosophy (Ph.D.) is outcome of research work carried out by me under the supervision of Dr. Tanima Dutta, Professor , in the Mittal School of Business of Lovely Professional University, Punjab, India. I declare that the research work embodied in this thesis is the result of my own independent efforts and has not been submitted, either wholly or in part, for any degree or diploma at any other university or institution. All sources of information and contributions by others have been properly acknowledged and cited in the relevant sections of this thesis.



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CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled “ **Exploring the relationship between farm size, productivity, and profitability in Punjab Agriculture**” in fulfilment of degree of **Doctor of Philosophy(Ph.D.)** in the Mittal School of Business, is a research work carried out by Shaveta Sharma, Registration No. 41900559, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

Background

The contribution of Punjab towards Indian agriculture has been significant since the Green Revolution. Sidhu et al. (2019) state that India's self-reliance on food grains is the outcome of Punjab's pioneering adoption of modern agronomic practices like high-yield variety seeds (HYV), mechanization of agriculture, use of chemical fertilizers, groundwater irrigation, pesticides, etc. The involvement of the Punjab population in the farming sector and its notable contribution to India's food basket made Punjab an agrarian economy by nature. Furthermore, Gulati et al. (2021) found that the state agricultural Gross Domestic Product (GDP) thrived at the rate of 5.7 percent per annum during the period from 1971 to 1985, resulting in Punjab having the minimum poverty ratios as per the Tendulkar poverty line in the country in 2011-

12. However, over the years, adopting monoculture practices, water table depletion, soil fertility loss, and the rising cost of cultivation slowed the state's agricultural growth (Bhullar & Mohan, 2016). In addition, the international trade agreements with the World Trade Organization (WTO) forced the reduction in subsidies that adversely impacted the agriculture growth rate in Punjab (Shoor, 2016). There is a need to introduce policy reforms that can contribute to productivity and profitability along with the agricultural growth rate in Punjab. Investment in rural infrastructure is crucial, and it involves the construction of roads, irrigation facilities, warehouses, etc. (Sekhon & Kaur, 2016).

Aim of the Study

The present study will help in analyzing the level of productivity, cost of cultivation, and profitability across the farm sizes of the Punjab state. The result of the study will help to understand the agricultural dynamics of Punjab, which involve farm categories like small, medium, large, etc. These categorizations of farm sizes have their variability, like operational efficiencies, level of technology, access to resources, and market opportunities. It would help to pinpoint the farm sizes that are more economically viable and contribute towards maintaining food security and sustainability of farmers. The outcome of this study can also guide policymakers in

the formulation of plans and policies that can enhance economic viability and sustainable farming practices.

Research Design

This Research Study comprises of data collected from the three Agro-climatic zones within Punjab state utilizing the stratified random sampling method. The population of our study is Punjab state, which is divided into three strata called Agro-climatic zones based on cropping patterns. Eight districts are selected randomly. After selecting districts, villages were selected, and data from different farm sizes were categorized. A structured, pre-tested questionnaire was used as a research instrument to collect data from targeted people.

Findings of the study

The study on the relationship between farm size, productivity, and profitability in Punjab agriculture suggested that a complex reciprocation exists between three variables, influenced by technology adoption, labour market, socio-economic characteristics, market imperfections, etc. The availability of agricultural machinery on a rental basis and other modern farming components such as high-yield variety (HYV) seeds, fertilizers, and pesticides in the market has eliminated the impact of farm size on productivity. Therefore, the productivity of farms is the same in Punjab state, irrespective of farm size. However, the adoption of these modern agronomic practices costs an arm and a leg for small and marginal farmers. The cost of cultivation of these farms is higher than that of large farms because of the lack of market access. Large farms receive discounts on bulk purchases, reducing their cultivation costs. Consequently, with an increase in farm size, the cost of cultivation was reduced, which increased profitability. In addition, certain factors of production and profitability can increase per-hectare productivity and profitability. Factors such as labour costs, imputed rent costs, fertilizer cost, seed cost, Irrigation machinery cost, leased in land cost, fixed capital cost, cropping intensity and the Agro-climatic zone category positively impact farm productivity. Landholding size, cropping intensity, and zone type positively influence profitability (returns on costs) per hectare. Factors such as lease-inland costs and fragmentation are negatively associated with the level of profitability across landholding sizes.

Conclusion

The relationship between farm size, productivity, and profitability in Punjab helps to frame policies promoting productivity and profitability across landholding sizes, ensuring less negative environmental impact. Small and marginal farmers should stress niche markets by growing non-staple crops and shift towards high-value crops and organic farming. These agronomic practices can increase the per-hectare productivity and profitability on small farms, which would not be possible with traditional farm practices. Large farms should also adopt the path of crop diversification and rotation to improve their soil fertility level. The Punjab water table is alarming because of paddy crop plantation. Therefore, the farmers should either replace the paddy with less water-guzzling crops like maize or follow the Direct Seeding of Rice (DSR). Finally, and most importantly, the government of Punjab should increase investment in the agriculture sector to develop innovative farming practices that can promote judicious use of farm inputs either solely or in partnership with the private sector. Investment in warehouses and freezer vans is also pivotal to reducing post-harvest loss in Punjab and maintaining food security and profitability.

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सर्वद्रव्येषु ईद्वैर् द्रव्यमाहुरनुत्तमम् ॥

अहर्वत्वादनर्धत्वादक्षत्वावच्च सर्वदा ॥

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(Shaveta Sharma)

TABLE OF CONTENTS

S.No	Particulars	Page NO.
1	Declaration	I
2	Certificate	II
3	Abstract	III-V
4	Acknowledgement	VI-VII
5	Table of Contents	VIII-XII
6	List of Tables`	XIII-XVIII
7	List of Figures	XIX
8	List of Maps	XIX
9	List of Appendices	XX
10	List of Abbreviations	XXI-XXII
Chapter- Wise Index		
Chapter-I	Introduction	1-32
1.1	Background of the study	1-2
1.2	Statement of the problem	2-5
1.3	Study Area	5-6
1.4	Significance of study	6-7
1.5	Literature Review	7-19
1.6	Research Gap	19
1.7	Research Questions	20
1.8	Research Objectives	20-21
1.9	Research Hypothesis	21

1.10	Database and Methodology	21-30
1.11	Research Instrument	31
1.12	Tools for Data Analysis objective wise	31-32
1.13	Study Structure	32
Chapter- II	Socio-economic traits of farmers over farm sizes in Punjab	33-59
2.1	Introduction	33-34
2.2	Literature Review	34-36
2.3	Methodology	37
2.4	Results & Discussions	37-59
2.4.1	Social Status of farmers across landholding size	37-50
2.4.2	Discussion on Economic Variables.	50-58
2.5	Conclusion	58-59
CHAPTER- III	Analysis of Input use and cost of cultivation across farm size	60-81
3.1	Introduction	60
3.2	Literature Review	60-62
3.3	Database and Methodology	62-63
3.4	Results and Discussions	64-79
3.4.1	Value of crop output (Rs. /ha of Net Sown Area)	64-65
3.4.2	Labour use and Labour cost per hectare	65-66
3.4.3	Machine use and Machine Costs per hectare of Net Sown Area	66-67
3.4.4	Irrigation machines use and Irrigation machine costs per hectare of Net Sown Area	67-69
3.4.5	Animal use and Animal costs per hectare	69-70

	of Net Sown Area	
3.4.6	Seed use and Seed costs per hectare of Net Sown Area	70-71
3.4.7	Fertilizers use and Fertilizers costs per hectare of Net Sown Area	71-72
3.4.8	Farm Yard Manure use and costs per hectare of Net Sown Area	73-74
3.4.9	Insecticides costs per hectare of Net Sown Area	74-75
3.4.10	Lease-in land cost per hectare of Net Sown Area	75-76
3.4.11	Imputed Rent Cost per hectare of Net Sown Area	76
3.4.12	Depreciation Cost per hectare of Net Sown Area	77
3.4.13	Fixed Capital Costs per hectare of Net Sown Area	77-78
3.4.14	Other costs per hectare of Net Sown Area	78-79
3.5	Conclusion	79-81
IV	Relationship between Farm size, Productivity, and Profitability in Punjab Agriculture	
4.1	Introduction	82
4.2	Literature Review	82-84
4.3	Database and Methodology	84-86
4.4	Results and Discussions	87-119
4.4.1	Relationship between farm size and productivity	87-89
4.4.2	Relationship between farm size and Cost of Cultivation	89-92
4.4.3	Relationship between farm size and labour costs (Rs	92-94

	/ha of NSA)	
4.4.4	Relationship between farm size and Machine costs (Rs /ha of NSA)	94-96
4.4.5	Relationship between farm size and Irrigation machine costs (Rs /ha of NSA)	96-99
4.4.6	Relationship between farm size and Animals use costs (Rs /ha of NSA)	99-101
4.4.7	Relationship between farm size and Seeds use costs (Rs /ha of NSA)	101-104
4.4.8	Relationship between farm size and Fertilizers use costs (Rs /ha of NSA)	104-106
4.4.9	Relationship between farm size and Farm Yard Manure use costs (Rs /ha of NSA)	106-108
4.4.10	Relationship between farm size and Insecticides and Pesticides use costs (Rs /ha of NSA)	108-110
4.4.11	Relationship between farm size and Land lease-in costs (Rs /ha of NSA)	110-112
4.4.12	Relationship between farm size and Depreciation costs (Rs /ha of NSA)	112-114
4.4.13	Relationship between farm size and other minor costs (Rs /ha of NSA)	114-117
4.4.14	Relationship between farm size and Profitability (Rs /ha of NSA)	117-119
4.5	Conclusion	119-120
V	Agricultural Production and Profitability in Punjab	
5.1	Introduction	121
5.2	Literature Review	121-124
5.3	Database and Methodology	124-128

5.4	Results and Discussions	128-165
5.4.1	Value of Crop Output (Productivity) Analysis per hectare	128-150
5.4.2	Return on Costs (Profitability) per hectare Analysis	151-164
5.5	Conclusion	164-165
VI	Conclusion and Suggestions	166-175
6.1	Conclusion	166-172
6.2	Suggestions	172-175
VII	Limitations and Future Scope for Research Work	176-213
7.1	Limitations	176
7.2	Future Scope for Research Work	177
	References	178-213

LIST OF TABLES

Table No.	Description	Page No.
1.1	Cropping Pattern of Punjab and share of different crops grown in state.	4
1.2	Selection procedure between zone, district, and village.	22
1.3	Sample size Distribution	24
1.4	Total number of landholdings in each size group across three zones.	25
1.5	Zone wise Probability Distribution.	26
1.6	Size group Probability Distribution	27
1.7	Combined Probability Distribution	28
1.8	Total weight after applying correction factor on landholding size	30
1.9	Final weight for each landholding size	30
2.1	Distribution of respondents by age groups across landholding groups	38-39
2.2	Distribution of respondents by education level across landholding groups	41-42
2.3	Distribution of respondents by family size across landholding groups	43-44
2.4	Dependency Status according to landholding size	45

2.5	Genders of farmers across landholding sizes.	46-47
2.6	Marital Status of farmers across landholding sizes	48-49
2.7	Land Holding size wise Average net cropped area, Area under border, Gross Cropped Area, and Land Value	51
2.8	Cropping Intensity across land holding size.	52
2.9	Average Land holding size wise Agriculture Machinery, Tools, and Farm Implements	53
2.10	Ownership of Tractor Status of farmers across landholding sizes	54-55
2.11	Land holding size wise Ownership of Harvester Combine	55-56
2.12	Livestock details as per land size holdings	57
3.1	Value of Product per ha	64
3.2	Labour cost per ha of Net Sown Area	65
3.3	Machine cost per ha of Net Sown Area	66-67
3.4	Irrigation Machinery cost per ha of Net Sown Area	68
3.5	Animal cost per ha of Net Sown Area	69-70

3.6	Seeds cost per ha of Net Sown Area	70-71
3.7	Fertilizer cost per ha of Net Sown Area	72
3.8	Farm Yard Manure cost per ha of Net Sown Area	73
3.9	Insecticides cost per ha of Net Sown Area	74
3.10	Average Lease in Land cost per hectare of Net Sown Area	75
3.11	Imputed Rent cost per hectare of Net Sown area	76
3.12	Depreciation cost per ha of Net Sown Area	77
3.13	Fixed Capital Cost per ha of Net Sown area	78
3.14	Other cost per ha of Net Sown area	79
4.1	Analysis of Variance of productivity (Rs. /ha of net sown area) among Farm size group	87
4.2	Results of Post Hoc test (Tukey's) on productivity (Rs. /ha of net sown area) among Farm size group	88-89
4.3	Analysis of Variance of cost (Cost A2+Family Labour) of cultivation (Rs. /ha of net sown area) among Farm size group	90

4.4	Results of Post Hoc test (Tukey's) on cost (Cost A2+Family Labour) of cultivation (Rs. /ha of net sown area) among Farm size group	90-91
4.5	Analysis of Variance of labour use costs (Rs. /ha of net sown area) among Farm size group	92
4.6	Results of Post Hoc test (Tukey's) on cost of labour use (Rs. /ha of net sown area) among Farm size group	93
4.7	Analysis of Variance of cost of machine use (Rs. /ha of net sown area) among Farm size group	94
4.8	Results of Post Hoc test (Tukey's) on cost of machine use (Rs. /ha of net sown area) among Farm size group	95-96
4.9	Analysis of Variance of cost of Irrigation use (Rs. /ha of net sown area) among Farm size group	97
4.10	Results of Post Hoc test (Tukey's) on Irrigation machine use (Rs./ha of net sown area) among Farm size group	97-98
4.11	Analysis of Variance of cost of Animal use (Rs. /ha of net sown area) among Farm size group	99
4.12	Results of Post Hoc test (Tukey's) on cost of Animal use (Rs. /ha of net sown area) among Farm size group	99-101
4.13	Analysis of Variance of cost of seed use (Rs. /ha of net sown area) among Farm size group	102
4.14	Results of Post Hoc test (Tukey's) on seeds use costs (Rs. /ha of net sown area) among Farm size group	102-104
4.15	Variance of cost of fertilizers use (Rs. /ha of net sown area) among Farm size group	104

4.16	Results of Post Hoc test (Tukey's) on fertilizers use costs (Rs. /ha of net sown area) among Farm size group	105-106
4.17	Analysis of Variance of cost of farm yard manure use (Rs. /ha of net sown area) among Farm size group	107
4.18	Results of Post Hoc test (Tukey's) on farm yard manure use (Rs. /ha of net sown area) among Farm size group	107-108
4.19	Analysis of Variance of cost of insecticides use (Rs. /ha of net sown area) among Farm size group	108-109
4.20	Results of Post Hoc test (Tukey's) on insecticides use (Rs. /ha of net sown area) among Farm size group	109-110
4.21	Analysis of Variance of cost of lease in land (Rs. /ha of net sown area) among Farm size group	111
4.22	Results of Post Hoc test (Tukey's) on cost of lease in land (Rs. /ha of net sown area) among Farm size group	111-112
4.23	Analysis of Variance of cost of cost of depreciation of farm building and implements (Rs./ha of net sown area) among Farm size group	112
4.24	Results of Post Hoc test (Tukey's) on cost of depreciation of farm building and implements (Rs. /ha of net sown area) among Farm size group	113-114
4.25	Analysis of Variance of other minor cost (Rs. /ha of net sown area) among Farm size group	115
4.26	Results of Post Hoc test (Tukey's) on other minor cost (Rs. /ha of net sown area) among Farm size group	115-116
4.27	Analysis of Variance of profitability on Cost A2+ Family Labour (Rs/ha of NSA) among Farm size group.	117

4.28	Results of Post Hoc test (Tukey's) on Profitability on Cost A2+ Family Labour (Rs/ha of NSA) among Farm size group.	118-119
5.1	Identification of variables to analyse Productivity & Profitability	121
5.2	Descriptive statistics of the variables used to analyse the Productivity	128-129
5.3	Descriptions of variables used in Table 5.4	129-130
5.4	Pearson Correlation Coefficient to determine factors of production	130-131
5.5	Regression Analysis	142-145
5.6	SPEC Test on factors of Production	150
5.7	Descriptive Statistics	151-152
5.8	Description of Variables	152-153
5.9	Pearson Correlation Analysis of Returns on Costs	153-154
5.10	Regression Analysis	159-160
5.11	SPEC Test for Profitability	163

LIST OF FIGURES

FIGURE NO.	DESCRIPTION	PAGE NO.
1.1	Growth rate of Agriculture and Allied Activities in Punjab	4

LIST OF MAPS

FIGURE NO.	DESCRIPTION	PAGE NO.
1.1	Study Area of Punjab	6

LIST OF APPENDICES

	APPENDIX -A	
Sr. No.	PUBLICATIONS	PAGE NO.
1	Scopus Publication Unlocking the Potential of Maize for Crop Diversification in India: Farm Size, Productivity, and Profit Analysis	214
2.	Conference Presentations	215-217
3	Book Chapters	218
	APPENDIX -B	
1	Survey Instrument(Questionnaire)	219-232

LIST OF ABBREVIATIONS

Sr. NO.	DESCRIPTION	ABBREVIATION
1.	HYV's	High Yielding Variety
2.	MSP	Minimum Support Price
3.	GSVA	Gross state value Added
4.	CGWB	Central Groundwater Board
5.	ESOP	Economic Survey of Punjab
6.	PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
7.	CAGR	Compound Annual Growth Rate
8.	CSD	Cross sectional dependency
9.	ANOVA	Analysis of Variance
10.	HSD	Honest Significant Difference
11.	CV	Coefficient Of Variation
12.	SD	Standard Deviation
13.	GOP	Government of Punjab
14.	U. S	United States
15.	IPCC	Intergovernmental Panel on Climate Change
16.	GDW	Groundwater depth level
17.	EPWR	Economic and Political Weekly Research Foundation
18.	NAP	National Agriculture Policy

19.	PDS	Public Distribution System
20.	BPL	Below Poverty Line
21.	IADP	Intensive Agriculture District Programme
22.	GDP	Gross Domestic Product
23.	N-P-K	Nitrogen, Phosphorus and Potassium
24.	NABARD	National Bank for Agriculture and Rural Development
25.	RRB	Regional Rural Bank
26.	KCC	Kisan Credit Card
27.	SHG	Self Help Group
28.	PSWC	Punjab State Warehousing Corporation
29.	AIBP	Accelerated Irrigation Benefit Programme
30.	HKKP	Har Khet Ko Pani
31.	CWC	Central Warehousing Corporation
32.	CADWM	Command Area Development and Water Management.
33.	PDMC	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
34.	IPM	Integrated Pest Management
35.	MIS	Micro- Management Information System
36.	MOSPI	Ministry of Statistics and Programme Implementation

CHAPTER I

INTRODUCTION

1.1 Background of the Study

"Land is an emotional subject with a farmer in India because it is his only means of Income."
- **Kushal Pal Singh**

Globally, agriculture holds the title of the largest industry, as it plays an immense role in dealing with poverty among the poor compared to industry and service. Thus, agriculture plays an important role in research, and special attention must be paid to growth (Christiaensen & Martin, 2018). The world population is forecast to reach 10 billion by 2050, putting additional pressure on agriculture (Basso et al., 2024). Holt-Gimenez (2019), the key question arose: Can we feed our growing population using already pushed scarce resources like land and water with adverse climate change intensification? However, with current agricultural practices, we could satisfy the increasing demand, but that would escalate the problem of land degradation, deforestation, and greenhouse gas emissions (Serraj & Pingali, 2018; Fróna et al., 2019). Therefore, countries worldwide, whether they belong to high-, medium-, or low-income groups, have invested in agricultural research and development activities to increase their agricultural productivity through less exploitation of their scarce resources.

Climate-smart agriculture, integrated farming systems, conservation agriculture, agroforestry, and precision farming are well-known ways to increase productivity and sustainability (Schoeneberger et al., 2012; Sekaran et al., 2021; Javaid et al., 2022). However, adopting innovation in agriculture has made it more capital-intensive, vertically integrated, and concentrated in fewer hands (Alston & Pardey, 2020). Marginal and small farmers are forced to migrate from the agriculture sector, which

would threaten world food security (Sabo et al., 2017). Across the world, 84 per cent of all farms are small, and they operate around 12 per cent of all agricultural operations, managing approximately 35 per cent of world food and maintaining equality (Lowder et al., 2021). Therefore, as part of the 2030 Agenda of Zero Hunger, we need to work sustainably without considering the division between developed and developing countries and small and large farms (Breuer et al., 2019; Von Braun et al., 2021). The most pivotal task is to increase productivity at every farm size worldwide, and the method can be crop diversification or innovation (Andrianarison et al., 2021; Barman et al., 2022). However, as per the United Nations, we need a holistic approach in which we must increase farmers' income through profitability.

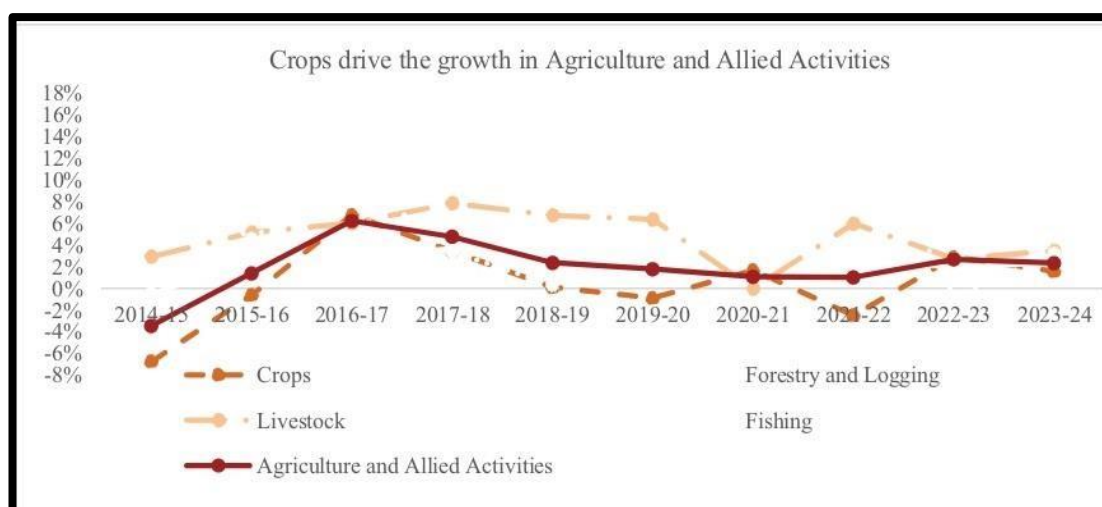
India has also dealt with twin problems. On the one hand, India's productivity level is less than the global average; and on the contrary, agricultural households have been living in debt and poverty. Agricultural household income on an average given monthly basis is Rs. 8337, and the average amount of outstanding loans per agriculture household is Rs. 74,121 (Ministry of Statistics and Program Implementations, 2021). Therefore, the Government of India introduced doubling farmers' incomes and tried its best to increase them. The strategies adopted to double farmers' income include increasing productivity and better prices for the produced output, reducing the cost of cultivation, providing farmers with reasonable prices at the doorstep, and crop diversification (Bihari et al., 2019). Additionally, India's government has been investing in agricultural infrastructure at a high rate to reduce the post-harvest loss of agricultural products. Proper supply chains are started, and farmers are encouraged to play a part in these supply chains (McNamara & Tata, 2015). Furthermore, farmers are guided to adopt marketing strategies like grading, packaging, and distributing the produced output through special informative seminars.

1.2 Statement of the Problem

Punjab is an agrarian state by nature, which has contributed 31.22 and 46.24 per cent rice and wheat, respectively, to India's food granary during 2023-24, while only comprising a mere 1.5 per cent land mass within India (Punjab Economic Survey, 2022-23). Productivity in Punjab is substantially greater when compared to its counterparts; therefore, state-farming households have the highest average monthly income

nationwide (National Bank for Agriculture and Rural Development, 2018). However, the contribution of the agricultural sector to the state's GSVA has been inconsistent due to climate change issues in Punjab. For illustration, in 2022-23 the main estimates for the agriculture and allied sector contribution were 26.98 per cent, which further reduced to 26.68 per cent per the advanced estimates. This was not the case for these two consecutive years; the same pattern was observed in the estimates for the past few years.

Figure 1.1: Growth rate of Agriculture and Allied Activities in Punjab



Source: Economics Survey of Punjab 2023

Punjab is acknowledged as country's food basket. Therefore, to maintain food security in the country for the growing population, special efforts are required to escalate productivity in the state, which is already at the pinnacle level. However, the increase in productivity in Punjab is a massive challenge because fallow land has been reduced from 13 per cent to 11 per cent between 1960-61 and 2022-23, which resulting in limited scope for any expansion in the area under cultivation(Punjab Economic Survey, 2022-23). Apart from this, Cropping Intensity in Punjab has already reached a saturation point of around 191.7 per cent during 2022-23 compared to 142.6 per cent of the national average, which further made an increase in productivity a challenge. Therefore, productivity cannot be increased through more areas geared towards crop production and cropping intensity. The only viable solution to increase productivity is to work with cropping patterns, production technology and efficient use of various farm inputs. The first and most significant concern for Punjab agriculture is a mono-cropping pattern that continuously reduced the per-acre productivity but also severely affects

Punjab's state water table; as per the report published in Nibber (2016), Punjab may turn into a desert within 15 to 20 years due to the mono-cropping pattern that follows in Punjab state. Thus, the government has been seriously promoting crop diversification in the state by introducing MSP for crops other than rice and wheat.

Table 1.1: Cropping Pattern of Punjab and share of different crops grown in state for the year 2023

S.NO	Crops	Percentage share of cropped area
1	Paddy	40.4
2	Wheat	44.9
3	Maize	1.2
4	Bajra	0.0
5	Barley	0.1
5	Pulses	0.2
6	Oilseeds	0.6
7	Sugarcane	1.2
8	Cotton	3.2
9	Vegetables	0.5
10	Fruits	1.0
11	Other Crops	6.7

Source: Directorate of Agriculture and Farmers Welfare Punjab

Table 1.1 shows that in Punjab, the lion's share of the total cropping pattern was devoted to wheat and rice, and the mono-cropping pattern prevailed in the state. Mono-cropping not only affects farmers' pockets due to the increasing cost of cultivation, but the per-acre yield also becomes stagnant, negatively affecting farmers' profitability. Stagnant yield affects landholding size differently. Small and marginal farmers make their livelihood outside of agriculture by renting out or selling their land to other peasants.

On the other hand, large and medium landholding farmers started agribusiness in Punjab at an ecological expense (Dhillon et al., 2011). For small and marginal farmers, profitability matters a lot for their continued existence.

The depeasantization rate is relatively high among small and marginal farmers; however, after leaving the agriculture sector, they join small occupations like vendor, small shops, and agriculture labourer, making their lives more vulnerable than working in the agriculture sector (Singh & Bhogal, 2014). Therefore, efforts should be taken to stop the migration of small and marginal farmers from agriculture. The government of Punjab has been doing their best to make agriculture lucrative for small farmers. Farmers Producer Organization (FPO) has been started at the district level to help small peasants with comprehensive services addressing all facets of farming, ranging from inputs and technical assistance to processing and marketing (Singh et al., 2022). Adopting horticultural practices is a new method that can give small and marginal farmers good returns. Horticulture is a labour-intensive job catering only to small and marginal farmers (Babu et al., 2022). However, the post-harvest loss demotivates the small farmers from moving towards the horticulture sector and makes them stick to old cropping patterns.

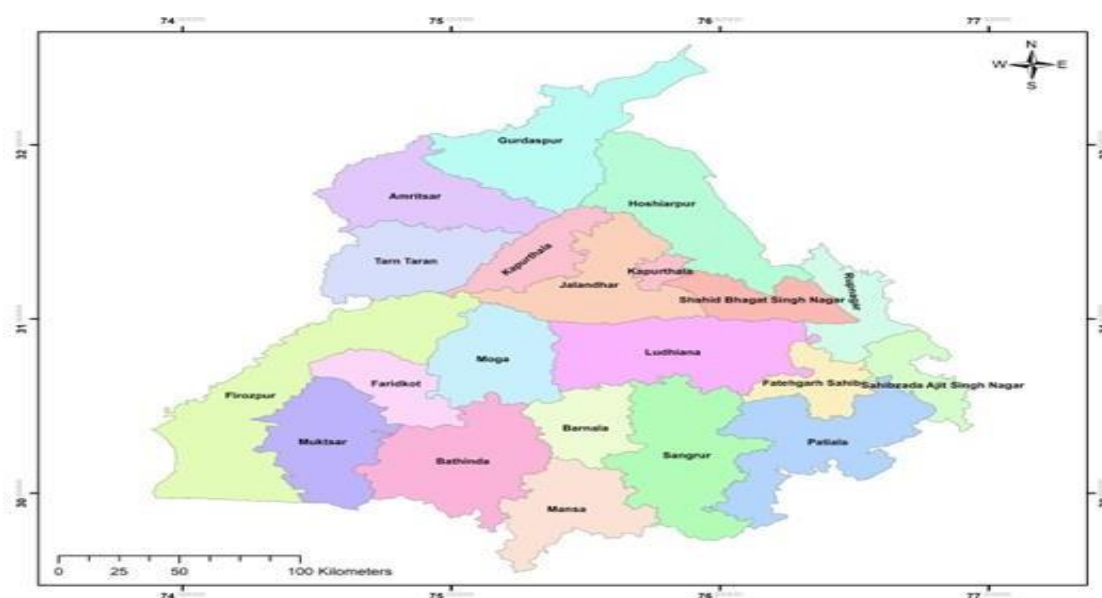
This study seeks to explore the link among farm size, productivity, and profitability across the three Agro-climatic zones of Punjab, as well as the factors that can promote productivity and profitability in the Punjab farming sector. The key area of this research work is determining whether landholding size matters for increased productivity and profitability. The answer to this question can help manage food security in the state and the country because Punjab is the country's food basket. However, the scope of this study is limited to the state of Punjab as it is a micro-level study. Moreover, the reliability of the study's results depends upon the data collected from the farmers in three Agro-climatic zones of Punjab.

1.3 Study Area

The present study deals with the Punjab state, which is situated in the northwestern part of the subcontinent that spans from 29° 30' to 32° 32' N latitude and 73° 55' to 67° 50' E longitude. Renowned as the Food Bowl of India for its immense contribution towards the country's food supply with its minute 50,362 square kilometers area, comprising

1.5 per cent of the landmass of India. The importance of Punjab from the viewpoint of agriculture did not start with the introduction of the Green Revolution alone; the Britishers also recognized the role of Punjab in food security and constructed various irrigation projects in Punjab. However, before independence, Punjab had five rivers for irrigation: Ravi, Beas, Jhelum, Sutlej, and Chenab. Now, the Beas, Ravi, and Sutlej are the source of irrigation projects in Punjab. In addition, high productivity per hectare in Punjab is also influenced by the state's soil. The soil in Punjab is categorized into three types: Bet soils, loamy soils, and sandy soils. The geographical landscape of Punjab is divided into three central regions: Siwalik Hills, foothills, and flat plains. These regions encompass 23 districts within the state, which are further divided into Agro-climatic zones.

Map 1.1: Punjab's Political Map Showing Study Area



Source: Author's

1.4 Significance of the Study

The current research work will help provide deep insights into agricultural efficiency across farm sizes and identify the farm size with maximum productivity and profitability at minimum cost of cultivation. The relationship among these three variables, which will be explored with the help of the present study, will also help to understand the cropping pattern, farm inputs level, adoption level of technology, and bargaining powers of farmers across landholding sizes.

1.5 Literature Review

Numerous studies have been documented detailing associations between farm size and productivity worldwide. However, no study has discussed profitability along with farm size and productivity, and more importantly, district-level analysis has never been performed so far in the state of Punjab to date. The following foray ventures to review the literature as per the objectives of the study in the following pattern:

1. Review related to the relationship between farm size and productivity.
2. Review linked to farm size and efficiency.
3. Review related to farm size and profitability.

Review related to relationship between farm size and productivity

Exploring the correlation between farm acreage and productivity outcomes began with comments by Amartya Sen in 1962 about Indian agriculture, based on data from Farm Management Studies (FMS) conducted in various territories of India in the 1960s. Dr Amartya Sen predicted a converse association between farm size in hectare and productivity in Indian agriculture due to the significantly increased family labour force used per hectare as farm size decreased. Following Dr. Amartya Sen's observations, multiple researches have been performed to understand the precise correlation between farm landholding size and associated output level in Indian agriculture. The various studies conducted by researchers can be divided into the following categories:

1. There is a contrary relationship between farm landholding size and output yield.
2. The Existence of a Converse correlation between cultivated land and productivity is not universally applicable.
3. The Existence of a positive connection between scale of farming and productivity outcomes.
4. A neutral connection exists between farm size and yield
5. A U-shaped relationship between farm size and output.

Review related to the contrary relationship between farm landholding size and output yield.

Following the direction of Sen, Mazumdar (1965) investigated the relationship between farm size and productivity using data from the Farm Management Survey. It asserted smallholdings derived higher output than their larger- scale counterparts. He supported this inverse relationship theory based upon intensive utilization of family labour, which indicates greater efficacy than hired labour. However, he was anxious because he found that small farmers' income levels were insufficient to maintain their household expenses. Therefore, increasing productivity through small farms is not a suitable option. A year later, Rao (1966) collected individual farm data to test predictions from the Farm Management Survey. However, he also discovered a converse correlation regarding landholding size and yield levels. He adopted the path of alternative explanations, like a fertility-based explanation, a labour-based explanation, and a farm size-based input and output explanation, to explain the inverse relationship. Later on, Bardhan (1973) tried to work with individual farm- level data and predicted results in favour of an inverse relationship between farm size and productivity. He studied paddy and wheat crops and found the interlinked phenomenon of land & labour market imperfections, which demonstrated that generally agricultural output declines as the cultivated area expands. This connected phenomenon of land and labour was cleared up through the swapping of labour with capital, which reduced the dependence on labour. This resulted in a positive association between land area and output produced (Deininger et al., 2018). In the age of modern farming, where agriculture has transformed from labour-intensive to capital-intensive, Sharma and Sharma (2000) forecast an inverse relationship between farm size and productivity valid for all studied crops, separately or together. Thus, the pattern of diminishing productivity while farm area increases is still evident.

Review related to the Existence of a Converse correlation between cultivated land and productivity is not universally applicable.

Over time, the inverse relationship between farm size and productivity has declined because the results of specific studies have challenged their universal applicability. Rudra (1968) stamped the universal non-applicability of a converse correlation

between cropped area and yield through his survey conducted in Punjab, Haryana, and Western Uttar Pradesh. He found that in some villages, as the size of the landholdings increased, so did their productivity, which remained true up to 20 acres, but for areas greater than 20 acres, the positive correlation weakened. However, in other villages, this positive association pattern in productivity with larger landholdings remained steady. between cultivated area and output remains continued. The relationship between productivity and farm size continues to increase with farm size. Likewise, Bhattacharya and Saini (1972) surveyed the Ferozpur district of Punjab and the Muzaffarpur district of Uttar Pradesh. They observed a converse correlation between farm size and productivity in Muzaffarpur district. However, in the Ferozpur district, the picture was completely different, as the level of productivity increased with farm size. Several investigations were carried out at a global level to reinvestigate the contrary link between farm area and output. In 1998, Chattopadhyay and Sengupta (1998) made an additional contribution to this ongoing debate through their study of farm-level disaggregated data of West Bengal for the years 1989–1990. The findings suggested that, in contrast to underdeveloped regions, West Bengal's developed regions approved a substantially inverse relation between the size of the farm and the productivity level. The ramification of the Green Revolution on smallholdings in agriculturally developed regions was responsible for this variation. Although he motivated further studies on this ongoing debate across all Indian states, some research was conducted to compare countries to validate the existence of the universal applicability of inverse relationships (Wang et al., 2015).

Review related to the existence of a positive connection between scale of farming and productivity outcomes.

Gradually, studies questioning the universal applicability of the converse correlation between farming area and production level have advocated for a perspective that favours a positive correlation between the two. These studies considered previously neglected factors in measuring farm productivity. Moreover, introducing the Green Revolution further opened the way for researchers to investigate other factors, apart from size, that can affect productivity. The Green Revolution motivated people to shift from labour-intensive production methods to capital-intensive production using

machines (Saini, 1969; Rani, 1971). Punjab was the most prominent state during the Green Revolution; thus, Chadha (1978) tried to explore the presence of a positive correlation between cultivated land and output using an increased capital-labour ratio in three regions of Punjab: Region I (sub-mountainous), Region II (central Punjab), and Region III (cotton belt). He hypothesized that with an increase in the capital- labour ratio, the converse correlation between farm size and productivity would disappear in Region II (Central Punjab). In contrast, Region III (Cotton Belt) is rapidly approaching but still prevails in Region I. Similarly, Bharadwaj (1974) explained the interconnection between farmland and productivity using broad characteristics of the rural market. Productivity is calculated as gross cultivated area per acre rather than net acre. Small farms are productive because of high cropping intensity. Later, researchers stressed numerous other variables that affect productivity besides farm size. Barbier (1984) stressed the use of organization and technical factors to determine employee productivity. Banik (1994) asserted that productivity should be measured while considering the role of water management in a country rather than farm size. Toufique (2005) investigated the parallels between farm size and productivity using labour market institutions. He justified his choice by analyzing the transaction costs of employing labourers in high-potential areas (Madhupur) and low-potential areas (Chandina). In the labour market institution, the transaction cost is lower for large farms because they hire labourers on a task-specific basis and higher for small farms. Key (2018) examined productivity by analyzing total factor productivity (TFP) and the unit costs associated with farms of varying sizes. He suggested that as technology progresses, the growth rate of TFP tends to slow down, and the smallest farms experience the highest unit costs. The concept of economies of size encourages the consolidation of land. However, it is crucial for the government to consider the needs of all societal segments. By focusing more on small farms, their economic sustainability could be enhanced, potentially decelerating consolidation and thereby reducing overall productivity. Conversely, to fully capitalize on technological advancements in agriculture, significant land consolidation would be necessary, which would lead to an increase in TFP rates and a reduction in unit costs.

Review related to a neutral connection exists between farm size and yield

The correlation between area under cultivation and output per acre took a different direction when certain studies conducted worldwide failed to establish either counter or favorable relationship with regard to both. Rao (1967) validated a neutral relationship by analyzing data from six Uttar Pradesh and Punjab villages. As per Farm Management Studies, he found the results differed vastly from the discovery of a converse connection between landholding size and farm output. He stated that if there were no differences in the proportion of areas irrigated, productivity would be constant for all holding size groups. A further addition to the literature supporting the neutral relationship between farm size and productivity was made by Sidhu (1974) by determining the relative efficiency of wheat production on different farm sizes. He found that efficiency difference does not exist between large and small farms.

Review related to a U-shaped relationship between farm size and output

The correlation between cultivated land and output has recently shifted to a U-shaped pattern. Muyanga and Jayne (2019) conducted research in Kenya's farms to ascertain the correspondence between size of farm and productivity level. This study covered a farm size ranging from 0.1 ha to 113 ha. He used three productivity measures: gross production per hectare, gross production minus input cost (including labour per hectare of cultivated land), and total factor productivity. These three productivity measures were found to have a U-shaped relationship between farm size and productivity. An inverse relationship was found between the size of the holdings, which was between 0 and 3 hectares. On the contrary, a noticeable positive association was detected between farmland and yield for areas comprising of 3 to 5 hectares. Farms ranging from 20 to 70 hectares generally exhibited higher productivity than those of 5 hectares.

Expenditure incurred on farm inputs per hectare were on knee high for farms with over 20 hectares of land, whereas they were about 15% higher on farms cultivating less than five hectares. Socioeconomic differences also exist between the sizes of the farms sampled. The head of a household with more than 20 hectares of land has a higher level of education. Most owners of 0-5 hectares were educated up to the primary level, whereas the owners of medium-sized farms were educated till

secondary or higher secondary education. To validate the U-shaped correlation between agricultural acreage and yield forecasted by Muyanga and Jayne (2019), the extension work conducted by Omotilewa et al. (2021) that satisfied the condition of the U-shaped association between size of farm and yield by including medium-sized farms operating up to 40 hectares. Medium-sized farms are divided in the African region into two categories: Stepping Up Medium-sized Farms and Stepping into Medium-sized Farms. Along with this, they used multiple productivity measures. The study's results confirmed the U-shaped relationship between farm size and productivity. The productivity was peaking for small farms, dipped for 5 and 10 hectares, and then receded again for farms between 10 and 20 hectares and then declining beyond 20 hectares. This relationship is validated irrespective of the productivity measurement method. Research conducted in East Africa also demonstrated the U-shaped link between farmland and output (Julien et al., 2021). Likewise, research conducted in Northern China supports this finding with Sheng et al. (2019) through a mild U-shaped pattern in the crop land and output per hectare. Although, the U-shaped connection between agricultural land and output rate requires further validation worldwide. Some research works suggest that this connection rely on the crops being cultivated. The crop-specific farm size productivity analysis showed that the influence of farm size on productivity is different for cereal crops and non-cereal crops (Das, 2021). The relationship between farm size and productivity has attracted particular attention in agricultural economies. Land consolidation policies and land rental markets are decided considering maximum profitability. However, small and large farms have their own importance and contributions. Chand et al. (2011) discussed the superiority of small farms over large farms. In India, small farms are more irrigated, use more fertilizer and HYV seeds, and have higher crop intensity than large farms. This approach helps us reduce land distribution inequity and increases productivity in Indian agriculture. However, the only issue is that an adverse landman ratio that reduces per capita income per person would mean that 62 per cent of Indian farmers having cultivable land less than 0.80 hectares would spend their life in poverty in case they lacked the chance to secure off farm employment opportunities. Deininger et al. (2013) explained the importance of large farms by investigating Ukrainian megafarms and discussing the economies of scale that promote

productivity. In summary, we can say that small farms improve productivity, whereas large farms improve profitability for almost all productivity levels, farms between 20 and 70 hectares are more productive than holdings of 5 hectares.

Review related to farm size and efficiency

Increasing cultivation costs have forced farmers to abandon the agriculture sector. However, unemployment in other sectors will allow them to work in their current sectors. Thus, a majority of the working population in India is still economically occupied in the agricultural sector. They need to follow the survival policy for the fittest. They should be more efficient in avoiding the wastage of resources, controlling the cost of cultivation, and increasing their profit level. In general, efficiency in agriculture refers to increased farm production without increasing input use. Efficiency is a farm-specific concept. Therefore, efficiency must be studied across farm sizes. We should examine input use across farm sizes to determine the efficiency of different farm sizes. The efficiency level is not only farm-specific but also depends on the characteristics of the region under investigation and the availability of farm inputs. Helfand and Levine (2004) studied the link between farm size and its corresponding efficiency in the center of Brazil, which is renowned for its agriculture and has large farms. The study disclosed that efficiency level fluctuated in relation to the association between crop land and efficiency, implying inefficiency initially rises with farm size and then falls with farm size. Large farms' efficiency level is higher due to access to institutional credit and modern inputs. However, if these resources were available to small farms (1-2 hectares) and medium farms (4-10 hectares), then their level of efficiency would be improved. Later, Li et al. (2013) tried to re-examine the relationship between farm size and efficiency and observed that the relationship could be positive, negative, or uncorrelated, depending on how we defined the efficiency. We must explore technical, economic, and allocative efficiencies across farm sizes to find the best possible use of agricultural inputs. They estimated the relationship between farm size and efficiency across farm sizes for maize production in the South African province of Cape East, considering technical, economic, and allocative efficiencies. They estimated that technical efficiency was influenced by gender, marital status, education, credit, experience, and farm size.

Cost efficiency depends on association membership, credit access, and occupation. The last type of efficiency—economic efficiency—was positively dependent on farm size, education, and experience and negatively affected by the marital status of the cultivator. Identifying the factors influencing technical, cost, and economic efficiencies is essential to improve overall efficiency. Therefore, it is a matter of discussion for policymakers and extension agents. A similar study was conducted in India by Manjunatha et al. (2013) to identify the factors influencing the efficiency level and experienced land fragmentation as the leading cause of inefficiency in India. However, efficiency increased with land ownership and crop diversity. In addition, efficiency is associated with farm size because farm inputs are more efficient in large farms in India than in small farms. This fact was further supported by Pal and Chakraborty (2020), who studied farm size and technical efficiency and found that farm size is an essential factor in determining efficiency; however, along with size, variations in efficiency also depend on the area under irrigation. Therefore, there is always scope for improvement in efficiency for all farm size categories through improvements in irrigation facilities. Using the physical and financial ratio, Dutta and Bhuyan (2019) compared the efficiency level across farm sizes in Assam. They predicted that overall efficiency generally declined with the increase in cultivated land, when farm sizes were assessed based on the physical ratio measures such as yield per hectare, production efficiency, person-day per hectare, and machine day per hectare. In contrast, financial ratio measures like profit per hectare, overhead charge, and operating ratios are more promising in large and small farms. Medium-sized farms can be the most efficient farm size category in maintaining a proper liquidity position. Several research works conducted worldwide found the role of socio-economic characteristics in determining efficiency. These studies found specific socio-economic characteristics positively related to efficiency, like farm size, experience, education level, farm machinery ownership, institutional credit availability, extension services, and off-farm income. It has been negatively associated with land fragmentation, age at the family head, diversification index, and abiotic stress (Reddy & Sen, 2004; Hashmi et al., 2016; Singh et al., 2017). Measuring efficiency is a challenging task in itself. We frequently lead to false conclusions regarding farm efficiency, as the farm production process deals with a

number of farm inputs that need to amalgamate in different portions. The practical challenges in assessing agricultural efficiency and contrasting farm sizes were examined using FMS data. They suggested that one should be careful when interpreting the connection between size and efficiency. Additionally, they stressed that we should not consider that enlarging a farm will necessarily inflate its efficiency. It is the dexterity of individual farmers to handle different farm sizes that matter. Researchers also attempted various structural dimensions and research methodologies to estimate efficiency across farm sizes. Garcia et al. (1982) determined economic efficiency using two structural dimensions—the size of operations and the level of land ownership of the farm operator. They predicted that as farms grow into larger categories, possibly increasing farmer income, but it does not undermine overall economic efficiency in society. The role of land tenure in terms of short-term profit maximization behaviour is also verified. It appears that tenure has a substantial role in deciding profitability for short-run. The operator's land ownership level was inversely related to profit maximization in short-run for the sample under observation. Bagi (1982) utilized stochastic frontier production function and the maximum likelihood method to understand the connection between size of farm and the efficiency level. He collected a sample of 193 West Tennessee farms and divided them into crop and mixed farms. Subsequently, he subdivided farms into small and large groups based on acreage and sales value. He suggested that the level of technical efficiency appears to be approximately equal in large and small farms. However, large mixed farms have a slightly greater technical efficiency than small mixed farms. Masterson (2007) used parametric and non-parametric- analyses to derive efficiency measures while estimating the relationship between farm size, productivity, and technical efficiency in 8131 representative Paraguayan households. The results were inconsistent with those of previous studies. He predicted from a non- parametric technical efficiency measure that efficiency would decline with the farms' size but increase for larger farms. Yan et al. (2018) studied the link between size of farm and production efficiency using output and profit determinants. A one-step stochastic frontier analysis (SFA) model is used to estimate the optimal size of land to achieve the efficiency of agricultural production in China. They estimated in China that output efficiency followed an inverted U-shaped trend with farm size, while

profit efficiency showed a U-shaped trend. Apart from farm and socio-economic characteristics, it was observed that the level of efficiency was also influenced by the land and agriculture policies adopted in the country (Elahi et al., 2020; Gulati et al., 2021). The literature was further enriched by discussing potential yields and yield gap comparisons across farm sizes to deal with the target of increasing farmers' income and yield per hectare. Pushpa and Srivastava (2014) studied rain-fed regions in eastern Uttar Pradesh to analyze yield gap and the factors influencing these analysis gaps for the crop's paddy, wheat, and sugarcane, utilizing multivariate regression analysis and yield gap index across different farm sizes. They found that the yield gap was maximum for small and marginal farms and minimum for large farms. The same results were validated with the yield gap analysis of wheat in the Amravati district of Maharashtra. They found that small farms have a more significant yield gap than medium and large farms due to economic conditions and unawareness. However, it is possible to reduce the yield gap by reducing input utilization gaps. In addition, farmers need to be educated about the benefits of using the recommended input level. Singh et al. (2019) gathered plot-level data obtained through the "Comprehensive Scheme for Cost of Cultivation (CCS) of Principal Crops" which was provided by the Directorate of Economics and Statistics from the Ministry of Agriculture for central cotton cultivation states. Data Envelopment Analysis (DEA) used to ascertain efficiency across farm sizes in different cotton-producing districts in India. They found a gap in the yield of cotton crops of approximately 851 kg/ha at the countrywide. Gujarat and Maharashtra are the two states with the maximum yield gap. Madhya Pradesh, on the contrary has the lowest yield gap. To identify areas where we can increase our yield by efficiently applying our resources, the idea of the yield gap needs to be explored.

Review related with Farm size and profitability

Net farm income should be positive to predict farmers' stability in the agriculture sector. While analysing farm management, Briggeman and Boehlje (2009) stated that cash may be the king in the short term; profitability is essential for long-term survival and growth. Therefore, the analysis of profitability and income should be at the heart of agricultural holding managers because these are the keys to the management,

maintenance and growth of the Kingdom. In addition to the inconclusive association between size of farm and productivity, measuring profitability and factors promoting profitability are challenging. At the outset, the correlation between farm size and profitability was explored, and it discovered that that raising input prices and free trade are huge problems for marginal and small farmers in the agricultural sector. Mottaleb and Mohanty (2014) investigated how skyrocketing farm inputs prices affected Bangladeshi farmers 'profitability the effect of increasing input prices on farmers' profitability across farm sizes. For the past ten years, small farms have transformed into unprofitable; the cost of cultivation one acre of rice has escalated around 170 per cent for small farm size category and just 91 per cent for large farms. Government also introduced cash subsidies and direct benefit transfers to address these problems. Furthermore, free trade has created issues for small and marginal farmers. Reddy (2003) explained the state of free world trade based on WTO rules through Fiji's sugar industry and suggested that farmers could increase their profits by controlling factors such as agricultural efficiency and productivity and by using optimal input levels because the concept of Subsidies would not exist shortly and output prices would be beyond farmers' control. However, free trade and higher input prices impact small farmers more than large ones. It has increased distress for small and marginal peasants. Due to their debts, they are forced to commit suicide or abandon agriculture by selling their land (Singh & Bhogal, 2014). As farms get larger, output per hectare decreases. Farm income variance declines with farm size, whereas local food production increases. It has proved that farmers benefit from larger farms and earn higher and more stable incomes, whereas consumers suffer from lower and more volatile food supply. Apart from farm size, other factors underlie the low level of profitability in the agricultural sector. The main reason for this is the cropping pattern. Most farmers followed a mono-cropping pattern to ensure returns through minimum support prices (MSP). It was observed that profitability levels changed with crop changes (Shergill, 2005). The cropping pattern also influences by farm size, as most small farmers prefer to grow more vegetables than medium and large farmers. Vegetables are short-lived crops that increase the cropping intensity of small and marginal farmers, thereby increasing their per-acre farm income. Likewise, minor crops' profitability is higher than major crops. However,

major crops' profitability has shown more stability, and farmers prefer to grow major crops to avoid fluctuations in returns (Abro & Awan, 2020). Certain other constraints are major contributors toward lower-level profitability, such as inappropriate fixed resource utilization, lack of better management practices, and overpayment of factor inputs. A comparison between low-profitable farms and higher-profitable farms was conducted by Bhoi et al. (2017) and Ibendahl (2015), who suggested that productivity and investment in machinery per acre are the main contributors to higher profitability. It was observed that the most profitable farms had the best farmland that could be used intensively. Using farmland more intensively requires more machinery investments than land that was farmed less intensively. Although the most profitable farms have more equipment value per acre and a higher depreciation cost, they still spend less on machinery and equipment than the least profitable farms. The most profitable farms had the lowest machinery ratio to total crop costs. In addition, it was found that deciding whether a farm is profitable or not is also challenging. Thus, different studies have mentioned different methods to measure farm profitability. Ibendahl (2016) attempted to correlate the viability of solvency ratios for predicting operational profitability. The solvency ratio uses net operating income minus the debt-to-assets ratio based on balance sheets. It makes the solvency ratio a preferred method for measuring future farm performance. However, net farm income and EBITA (Earnings before interest, taxes, and amortization) are preferred when calculating profitability. Langemeier and Shockley (2019) proposed an operating profit margin ratio to compute farm profitability. The operating profit margin ratio is computed by adding interest expense, subtracting operator and family labour from net farm income, and dividing the result by the value of farm production. No matter how profitability is calculated, agriculture is unpredictable by nature, which results in the non-stability of farmers' income. On the one hand, input prices have been increasing day by day, but on the other hand, output prices remain constant. Thus, we must identify the factors that promote profitability and those that negatively affect profitability. Hyde et al. (2008) supported the inclusion of human resources management (HRM) measurement models to explain agricultural profitability. They used the Return on Asset (ROA) model to analyze variables that strongly affect farm profitability and the Return on Equity (ROE) model to study some statistically

significant variables that negatively affect profitability. Sharma (2016) studied the feasibility of contract farming practices for different groups of farmers and found that participation was mostly among medium-sized and relatively large farmers compared to small farmers. The government should encourage the participation of small farmers in contract farming. It helps farmers increase their incomes. The average overall wealth index for contract farmers is 1.31, and that for non-contract farmers is 0.96. Mishra et al. (1999) investigated the factors affecting the profitability of limited resources and other small farms. Their results indicate that the profitability of holdings of limited resources depends on the factors such as the operator's age, soil productivity, debt-to-asset ratio, and the ratio of variable and fixed production costs relative to the agricultural output. For other small landholding, profitability is related to the other small holdings depends on the operator's age, farm size, diversification of activities, and crop insurance. Additionally, one significant factor contributing to variations in performance across both limited resource and other small farms is the ratio of variable costs to the value of agricultural production. Furthermore, several studies published across the world have been conducted to understand the factors affecting profitability like farm size, Government policies, climate change, input use, socio-economic characteristics, marketing strategies, and source of credit (Masuku & Xaba, 2013; Lososova & Zdenek, 2014; Tey & Brindal, 2014). Mugula et al. (2023) proposed Sustainable Agricultural Practices (SAPs) as a practical means of addressing the issues of profitability and soil fertility. However, government assistance is needed to implement SAP practices properly. Financial institutions should be opened up to finance expenditure on SAP practices that include expensive agricultural inputs beyond the reach of smallholder funds. In Nut Shell, farm profitability depends on cooperation between farming communities and the government.

1.6 Research Gap

A limited number of research available on how area under cultivation is linked to productivity, and profitability. This study is important as it explores these associations particularly in Punjab, India's most agriculturally advanced state. The study's results help to know the how agricultural land influences both productivity

and profitability. Furthermore, it could guide policymakers to achieve the target of food security, rural livelihood, and economic stability through the formulation of policies of subsidies and direct benefit transfers. This study is also important in providing information about which farm size follows sustainable practices through the study of input use, cropping patterns, and farming practices. It also provides a valuable informative material for researchers and academicians on the association between agricultural acreage, output rate, and return on costs. Thus, the current study intends to narrow the gaps presented in the previous studies and assist as a reference for future studies.

1.7 Research Questions

1. What is the relationship between farm size and productivity across different Agro-climatic zones in Punjab?
2. How does the cost of cultivation vary across different farm size categories in Punjab, and what are the implications for farm profitability?
3. To what extent do input use patterns (e.g., seed, fertilizers, machinery) differ across landholding sizes, and how do they affect per hectare profitability?
4. What socio-economic characteristics (such as education, access to machinery, cropping intensity) influence productivity and profitability at different farm sizes?
5. Is there a statistically significant relationship between land fragmentation and profitability across landholding sizes in Punjab agriculture?
6. Which factors of production (e.g., cropping intensity, irrigation cost, leased land cost) have the most significant impact on per hectare profitability, and how do these vary with farm size?

1.8 Research Objectives

The main objective of this study is to investigate the relationship between farm size, productivity, and profitability in Punjab agriculture. The specific objectives of the study are:

1. To examine the Socio-economic characteristics across land holding size in the state of Punjab.
2. To estimate the input use and cost of production across farm size.
3. To Analyze the relationship between farm size, productivity, and profitability.
4. To determine the factor of production and profitability.

1.9 Research Hypotheses

In order to explore the relationship between farm size, productivity, and profitability and how it links to parameters like socio-economic characteristics and, input use, cost of cultivation in Punjab state, the following null- hypotheses were formulated:

1. Socio-economic characteristics have no impact on landholding sizes.
2. There is no significant relationship between Input use and cost of production across farm sizes.
3. The farm size has no significant impact on productivity and profitability.
4. The factors of production have no significant impact on profitability.

1.10 Data base and Methodology

Sampling Procedure

As per the NSSO guidelines, A multi-stage stratified random sampling strategy was used to divide the population of Punjab into three strata, referred to as agro-climatic zones. These zones are: the Paddy/Maize-Wheat Zone (Zone 1), the Paddy-Wheat Crop Zone (Zone 2), and the Cotton/Paddy-Wheat Crop Zone (Zone 3). Districts were selected based on their geographical location to represent each zone. Three districts were randomly chosen from Zones 1 and 2, while two districts were selected from Zone 3. Similarly, villages were randomly selected within these districts to ensure representation. Both districts and villages were chosen randomly to guarantee that every unit in the population had a known and equal chance of selection. Furthermore, probability-based selection is necessary for statistical inference, helping the estimation of sampling variance, standard errors, and confidence intervals.

These statistical measures assist the generalization of findings from the sample to the entire population. Data were collected from all five landholding size categories.(Marginal, Small, Semi-Medium, Medium, and Large) to make sure that farms of every size were represented.

Table 1.2: Selection Procedure between Zones, Districts, and Villages.

S.NO	Zone	Districts	Villages
1	Paddy/ Maize-Wheat (Zone 1)	Amritsar, Gurdaspur, and Patiala	Jandiala guru, Dorangla, Kami Kalan
2	Paddy-Wheat (Zone 2)	Jalandhar, Ludhiana and Sangrur	Ishaewal, Jodhan, Ubawal
3	Cotton/Paddy-Wheat (Zone 3)	Bathinda and Mansa	Tungwali, Matti

Source: Author's Estimation

The total landholding of the state is 1092754 as per the Agriculture Census 2015. However, in order to calculate a farm level characteristic like cost of cultivation, productivity, and profitability the census does not need and requires only a sampling. In case if the population is very large, the sample size should be depended upon desired precision and confidence level. Cochran's Sample Size Formula is used when the population is large for estimating means under simple random sampling (SRS).

Cochran's Sample Size Formula

For large populations:

$$n_0 = \frac{Z^2 \cdot p(1 - p)}{e^2}$$

Where:

- n_0 = required sample size
- Z = z-value for desired confidence level (1.96 for 95%)

- p = estimated proportion of the population (0.5 gives maximum sample size)
- e = desired margin of error(0.05)

$$n_0 = \frac{1.96^2 \cdot 0.5(1 - 0.5)}{0.05^2}$$

$$n_0 = 384.16$$

Therefore, as long as population is large on average 385 sample is required for 95% confidence with $\pm 5\%$ precision. It should be noted that in our research work, we need to use **Cochran's corrected sample size** as the population size N is known.

Cochran's corrected sample size:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

where $N = 1,092,754$ and $n_0 = 385$

$$n \approx 383.65$$

Since the population is very large and our corrected sample is almost same due to small effect of Finite Population character. However, 385 is not our sample size as we followed NSSO guidelines, and the NSSO use stratified and clustered sampling design instead of simple random sampling that increase the chance of sampling variance, so the sample size must be increased using adjustment for **Design Effect(DEFF)**. $DEFF > 1$ is usually considered and NSSO uses $DEFF = 1.06$ for agricultural survey which is a modest value. Therefore, the sample size after adjustment is :

$$n_{\text{deff}} = n \times DEFF$$

$$n_{\text{deff}} = 384.85 \times 1.06 = 407.94 \approx 408$$

Thus, our sample size is 408 for our research work.

Since the landholdings in Punjab are not evenly distributed among five landholding size classes. Therefore, NSSO does not follow proportional allocation strategy to avoid the problems like unstable estimations, confidence intervals turned too wide, regression analysis would lose its reliability, and meaningless comparison across farm sizes. Therefore, approximately equal allocation is used which is calculated as follows :

$$n_h \approx \frac{n}{H}$$

where n= 408(Sample Size) and H= 5(Number of categories of farm sizes in Punjab) Substitute:

$$\frac{408}{5} = 81.6$$

Thus, after round off and adjusting zone wise. We found sample size for Marginal farms=82, Small=80, Semi-Medium=83, Medium=82, and Large= 81. In addition, every landholding size is split across three zones by dividing its total sample into roughly three equal parts, adjusting for zone population share, and ensuring each zone gets at least 20–30 samples so the estimates remain reliable.

Table 1.3 Sample size Distribution

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	30	29	31	30	30
2	30	29	30	30	28
3	22	22	22	22	23
Total	82	80	83	82	81

Source: Author's Estimation

Use of weights

In order to generalize the results to the entire population, we have followed the NSSO

method and used weights. This not only helps convert sample data into population-level estimates but also addresses non-response, ensures unbiased estimates of cost and productivity, and corrects for unequal selection probabilities.

A detailed explanation of the above procedure is as follows:

Step 1: Ascertain population totals (e.g., landholdings by size class in Punjab)

As NSSO links probabilities with the actual population size of groups (zones, size classes), we use the population of landholdings across each category from each zone using data from the Agriculture Census 2015–16.

Table 1.4: Total number of landholdings in each size group across three zones in Punjab.

Zone	Marginal	Small	Semi-Medium	Medium	Large	All Holdings
1	87043	110846	168223	118015	18659	502786
2	37529	53711	114976	103827	20941	330984
3	29845	42919	84739	83378	18103	258984
Total	154417	207476	367938	305220	57703	1092754

Source: Agriculture Census 2015-16

Step 2: Allocate sample to strata (Zones) using probability

Since each agro-climatic zone has different number of villages, different numbers of marginal, small, medium, and large landholdings, and distinct cropping patterns etc. Therefore, NSSO uses zone-wise probability distribution to avoid the problem of biased sampling.

Formula used by NSSO to calculate zone wise distribution:

for each landholding size class h (Marginal, Small, etc.) and for each zone z (1, 2, 3), the zone-wise probability is:

$$P_{hz} = \frac{N_{hz}}{\sum_z N_{hz}}$$

Where:

- N_{hz} = number of operational holdings of size class h in zone z
- $\sum_z N_{hz}$ = total number of holdings of that size class in Punjab

This gives the proportion (probability) of that size class belonging to each zone.

Table 1.5 Zone Wise Probability Distribution

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	0.56	0.53	0.46	0.39	0.32
2	0.24	0.26	0.31	0.34	0.36
3	0.19	0.21	0.23	0.27	0.31
Total	0.99	1	1	1	0.99

Source: Author's Estimation

Step 3: Allocate sample to strata (Size-group) using probability

NSSO uses size-group probability distributions to make sure that each farm-size class receives a minimum adequate sample, balanced representation, and statistically reliable estimates for every landholding class, regardless of their population share.

Method to calculate:

1. Step 1: Count holdings in each size class within each zone: N_{hz}
2. Step 2: Compute column totals for each size class: $\sum_z N_{hz}$
3. Step 3: Apply the formula:

$$P_{hz} = \frac{N_{hz}}{\sum_z N_{hz}}$$

4. Step 4: Multiply these probabilities with class sample sizes:

$$n_{hz} = n_h \times P_{hz}$$

5. Step 5: Round to integers to get final zone-wise allocation.

Where:

- N_{hz} = number of operational holdings of size group h in zone z
- $\sum_{z=1}^Z N_{hz}$ = total holdings of size group h in all zones
- P_{hz} = probability that a holding of size group h belongs to zone z
- Z = total number of zones (3 in your case)

Table 1.6 Size Group Probability Distribution

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	0.17	0.22	0.33	0.23	0.04
2	0.11	0.16	0.35	0.31	0.06
3	0.12	0.17	0.33	0.32	0.07

Source: Author's Estimation

Step 4: Calculation of Combined Probability

After calculating sample and zone probability scores, NSSO calculates combined probability as sample must be allocated jointly across zones and size classes.

Method:

- **Zone proportion:** $P_z = \frac{N_z}{N}$
- **Size group proportion:** $P_h = \frac{N_h}{N}$

NSSO combines them to obtain the **stratum-level probability**:

$$P_{hz} = P_z \times P_h$$

Table 1.7 Combined Probability

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	0.098	0.118	0.153	0.091	0.012
2	0.028	0.042	0.109	0.107	0.023
3	0.022	0.034	0.075	0.088	0.022
Total	0.1	0.2	0.3	0.3	0.1

Source: Author's Estimation

This entire procedure of allocating weights has helped the study to give representation to the total households in each strata and sub-strata. Table 1.7 is the representation of the study sample as per the weights.

Step 5: Assigning Weights

NSSO assigns weights because the sample does not represent the population in the same proportion. Moreover, because the sample is not proportional to population and some size groups are over-represented and some under-represented in the sample which is corrected through weights to get the results which represent the true population.

$$\text{Weight} = \frac{\text{Total population in that group}}{\text{Sample selected from that group}}$$

In order to compensate for mismatch between the planned and achieved sample, non-response, and sampling deviation, we prefer to use correction factor.

In present, we used NSSO methodology to find out correction factor

NSSO uses the Kish–Hansen adjustment for multi-stage sampling:

$$\text{Correction Factor} = \sqrt{1 - f}$$

where:

$$f = \frac{n}{N}$$

And

- **n = number of selected villages (FSUs) in the zone**
- **N = total number of villages in the zone (as per the frame, e.g., Agriculture Census)**

So the full formula is:

$$\text{Correction Factor}_z = \sqrt{1 - \frac{\text{Selected villages}_z}{\text{Total villages}_z}}$$

from the NSSO manuals $f=10\%$

Therefore=

$$\text{Correction Factor}_z = \sqrt{1 - 0.1} = 0.9487$$

Therefore, Total landholding numbers after using correction factor is =1092754 *0.9487= 1036696. We need to calculate Total weight= Combined Probability X Total landholdings after applying correction factor (1036696)

Table 1.8: Total weight after applying correction factor on landholding size

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	101,167	122,107	158,586	94,087	12,441
2	28,568	43,551	112,534	110,625	23,803
3	23,090	35,539	78,121	91,173	22,734

$$\text{Final Weight} = \frac{\text{Total Weight}}{\text{Sample selected from that group}}$$

Table 1.9 Final Weight for each landholding

Zone	Marginal	Small	Semi-Medium	Medium	Large
1	3372.2	4210.6	5115.7	3136.2	414.7
2	952.3	1501.8	3751.1	3687.5	850.1
3	1049.6	1615.4	3551.0	4144.2	988.4

Source: Author's Estimation

Table 1.5 shows that that the sample of 30 represents 3372 marginal households in zone 1. Similarly, 30 marginal sampled households in zone 2 represent 952 households and 22 sampled marginal household in zone 3 represent 1049 households.

1.11 Research Instrument

We adopted the modified version of questionnaire used by the National Sample Survey Organization (NSSO) to collect the data for their plot-wise data survey. The modifications were done as per our research objectives.

1.12 Tools for Data Analysis objective wise

This chapter is a brief introduction to statistical tools that were used objectively. However, a detailed analysis of these tools is given in the concerned chapters.

1. To examine the Socio-economic characteristics across land holding size in the state of Punjab.

Statistics Tools adopted

Descriptive statistics was used to summarize the Socioeconomic characteristics. In our current objective, we used frequency and percentage. Frequency is a descriptive statistics tool that helps produce an efficient counting summary of a sample of data points for ease of interpretation. Cooksey (2020) states that frequency tabulation occurs in two stages; in the beginning, the scores in a data set are ranked in increasing order. Furthermore, the number of times each specific score occurs in the sample is counted for that specific value. On the other hand, percentage is relatively more straightforward than frequencies because we include the aggregate number of scores while computing the values in percentage.

2. To estimate the input use and cost of production across farm size.

Statistics Tools adopted

We used descriptive statistics to explain the data set in depth. The main descriptive statistics tools we used to describe our data were Mean, Minimum, Maximum, Standard Deviation and Coefficient of Variation. Mean is the measure of central tendency, which refers to the sum of all the scores divided by the number of scores. Extreme variables may influence the mean (Ali & Bhaskar, 2016). Furthermore, minimum and maximum statistical tools were used to determine the variation among the different variables' landholding sizes. Lastly, Standard Deviation and Coefficient of Variation are used. In order to compare variation within a single dataset, we used Standard Deviation. However, to compare the variation among landholding sizes, we used the coefficient

of variance because comparing two different landholding groups is not possible with the help of Standard Deviation (Valchanov, 2024).

3. To Analyze the relationship between Farm size, productivity, and profitability

Statistics Tools adopted

In order to explore the relationship between farm size, productivity, and profitability, we used one-way ANOVA to analyse whether the difference between the means of two or more groups is statistically significant. (Kim, 2017). On the other hand, we used a post hoc test after a statistically significant result in our ANOVA test, and it was used to determine where our difference came from (Prasad et al., 2023).

4. To determine the factor of production and profitability.

Statistical Tools adopted

Multiple regression is used to identify the factor of production and profitability, which involves the Pearson correlation coefficient and regression analysis.

1.13 Study Structure

The present research work is organized into six different chapters. The first chapter is dedicated to the background of the study, literature review, research objectives, research gap, study needs, database, and methodology. In the second chapter, the first objective of our study is discussed, which deals with examining the socio-economic characteristics of farmers across landholding sizes in Punjab. The third chapter explained the input use, cost of cultivation, and output across the size of landholding. The fourth chapter demonstrated the relationship between farm size, productivity, and profitability across the landholding sizes. The fifth chapter determined the factors of production and profitability. The sixth chapter of the thesis focused on conclusions and suggestions for improving productivity and profitability across landholding sizes. The last chapter included the references and annexure.

CHAPTER II

SOCIO-ECONOMIC TRAITS OF FARMERS OVER FARM SIZES IN PUNJAB

2.1 Introduction

Punjab is considered the pinnacle agrarian state within India in terms of stocking the food granary of the country. Comprising a mere 1.53 per cent landmass, it provides a substantial 21 and 31 per cent rice and wheat production, respectively, towards India's total food basket (Economic and Statistical Organisation, 2022). The utmost reason behind this enormous contribution from a small state like Punjab is the rapid diffusion of the Green Revolution technology over the rest of the Indian states (Kohli & Singh, 1977). However, it is observed from the State Domestic Gross Product that over time, the share of the agriculture sector has been declining continuously (Directorate of Statistics, 2023). Growth and development in economics are indicative of the structural transition to the service sector from the agriculture sector, the leading impact this transition being on the labour force. In the case of Punjab, this structural transformation resulted in a crisis in the agriculture sector that has forced the migration of the farmers from the agriculture sector to other sectors to seek better employment opportunities (Singh, 2000). Farmers that do leave agriculture, citing better employment opportunities, typically come from the marginal and smaller segments of landholding sizes (Singh, 2012). Farmers belonging to the large landholding size group are not affected by the prevailing agricultural crisis. However, they diversified their economic portfolio for better earnings through investment in grain mandis, emigration to foreign countries, and other urban business activities (Sinha, 2019). Changes in ownership and the use of land can be attributed to the migration of farmers. The small farmers have let out their lands to large farmers, which further increased their land holdings (Singh & Sekhon, 2018). The application of reverse tenancy practices in Punjab influenced the average size of operational holdings. In Punjab, 33 per cent of the total operational holdings is attributed to

medium and large land holdings, whereas the national average is 5 per cent. The share of small and marginal landholdings in total operational holdings is 33 percent in Punjab, in contrast to the national average, which is 86 per cent of total operational holdings (Ministry of Agriculture & Farmers Welfare, 2020).

The increased landholding sizes further promoted mechanization in state agriculture (Bansal, 2020). The mechanization of Punjab agriculture is the reason behind the increased per-hectare production and productivity of different crops, as farmers can finish their farming operations on time. It further escalates the cropping intensity and efficient utilization of various farm inputs (Dhiman & Dhiman, 2015; Guleria et al., 2022). On the contrary, farm mechanization in Punjab led to mono-cropping farming practices, with farmers cultivating only rice and wheat for higher and guaranteed income through the Minimum Support Price (Singh, 2021; Rani et al., 2021). The rice-wheat cropping pattern in Punjab has created immense environment-related issues along with the increased cost of cultivation, which reduced the farmers' profitability and sustainability, particularly for small and marginal farmers (Chand & Haque, 1998; Kumar et al., 2014; Mann, 2017). For the guarantee of Minimum Support Price (MSP), small and marginal farmers follow mono-cropping practices that are inefficient for them and put them into the clutches of debt. They either follow the path of lowering the number of labour or commit suicide due to the debt cycle on them (Singh et al., 2014).

The above-described socio-economic problems prevailing in the Punjab agriculture sector made it imperative to examine socio-economic characteristics in order to obtain a detailed picture of farmers of all farm sizes. Therefore, while exploring the relationship between farm size, productivity, and profitability in Punjab agriculture, we set our first study objective to analyse socio-economic characteristics across Punjab land sizes.

2.2 Literature Review

The literature on Punjab's economy mainly focuses on the state's agrarian system. Punjab is naturally endowed with perennial rivers, vast pieces of plain land, and one of the most hardworking communities of Sikhs. To achieve this objective, the

literature was reviewed thematically. At the outset, technological dissemination was addressed, which led to diminishing returns. The second set of papers reviewed the debt trap derived from the ill effects of the —Green Revolution. Finally, the issue of crop diversification was examined to understand why farmers practice monocropping and the possible effect of crop diversification on their income.

After India's independence, Punjab's geographical location was ranked as the best for agricultural infrastructure development programs. For example, the Bhakhra Nangal Dam and Green Revolution projects were initiated in Punjab (Bhalla & Mellor, 1995; Kohli & Singh, 1977). Owing to the success of these projects, Punjab is now known across India for its agricultural growth and development (Randhawa, 1974). However, it increased distress among specific landholding sizes. Farmers who could afford modern farming continued, and the rest were forced to depart (Pinstrup-Andersen & Hazell, 1985). Depeasantization has escalated among small and marginal farmers, making large farmers more prosperous and affluent by doubling their production and profitability (Chadha & Bhalla, 1982; Dhanagare, 1988). With the advent of the New Economic Policy of 1991, agricultural issues prevailing in the state were further escalated by marginalizing the role of the state vis-à-vis agriculture. It reduced subsidies and other incentives for farmers who needed to participate in global competition (Krishnaswamy, 1994; Thamarajakshi, 1999; Narayanan, 2003). The reduction of subsidies increased farm input prices, resulting in farmers needing to take on debt from institutional and non-institutional sources to meet their needs. This has caused suicides to increase in the small and marginal farmer categories, as agriculture is a risky profession where yield and profit are uncertain (Gill & Singh, 2006; Satish, 2006).

In Punjab, the distressed farmers and the environment were miserable during the post-Green Revolution period. The introduction of the *Minimum Support Price (MSP)* to promote cereal crops such as rice and wheat has lowered the crop diversification index. Monocropping practices have undoubtedly increased the specialization of Punjab farmers in growing wheat and rice. However, this decreased the soil nutrients, and farmers had to spend more on fertilizers. The state's water table has decreased to an alarming level, and the state's productivity has become stagnant (Dutta, 2012;

Bhullar & Mohan, 2015). The Punjab government is now trying to replenish the losses created by the monocropping pattern in Punjab. Crop diversification has been promoted through contract farming (Kaur et al., 2021) and buying crops other than rice and wheat, such as moong, from farmers at a minimum support price (MSP). The government has been trying its best to promote crop diversification and crop management practices through promotional schemes and extension services in partnership with the Punjab Agriculture University. Different components of socioeconomic characteristics determine the adoption of crop diversification, crop management, and extension practices (Makate et al., 2016). Globally, these practices indicate the impact of socioeconomic traits, particularly farmers' age, experience, landholding status, farm size, access to credit, time worked per day, non-farm income, perception of climatic change risks, and discussions and exchanging information among co-farmers (Rehima et al., 2013; Pham & Smith, 2014; Kabir & Rainis, 2015; Komba & Muchapondwa, 2015; Bedeke et al., 2018; Bakhsh & Kamran, 2019; Maya et al., 2019). The importance of socioeconomic characteristics in India cannot be discredited, as they ultimately determine the cropping practices of farmers (Kusnandar et al., 2019; Sambasivam et al., 2020; Jha & Gupta, 2021; Singh et al., 2023). In addition to socio-economic traits, regional diversity is essential for India to adopt crop diversification, climate change technology, and farming methods (Neogi & Ghosh, 2022).

At the Punjab level, there is an urgent need to evaluate the socioeconomic traits that affect the promotion of crop diversification, crop management and extension services, and climate change strategies because Punjab is a strategic state from an agricultural viewpoint. The adoption of crop diversification is positively related to the adoption of contract farming, accessibility of markets and roads, and education level of the Punjab farmers, whereas excessive use of fertilizer, the intensity of irrigation, and rainfall harm crop diversification (Sajjad & Prasad, 2014; Singh, 2000). Crop management practices help improve farm crop growth, development, and yield. Factors such as a farmer's age, media exposure, socioeconomic status, on-site training, farm size, and the gross value of crops directly affect the approval of crop management and extension services.

2.3 Methodology

The data for this objective was taken from the research instrument. The first part of the questionnaire had a demographic profile of the respondents. The variables chosen are

1. **Social Components:** To understand the social conditions of Punjab farmers, we have selected specific social characteristics such as the farmer's age, education, family size, dependence status, gender, and marital status.
2. **Economic Components:** Land ownership, gross cropped area, net cropped area, agricultural tools and implements stock, and livestock stock help study farmers' economic conditions.

Descriptive Statistics

The count and percentage of these variables have been calculated to get an overview of the respondents.

Dependency Ratio: The dependency ratio is calculated to know about the dependency level on the head.

$$\text{Dependency Ratio} = \frac{\frac{\text{Total number of Dependents}}{\text{Non-earner family members}}}{\frac{\text{Total number of Independent}}{\text{Earner family member}}}$$

2.4 Results and Discussions

2.4.1 Social Status of farmers across landholding size

In this section, we analyzed the social components of the farming community of the state of Punjab. Our primary aim was to know about the social differences of farmers across landholding sizes. This section's results helped us find out the social characteristics of farmers across landholding sizes in the sample taken. The main social components we included in our study are as follows:

1. Age Group

Age group is a significant factor in understanding the agricultural conditions of the state (Tauer, 1984). The states having the maximum proportion of the economically active group of farmers have a greater chance of adopting modern farming practices

and vice versa (Tauer, 1995). The age group helps to understand the agricultural universities' decision about the segmentation of farmers while imparting training to them. They choose a segment of farmers as per their targets (Zhang et al., 2023).

Table 2.1: Distribution of respondents by age groups across landholding sizes

Sampled Data						
Size group	Particulars	<25 years	25-40 years	40-60 years	>60 years	Overall
Marginal	Freq	6521	21302	74479	50524	152826
	%	4.27	13.94	48.73	33.06	100
Small	Frequency	0	28331	84064	88803	201198
	%	0	14.08	41.78	44.14	100
Semi-Medium	Frequency	5116	57995	183738	102393	349241
	%	1.46	16.61	52.61	29.32	100
Medium	Frequency	3136	95953	155016	41779	295885
	%	1.06	32.43	52.39	14.12	100
Large	Frequency	0	18206	35022	5751	58979
	%	0	30.87	59.38	9.75	100
Overall	Frequency	14773	221788	532320	289249	1058128
	%	1.4	20.96	50.31	27.34	100
Weighted Data						
Marginal	Freq	6521	21302	74479	50524	152826
	%	4.27	13.94	48.73	33.06	100
Small	Frequency	0	28331	84064	88803	201198
	%	0	14.08	41.78	44.14	100

Semi-Medium	Frequency	5116	57995	183738	102393	349241
	%	1.46	16.61	52.61	29.32	100
Medium	Frequency	3136	95953	155016	41779	295885
	%	1.06	32.43	52.39	14.12	100
Large	Frequency	0	18206	35022	5751	58979
	%	0	30.87	59.38	9.75	100
Overall	Frequency	14773	221788	532320	289249	1058128
	%	1.4	20.96	50.31	27.34	100

Source: Estimates based on primary survey data 2022-23.

Table 2.1 showcases the farmers with various landholding sizes as per their age. This study has categorized the farmers into four age cohorts. The maximum number of farmers across all landholding sizes fall in the 40-60 years cohort. The percentage ranges from 48.73 per cent for marginal farmers to 59.38 per cent for large farmers, which indicates that middle-aged farmers dominate Punjab agriculture. This study also confirms the findings of other scholars regarding the disinterest of youth in farming activities (Singh & Kahlon, 2016). Farmers under the age of 25 years constitute only 1.4 percent of Punjab's farming population. The highest presence of youth farmers (<25) was shown by the marginal group at 4.27 per cent, whereas it was completely absent in small and large landholding groups. The trend of migration among the rural youth is very high, which translates to zero young farmers in small and large landholding segments. However, official records are unavailable regarding individuals who have emigrated from India annually for further education and employment prospects within the age bracket of less than 25. The latest study on migration is the Periodic Labour Force Survey (PLFS) report of 2020-21, but it does not carry the data of the youth who emigrated for education. It is found that within the last five years, one out of every thirty-three individuals from the state of Punjab emigrated, comprising a notable number of students (Rampal et al., 2022). The state has also effectively engaged many farmers aged 60 years and above. It is around 33 per cent in marginal and 44

per cent in small farms, which indicates the elderly population concentrates towards small landholdings. The survey also revealed that individuals within the age bracket of 25 to 40 years are more available in medium (32.43 per cent) and large farms (30.87 per cent) than small and marginal farms because medium and large farmers have better economic stability and access to resources, which allow them to continue agriculture. In contrast, small and marginal farms need to work in off-farm activities alongside part-time involvement in agricultural activities. It, in turn, made their contribution towards agricultural pursuits relatively less, especially among the economically active age group (25-40). Thus, the share of marginal and small farmers is highest among off-farm employment participation under the age of 25-40 years (Pavithra & Vatta, 2013). The weighted data were derived from the sampled data following the NSSO methodology. For example, the weighted frequency for marginal farmers aged below 25 years (6521) is obtained from the four respondents in this category in our survey. These four farmers belonged to Zone 1 and Zone 3—one from Zone 1 and three from Zone 3. As per Table 2.5, the final weight for each marginal farmer in Zone 1 is 3372.248, while the corresponding weight for Zone 3 is 1049.551. Therefore, the weighted frequency is calculated as:

$6521 = 3372.248 \text{ (for Zone 1 farmer)} + 3 \times 1049.551 \text{ (for Zone 3 farmers)}.$

Using the same procedure, weighted data for all other landholding categories and age groups (25–40, 40–60, and >60 years) were computed.

2. Education Level

Farming is no longer an activity where education is of no importance. Education is the tool that increases one's decision-making capability. It helps farmers in the agriculture sector decision-making process as well. An educated farmer can give him maximum output with the minimum use of inputs (Lockheed et al., 1980).

Table 2.2: Distribution of respondents by Education across landholding sizes

	Sampled Data							
	Particulars	Illiterate	Up to Primary	Up to Metric	Upto Secondary	Upto Graduate	PG & Above	Overall
Marginal	Freq	23	15	30	12	2	0	82
	%	28.41	18.7	36.42	13.92	2.56	0	100
Small	Frequency	8	11	40	16	5	0	80
	%	10.5	13.22	49.5	20.1	6.68	0	100
Semi-Medium	Frequency	7	20	36	15	5	0	83
	%	8.01	24.5	42.76	18.58	6.15	0	100
Medium	Frequency	4	13	38	17	9		82
	%	4.92	15.55	45.55	21.24	11.34	1.4	100
Large	Frequency	7	11	33	22	8	0	81
	%	9.08	13.37	41.29	26.44	9.82	0	100
Overall	Frequency	43	75	180	79	30	0	408
	%	10.62	18.39	43.82	19.38	7.39	0.39	100
Weights								
Marginal	Freq	43411	28580	55656	21273	3906	0	152826
	%	28.41	18.7	36.42	13.92	2.56	0	100
Small	Freq	21117	26602	95958	40441	13448	0	201198
	%	10.5	13.22	49.5	20.1	6.68	0	100

Semi-Medium	Freq	27965	85560	149335	64897	21485	0	349241
	%	8.01	24.5	42.76	18.58	6.15	0	100
Medium	Freq	14561	46000	134770	62861	33550	4144	295885
	%	4.92	15.55	45.55	21.24	11.34	1.4	100
Large	Freq	5357	7886	24350	15593	5792	0	58978
	%	9.08	13.37	41.29	26.44	9.82	0	100
Overall	Freq	112411	194629	463698	205065	78181	4144	1058128
	%	10.62	18.39	43.82	19.38	7.39	0.39	100

Table 2.2 highlights the education levels among farmers in Punjab based on their landholding sizes. Marginal farmers show the highest illiteracy rate at 28.41 per cent with only 2.56 per cent having attained a college degree. During our interaction while collecting data, the farmers informed us that access to education is their most significant detriment. Most of the schools in the villages are at the secondary level. Senior-secondary-level schools are available in rare towns. They cannot afford private schools due to the family's financial conditions. Small farmers show significant improvement, with 10.5 per cent illiteracy and 6.68 per cent graduates. Semi-medium farmers further reduce illiteracy to 8.01 per cent, with 6.15 per cent holding graduate degrees. Medium farmers emerge as the most educated group, having the lowest illiteracy rate of 4.92 per cent, alongside 11.34 per cent graduates and 1.4 per cent postgraduates. Large farmers fall in between, with 9.08 per cent illiteracy and 9.82 per cent graduates. Thus, with the increase in landholding, the illiteracy rate among farmers has reduced (Dev, 2012). Access to senior secondary and college education is the least among the marginal farmers. Semi-medium and medium-sized landholding owners are the most educated farmers in Punjab. The education level among the large farmers is high because of obvious reasons, but it is much lower than that of semi-medium and medium

landholding-size farmers. Only the medium-sized farmers have post-graduation degrees.

3. Family Size

Family size is an essential factor that decides the farming practices adopted by farmers (Areri et al., 2022). In our household survey in Punjab, we came across nuclear and joint family systems. The majority of families follow a joint family system. They belonged to the Jat caste.

Table 2.3: Distribution of respondents by family size across landholding groups

<i>Size Group</i>	Sampled Data						
	Particulars	1 (<3)	2 (3-6)	3 (6-9)	4 (9-12)	5 (>12)	Overall
Marginal	Freq	6	50	23	3	0	82
	%	6.91	61.65	27.99	3.45	0	100
Small	Freq	0	37	34	4	5	80
	%	0	45.92	42.58	4.93	6.57	100
Semi-Medium	Freq	4	44	27	8	0	83
	%	4.39	53.58	32.22	9.81	0	100
Medium	Freq	3	38	26	13	2	82
	%	3.18	46.33	31.74	16.10	2.65	100
Large	Freq	1	24	35	24	2	81
	%	1.44	29.16	37.12	29.16	3.12	100
Overall	Freq	15	203	139	42	9	408
	%	3.42	49.9	34.09	10.43	2.16	100
Weighted Data							

Marginal	Freq	10554	94216	42779	5277	0	152826
	%	6.91	61.65	27.99	3.45	0	100
Small	Freq	0	92389	85664	9923	13221	201198
	%	0	45.92	42.58	4.93	6.57	100
Semi-Medium	Freq	15347	187125	112524	34245	0	349241
	%	4.39	53.58	32.22	9.81	0	100
Medium	Freq	9409	137069	93904	47672	7832	295885
	%	3.18	46.33	31.74	16.10	2.65	100
Large	Freq	850	17197	21893	17197	1840	58978
	%	1.44	29.16	37.12	29.16	3.12	100
Overall	Freq	36159	527997	360721	110359	22891	1058128
	%	3.42	49.9	34.09	10.43	2.16	100

Source: Estimation based on survey data 2022-23.

Table 2.3 reveals that in Punjab, the majority of farming households have family sizes between 3 and 6 members. The 61.65 per cent of marginal farmers, 45.92 per cent of small farmers, 53.58 per cent semi-medium farmers, 46.33 per cent medium farmers, and 29.16 per cent large farms belong to this category. Families with 6 to 9 members also represent a significant share, with 27.99 per cent of marginal farmers and 42.55 per cent of small farmers in this group. Larger families with 9 to 12 members are less common among marginal (3.45 per cent) and small farms (4.9 percent), but families with more than 12 members are rare or absent among marginal farmers but high among medium (46.33 per cent) and large farmers (29.16 per cent). Family size > 12 exists in small (6.57 percent), medium (2.65 per cent), and large farm families (3.12 percent), but is completely absent in marginal farmers. The results show that family size is positively associated with farm size. During interactions with farmers, they discussed the minimization of costs with large landholdings, which led to the continuation of large

families.

4. Dependency Status

Dependency Status refers to the level of economic dependence of family members on the working head of the family. It is studied in the socio-economic characteristics to know about the family members and their characteristics.

Table 2.4: Dependency Status according to landholding size

	Dependency Level								
Size Groups	Complete ly	Stude nt	Earne r	Margin al Earner	Domest ic Worker s	Old Age Depende nt	Under Age	Other s	Disable d
Marginal	6	51	82	66	26	17	17	2	3
Small	2	59	80	65	38	18	14	0	2
Semi- Medium	7	56	83	74	15	20	17	0	5
Medium	4	56	82	73	21	16	23	0	2
Large	3	74	81	72	28	30	16	0	7
All	22	296	408	350	128	101	87	2	19

Source: Estimation based on survey data 2022-23.

Table 2.4 presents the dependency status of farming families across farm sizes. All family members are divided into earners, students, domestic workers, old-age dependents, and other dependent groups. Marginal farmers have 82 earners, 51

students, 66 domestic workers, and 26 old-age dependents. Small farmers report same figures with 80 earners, 59 students, 65 domestic workers, and 38 old-age dependents. Semi-medium farmers have the highest number of earners at 83, alongside 56 students, 74 domestic workers, and fewer old-age dependents at 15. Medium farmers also show strong earning participation with 82 earners, 56 students, 73 domestic workers, and 21 old-age dependents. Large farmers have slightly fewer earners (81) but more students (74) and old-age dependents (28). It was found that the dependency ratio of semi-medium landholdings was the lowest, which pointed out that semi-medium landholding farmers have the maximum share of earning family members compared to non-earners. In contrast, the large landholding group had the highest dependency ratio, 103.26, meaning the earners of large landholdings support a maximum number of non-earner family members. The maximum number of large landholders have a family size of 6-9 members. Their family members have the most significant share of students and old-aged people, which increased their dependency ratio. The high dependency ratio indicates that the farming household deals with self-employment profiles to support their dependent family. They diversify their economic portfolio to earn money to support their dependent family through self-employment. In contrast, a low dependency ratio predicted that the earning family members would involve themselves in employment opportunities instead of self-employment (Suratiyah, 2016).

5. Gender

Agriculture is a male-dominated profession, and mainly in every Indian state, the number of male farmers is more than that of female farmers. However, Punjab shows a unique picture; female farmers are absent in the state agriculture sector.

Table 2.5: Genders of farmers across landholding sizes

Size group	Sampled Data				
	Particulars	Male	Female	Other	Total
Marginal	Freq	82	0	0	82
	%	100	0	0	100
	Freq	80	0	0	80

Small	%	100	0	0	100
Semi-Medium	Freq	83	0	0	83
	%	100	0	0	100
Medium	Freq	82	0	0	82
	%	100	0	0	100
Large	Freq	81	0	0	81
	%	100	0	0	100
Overall	Freq	408	0	0	408
	%	100	0	0	100
Weighted Data					
Marginal	Freq	152826	0	0	152826
	%	100	0	0	100
Small	Freq	201198	0	0	201198
	%	100	0	0	100
Semi-Medium	Freq	349241	0	0	349241
	%	100	0	0	100
Medium	Freq	295885	0	0	295885
	%	100	0	0	100
Large	Freq	58978.5	0	0	58978.5
	%	100	0	0	100
Overall	Freq	1058128	0	0	1058128
	%	100	0	0	100

Source: Estimation based on survey data 2022-23.

Table 2.5 shows the complete absence of females in the Punjab agriculture sector. The complete absence of women from Punjab agriculture indicated increased depeasantization. Most farmers in Punjab who want to move to another place for better non-farm employment opportunities must either sell their land or lease it out. They consider it in a depeasantization category. However, in other states of India, females continue agriculture even when the male (head of the family member) goes out to work in the non-farm sector (Pattnaik & Lahiri-Dutt, 2020). The more problematic issue of Punjab agriculture is that though women are working as agricultural labour, albeit in a small number, when it comes to ownership of land, women are far behind. The patriarchal structure of the society is mainly to blame, as, in spite of laws giving equal rights to women, the real-world scenario is disheartening. Only 1.55 per cent of land was registered in the name of women (Aujla, 2019).

6 Marital Status

The analysis of marital status across landholding sizes allows us to better comprehend the social characteristics of Punjab state. However, there is no correlation between farmers' marital status and output level (Ngeywo et al., 2015). It is still critical to understand the state's demographic profile.

Table 2.6: Martial Status of farmers across landholding sizes

Size Groups	Sampled Data				
	Particulars	Married	Unmarried	Widowed	Overall
Marginal	Freq	68	6	8	82
	%	82.98	6.82	10.2	100
Small	Freq	74	1	5	80
	%	92.23	1.49	6.28	100
Semi-Med	Freq	77	5	1.46	83

	%	92.44	6.09	4	100
Medium	Freq	78	0	4	82
	%	94.7	0	5.3	100
Large	Freq	78	1	2	81
	%	96.92	0.7	2.38	100
Total	Freq	375	13	20	408
	%	91.91	3.32	4.76	100
Weighted Data					
Marginal	Freq	126810	10427	15588	152826
	%	82.98	6.82	10.2	100
Small	Freq	185562	3003	12632	201198
	%	92.23	1.49	6.28	100
Sem-Med	Freq	322841	21285	5116	349241
	%	92.44	6.09	1.46	100
Medium	Freq	280204	0	15681	295885
	%	94.7	0	5.3	100
Large	Freq	57161	415	1403	58978
	%	96.92	0.7	2.38	100
Overall	Freq	972579	35130	50420	1058128
	%	91.91	3.32	4.76	100

Source: Estimation based on survey data 2022-23.

Table 2.6 depicts the marital status of Punjab state farmers. It was found that most Punjabi farmers belonged to the married category irrespective of the landholding size. 82.98 per cent of marginal farmers are married, rising to 94.7 per cent among medium

farmers. It further escalated to 96.92 per cent for large farmers. The proportion of unmarried and widowed farmers decreases with larger landholdings. Thus, a positive relationship exists between land size and the married category in the Punjab. This suggests marriage is linked to greater economic stability and land ownership. Marital status leads to economic stability and workforce participation. While collecting data, the older generation pointed out a positive relationship between land inheritance rights and marital status. The respondents also mentioned the fact that banks and other financial institutions tend to favour married individuals while giving loans, as it is considered that repayment would be timely. A contrarian view was also shared. Marginal and small farmers regaled the fact that families also led to high indebtedness, making them more susceptible to debt traps, distress migration, and even suicides. The results of our household validated the results predicted in other countries (Strassmann & Clarke, 1998).

2.4.2 Discussion on Economic Variables

In this section, the economic features of the farmers as per their landholding size are discussed. The farmers of Punjab are technically sound, as the density of farm tools is very high (Narayanamoorthy & Kalamkar, 2005). The farmers are also aware of the various government schemes regarding subsidies, which help them to take advantage of these schemes in acquiring tractors, harvesters, combines, and other heavy tools. The first variable discussed was the gross cropped area and net cropped area, as the land size is one of the major indicators of economic well-being. Thereafter, agricultural machinery and livestock are discussed.

1. Gross Cropped Area, Net Cropped Area, Area Under Border, and Land Value

Gross cropped area, also called gross area or total sown area, refers to the total area that is sown at least once a year. Net area, on the other hand, refers to the physical land area on which crops are planted and harvested. Areas below the boundary are conservation management practices, including contour lines, strip cropping, and embankment farming patterns. Land value is the worth of land owned by farmers.

Table 2.7: Land Holding size wise Average net cropped area, Area under border, Gross Cropped Area, and Land Value

Land Holding Size Group	Net Cropped Area (Ha)	Area Under Bordered Path	Land Value (Rs)	Gross Cropped Area (Ha)
Marginal	0.72	0.01	3591986.21	1.47
Small	1.59	0.02	7986573.20	3.09
Semi-Medium	2.99	0.04	14710728.40	5.80
Medium	5.01	0.06	24118402.91	9.81
Large	8.62	0.10	40733218.43	16.82
Overall	3.28	0.04	15907409.94	6.41

Source: Estimation based on survey data 2022-23.

Table 2.7 shows that the gross cropped area is almost double the net sowed area regardless of landholding size, which validates the data provided by the Government of Punjab on their official websites (Statistical Abstract of Punjab, 2022). The main reason behind doubling the gross cropped area to the net cropped area is the cropping Intensity. The cropping intensity, the ratio of the gross area sown to the net sown area, is relatively high for the state.

The formula for the cropping intensity used:

$$\text{Gross Cropping Intensity} = \frac{\text{Cropped Area}}{\text{Net Sown Area}} \times 100$$

Table 2.8 Calculated Cropping Intensity across land holding size.

S.NO	Size of Landholding	Cropping Intensity (%)
1	Marginal	204
2	Small	194
3	Semi Medium	194
4	Medium	195
5	Large	195
6	Average	195

Source: Author's Estimation

Farm size and cropping intensity are inversely related (Sengar et al., 2019). The marginal farmers grew more seasonal crops, increasing their cropping intensity (Samra & Kataria, 2014). The area under the bordered path and land value directly relate to landholding size. The area under the border increases as landholding sizes increase because large farmers adopt more land conservation practices (Abebe & Sewnet, 2014). Land value also increases with the increase in land sizes.

2. Agriculture Machinery, Tools, and Farm Implements

The ownership of farm machinery is a way to assess the financial soundness of a farmer. Punjab has the highest farm power availability, around 2.6 kW/ha; it is almost double India's national average of 1.5 kW/ha. In addition, the state has a ratio of one tractor for every 9 hectares of net cultivated land, though the national average ratio is one tractor per 62 hectares (Moudgil et al., 2023). Laser land levellers and happy Seeders are often used in Punjab for efficient farm practices.

Table 2.9: Average Land holding size wise Agriculture Machinery, Tools, and Farm Implements

Landholding Size Groups	Durable_Containers_value (Rs)	Tools Value (Rs)	Implements Value (Rs)	Machinery Value (Rs)	Tractor Value (Rs)
Marginal	2710	1006	7224	47632	21628
Small	2556	2400	25922	137473	99298
Semi-Medium	4049	1343	87455	205341	167895
Medium	3549	1691	136335	318126	257841
Large	5895	1906	190141	517679	409577
All	3535	1624	83559	218606	172349

Source: Estimation based on survey data 2022-23.

Table 2.9 illustrates a positive link between the size of farms and the level of mechanization. As farm size increases, so does the investment in capital assets per farm. Farmers with larger farms are the most mechanized (Singh, 2017; Sarkar, 2020; Rajkhowa & Kubik, 2021). Currently, large-scale farmers possess the highest value of tractors, amounting to Rs 409576.75, with significant horsepower (hp). In contrast, marginal farmers own tractors valued at Rs. 21628.34. Consequently, our research confirms a positive correlation between farm size and the value of tractors (Aybek & Boz, 2006).

3. Ownership of Tractor & Harvester Combine

The ownership of tractors and combines plays a major role in the production and productivity. Both these pieces of equipment require huge investment.

Table 2.10: Ownership of Tractor Status of farmers across landholding sizes

Size Group	Sampled Data (Tractor Ownership (1 if owned otherwise 0))			
	Particulars	0	1	Total
Marginal	Freq	70	12	82
	%	85.24	14.76	100
Small	Freq	36	44	80
	%	45.48	54.52	100
Semi-Medium	Freq	12	71	83
	%	14.91	85.09	100
Medium	Freq	2	80	82
	%	2.8	97.2	100
Large	Freq	1	80	81
	%	1.44	98.56	100
Total	Freq	121	287	408
	%	29.65	70.35	100
Weighted Data				
Marginal	Freq	130269	22557	152826
	%	85.24	14.76	100
Small	Freq	91505	109693	201198
	%	45.48	54.52	100
Semi-Medium	Freq	52072	297169	349241
	%	14.91	85.09	100

Medium	Freq	8285	287600	295885
	%	2.8	97.2	100
Large	Freq	849	58129	58978
	%	1.44	98.56	100
Total	Freq	282980	775148	1058128
	%	29.65	70.35	100

Source: Estimation based on survey data 2022-23.

Table 2.10 shows that approximately 70.35 per cent farmers owned tractors, and the remaining 29.65 per cent did not. Small farmers had 54.52 per cent ownership This increased to 85.09 per cent for semi-medium farmers .97.2 per cent for medium farmers and 98.56 per cent for large farmers owned tractors. This clearly shows that larger farmers have greater tractor ownership due to better financial conditions, while marginal farmers rely more on rentals or shared models to overcome issues related to affordability, which indicates mechanization disparities based on farm size.

Table 2.11: Land holding size wise Ownership of Harvester Combine

Size Group	Sampled Data (Harvester Combine Ownership (1 if owned otherwise 0))			
	Particulars	0	1	Total
Marginal	Freq	82	0	82
	%	100	0	100
Small	Freq	80	0	80
	%	100	0	100
Semi-Medium	Freq	83	0	83
	%	100	0	100
Medium	Freq	80	2	82

	%	97.51	2.49	100
Large	Freq	73	8	81
	%	90.41	9.59	100
Total	Freq	398	10	408
	%	98.77	1.23	100
Weighted Data				
Marginal	Freq	152806	0	152826
	%	100	0	100
Small	Freq	201198	0	201198
	%	100	0	100
Semi-Medium	Freq	349241	0	349241
	%	100	0	100
Medium	Freq	288510	7375	295885
	%	97.51	2.49	100
Large	Freq	53324	5656	58979
	%	90.41	9.59	100
Total	Freq	1045099	13029	1058128
	%	98.77	1.23	100

Source: Estimation based on survey data 2022-23.

Table 2.11 discusses the ownership of harvesters combined across sampled and weighted landholding sizes. On average, the number of households surveyed that owned harvester combines was 1.23 per cent of the total farmers in Punjab state. None of the marginal farmers, small farmers, and semi-medium farmers owned a harvester combine. Ownership begins at the medium farm level, where 2.49 per cent

owned combines. Large-scale farmers showed significantly higher ownership, with 9.59 per cent possessing a harvester combine. The ownership of harvesters, combined with their high cost, lies only in the medium and large categories in Punjab (Mehta et al. 2014). In contrast, small and marginal farmers prefer to use rental machines, and the rent varies by district and village depending on the availability of the machine. Rental services have made farm mechanization possible even for small and marginal farmers (S. Singh, 2017). It promotes inclusiveness because farmers can use machinery at an affordable cost instead of purchasing agricultural machinery beyond their purchasing power. The Punjab government further facilitated the rental model by introducing the *Pau's Farm Machinery App* (2022).

4. Livestock

One of the primary sources of supplementary earnings for the farmers is livestock. The government in recent times promoted cattle farming along with goatry, pig farms, and others. The 20th livestock census of Punjab showed that the maximum cattle population belonged to the buffalo category, as the state farmers considered selling milk their secondary occupation. Goats and sheep were also favourites among farmers for meat and milk. Pigs were the least-reared cattle in the state. Our household survey in the state found the details of milch and draught buffaloes and cattle.

Table 2.12: Livestock details as per land size holdings

Landholding Sizes	Milch Buffaloes	Draught Buffaloes	Other Buffalos	Milch Cattle	Draught Cattle	Other Cattle	Other animal	Livestock (in number)	Value Livestock (Rs)
Marginal	281000	20000	10000	227000	32000	3000	0	573000	132582
Small	313000	20000	16000	304000	52000	8000	18000	732000	174508
Semi-Medium	357000	26000	22000	264000	40000	11000	9000	728000	171401
Medium	434000	47000	10000	177000	30000	7000	0	705000	181811
Large	480000	46000	22000	276000	35000	6000	14000	780000	225765
All	366000	31000	16000	243000	38000	8000	7000	708000	172995

Source: Estimation based on survey data 2022-23.

Table 2.12 discusses the livestock details of the surveyed households. Dairy is considered the second most common occupation of most farmers in the state (Government of Punjab, 2023). A mixed crop/livestock system is a way to increase the sustainability of farmers in developing countries where crop specialization would not work as in developed countries. Moreover, it is a means of improving food security, especially for small farmers. According to this analysis, a positive relationship exists between farm size, livestock number, and livestock value, which is validated by the results predicted by another research work in Punjab.

2.5 Conclusion

Socio-economic characteristics are a way to know the factors that decide farming practices, such as cost of cultivation, productivity level, and profitability. Social characteristics involve features like age of farmers, education level, gender, family size, marital status, and dependency status. On the other hand, economic characteristics involve farm ownership, land value, the area under the bordered path, farm mechanized status, and livestock. Understanding the socio-economic characteristics according to landholding sizes helps us provide comprehensive views to decide the resource allocations to promote productivity and profitability. Starting with age, it was observed that our young generation prefers to avoid making their career in agriculture irrespective of farm size, which concerns the farming community. The landholding size showed a positive relationship with education level in Punjab state. Most senior-secondary, graduate, and postgraduate farmers belong to large farm sizes. It showed the inequalities in education systems in our state. Punjab agriculture is also dominated by males, with a complete absence of female involvement. Family size and the dependency ratio showed a positive relationship with farm size. The family size and dependency were increased with an increase in farm size. The Marital status of a farmer was not impacted by the size of the landholding.

An economic characteristics study showed that the economic conditions of farmers change with farm size. The net cropped area of large farms is more than small farms, which indicates that larger farms cultivate more land and produce more output and farm profits. Large farms' economic potential and investment capacity increase in

average land value compared to small farms. The ownership of farm machinery also exhibited inequalities, as most farm machinery, like tractors, rotavators, and Happy Seeders, is owned by large farms. Large farms have good access to resources like credit, agricultural inputs, and technology, further creating gaps among farmers in small and extensive landholdings. The study of socio-economic characteristics signified that many variations in farmers' social and economic lives increase with farm size. The government should make policies to reduce the inequalities between small and large farm owners. To improve productivity and profitability, efforts should be made to uplift small farmers through subsidies and other concessions.

CHAPTER III

ANALYSIS OF INPUT USE AND COST OF CULTIVATION ACROSS FARM SIZE

3.1 Introduction

Punjab's agriculture is suffering from negative returns as the repercussions of the green revolution leading to extensive use of chemical fertilizers and other inputs were reflected in production and productivity. The state government is trying to address the issue of falling productivity, rising costs, and dependence on resource-intensive crops, namely wheat and paddy. Wheat is a natural choice for this geographical area, but paddy is a water guzzler, which has exacerbated groundwater depletion (Srivastava et al., 2015). With the increase in the acreage under paddy, the cost of irrigation and other inputs has also gone up. The withdrawal of input subsidies by the government in the name of economic reforms increased the financial burden, particularly for marginal and small landholding operators.

This chapter analyzes the second objective, which involves exploring farm input usage and production costs across the landholding sizes in Punjab. In-depth analysis of the various cost components and the contribution of each towards overall cultivation expenditures is discussed. Furthermore, this analysis assists us in knowing the pattern of inputs followed through the land sizes and its effect on cultivation costs, ultimately determining the productivity and profitability of these landholding sizes. By examining these factors, this study aims to contribute to the existing literature on agricultural sustainability and farmer welfare.

3.2 Literature Review

Adopting the Green Revolution has also led to regional disparities in India; some states' situations have remained the same, and they are still vulnerable to famines (Chakravarti, 1973). In the context of the Green Revolution, crops such as wheat and paddy became strategically important, which started the mono-cropping culture in states like Punjab and Haryana (Singh & Sidhu, 2004). Furthermore, the mechanization of the agricultural process has increased energy consumption per acre,

thereby increasing the environmental carbon footprint (Wang et al., 2015; Aguilera et al., 2019; Xiong et al., 2020). Beyond mono-cropping and adverse environmental effects, the Green Revolution has made it difficult for farmers to survive in the agricultural sector. The continuous rise in the prices of farm inputs increased the cultivation costs. Moreover, the farmers are compelled to spend more on modern farming technologies on account of climate change (Narayanamoorthy, 2013; Zhang et al., 2015).

The issue of rising crop expenses on account of escalating costs of farm inputs is not a country-specific issue. Farmers worldwide have been struggling to continue to be lucrative regardless of heavy reliance on energy-based inputs. Farmers even move away from the point of equilibrium, failing to cover even cultivation costs (Myers, 2022; Eardley, 2022). In India, input prices also increased manifold with the increased use of petrochemical-based farm inputs that are giving challenges to the farmers' sustainability and creating difficulty for farmers to survive under a conventional farming system (Kumar & Rosegrant, 1994; Chand et al., 2015; Srivastava et al., 2017; Mariappan & Zhou, 2019). Currently, governments in different countries have been trying to manage the situation through subsidies that have helped them to overcome the rising cost of fertilizers and other energy-based inputs (Resnick et al., 2012; Jayne & Rashid, 2013; Saran et al., 2013; Kaur et al., 2015). Besides the increase in energy input prices, cultivation costs have increased in many ways, like an increase in human labour costs, followed by the migration of labour from the agricultural sector to the industrial and tertiary sectors, leading to the problem of labour shortages and increased wage rates (Srivastava et al., 2020).

Solutions to these problems involve the introduction of precision farming practices (Bongiovanni & Lowenberg-Deboer, 2004; Beluhova-Uzunova & Dunchev, 2019; Raj et al., 2021) and contract farming, which could effectually increase farmers' income (Singh, 2002; Kumar, 2006; Sharma, 2016). The country's prime minister is committed to doubling the farmers' income, and one way of doing so is by reducing the cultivation costs and increasing the farmers' profitability. Therefore, this study thoroughly examines the cultivation costs to know the cost components that affect the maximum total cost of cultivation. In addition, this work enriched the literature

because it tried to investigate the cost according to the farm size, which made it a unique and unexplored region in Punjab agriculture.

3.3 Database and Methodology

3.3.1 Descriptive Statistics

Mean

It is the simplest descriptive statistics method to interpret the given data set and derive meaningful conclusions about the population. It encapsulates a whole dataset into a single number representing the data's center point (Ostasiewicz & Ostasiewicz, 2000). Usually, the mean is calculated using a formula:

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n}$$

Range (Minimum & Maximum)

Maximum and minimum are the parts of descriptive statistics that help us know the data range within a data set. A more extensive range indicates more significant variations among data points in a dataset and vice versa. It also helps us find outliers in the dataset (Yan & Wu, 2015). Estimation of range using the formula as below:

$$Range = Maximum - minimum$$

Standard Deviation & Coefficient of Variation

Standard deviation and coefficient of variation are descriptive statistics tools used to estimate a given dataset's dispersion and variability in a population. However, the method of calculation and conditions of application are different. Standard deviation measures how much variation is in a given dataset by considering a single variable at a time. In contrast, the coefficient of variation compares datasets with different scales (Lovie, 2005). The choice between these two methods depends upon the goal we need to achieve.

$$SD = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

To estimate the Coefficient of Variance using formula as below:

$$CV = \frac{\frac{\sigma}{\mu}}{\frac{\sigma}{\mu}} \times 100$$

Where:

- σ = Standard Deviation
- μ = Mean

The government estimates the Minimum Support Price (MSP) using Cost A2 + FL. Therefore, we included all the components of Cost A2 in our study. The main variables included in our study were:

- Labour use & costs
- Machines use & costs
- Irrigation Machines use & costs
- Animals use & costs
- Seed use & costs
- Fertilizers use & costs
- Farm yard manure
- Insecticides costs
- Imputed rent costs
- Leased in Land costs
- Depreciation
- Fixed Capital costs
- Other Costs

Method adopted to do calculation of profitability

Estimation of Profitability

There are several methods to measure profitability like Benefit -Cost Ratio (BCR) and Return on Investment but we have used Net returns per hectare because as it makes comparisons between marginal, small, semi-medium, medium, and large farms more

consistent and meaningful, especially when landholding sizes vary.

Formula:

$$\text{Net Returns/ha} = \text{Gross Returns/ha} - \text{Cost of Cultivation/ha}$$

3.4 Results and Discussions

3.4.1 Value of crop output (Rs/ha of Net Sown Area)

The comparison of productivity between farm size groups, is possible by evaluating the value of crop output, which refers to the monetary value of the total agriculture produced on a farm during a year. This method is preferred because different farms follow different cropping patterns. Productivity is estimated by multiplying the quantity of agricultural products produced, like crops, livestock, and by-products, by their respective market prices.

Table 3.1: Comparative value of crop output among farm size groups (Rs/ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	211738	73280.4	333961.3	1738461.5	821.0
Small	203940	48300.0	281368.5	1690752.6	829.0
Semi-medium	204801	40343.0	322817.3	2793811.4	1364.2
Medium	212449	87728.7	285922.7	1966577.1	925.7
Large	220605	85501.9	495723.5	1471944.3	667.2
Overall	208659	40343.0	495723.5	1995733.7	956.5

Source: Estimates based on primary survey data 2022-23.

The table 3.1 clearly indicates that larger the farm size, higher is the average value of crop output. However, if the difference between the average value across landholding size is analysed, the study points out that the difference is not much. Thus, the marginal and small farmers are able to achieve comparable productivity in spite of small landholdings. The cropping pattern, intensive use of technology and cultivation techniques and high labour output are the main reasons for these farmers to perform

well (Ayaz & Mughal, 2022). The range in the value of crop is the highest among the semi-medium and large farmers. This difference can be because of difference in soil fertility, the choice of crops and saturation in the use of technology. The interaction with farmers led to the conclusion that large farmers reaped the benefits of economies of scale initially with the introduction of technology but with the passage of time, new influx of technology is required. One interesting data point is that the maximum value of production is INR 495723 which is indicative of the potential of the state. The semi-medium farmers have the highest variability (shown by standard deviation) and relative variability (shown by CV) which is the result of lack of credit facilities, mono cropping and heterogenous farming practices.

3.4.2 Labour use and labour cost per hectare of Net Sown Area

This segment evaluates the impact of labour on production through labour working hours and costs of labour per hectare. This double analysis helps to completely evaluate the influence that labour has on production.

Table 3.2: Labour use (Whr/ha of Net Sown Area) and labour costs among land holding size group (Rs. /ha of Net Sown Area)

Size group	Labour use (Whr/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	648.7	357.5	1269.5	9691.9	1494.1
Small	543.1	62.5	1185.3	9693.5	1785.0
Semi-medium	478.9	54.8	1030.4	9612.8	2007.1
Medium	471.0	277.4	990.2	7296.9	1549.2
Large	459.6	155.4	1098.1	4090.3	889.9
Overall	512.4	54.8	1269.5	8915.2	1740.1
Labour cost (Rs./ha of Net Sown Area)					
Marginal	31285.2	16099.4	63029.5	474412.2	1516.4
Small	26286.1	3074.7	55957.9	464642.1	1767.6
Semi-medium	22882.6	2744.3	49379.3	439369.4	1920.1
Medium	22571.1	14552.1	49017.8	322030.6	1426.7
Large	22151.5	8132.6	51833.5	182993.9	826.1

Overall	24615.5	2744.3	63029.5	421177.5	1711.0
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Source: Estimates based on primary survey data 2022-23.

Table 3.2 predicts that farm size negatively affected the relationship between labour hours and labour costs. With the increase in farm size, per-hectare labour use and costs decrease. This inverse relationship indicates the dependency on labour because with the increase in farm size, farmers prefer to move towards machinery for their farming operations. In addition, the signs of efficient management and economies of scale help larger farmers reduce their per-hectare labour costs (Ayaz & Mughal, 2022). The variation in labour cost is the highest in small and semi-medium landholdings, mainly because of variation in crop type, management skills, too much reliance on family labour, limited access to hired labour (Ghuman et al., 2007; Benny et al., 2016). The higher standard deviation and coefficient of variation in the marginal, small, and semi-medium farm sizes show greater instability with respect to labour use and cost. As these sizes are more labour intensive, the fluctuation in cultivation pattern, climate change, and market instability has a greater influence on their demand for labour.

3.4.3 Machine use and machinery cost per hectare of Net Sown Area

Punjab took advantage of the Green Revolution because of its quick and early adoption of mechanization. Over time, Punjab witnessed a shortage in agricultural labour, more government schemes subsidizing mechanization, and an overall increase in agricultural income, which prompted a shift from labour intensive cultivation to capital-intensive cultivation (Devi et al., 2013).

Table 3.3: Machinery use (Whr/ha of Net Sown Area) and Machinery Costs (Rs/ha Net Sown Area)

Size group	Machine use (Whr/ha of NET SOWN AREA)				
	Mean	Min	Max	Std	CV
Marginal	33.3	15.0	79.2	429.0	1288.6
Small	33.4	10.7	57.2	493.9	1479.6

Semi-medium	35.1	6.7	69.5	733.3	2090.6
Medium	35.8	16.8	59.6	535.8	1497.4

Large	35.9	14.7	61.7	270.2	753.2
Overall	34.7	6.7	79.2	516.3	1486.3
	Machine cost (Rs./ha of NET SOWN AREA)				
Marginal	66976.4	16876.9	260316.6	2033399.6	3036.0
Small	27252.3	7987.8	79482.2	820132.8	3009.4
Semi-medium	16280.2	4078.0	69457.7	771702.5	4740.1
Medium	9594.6	2446.3	27375.3	285203.3	2972.5
Large	6836.7	1126.1	27849.6	140651.1	2057.3
Overall	23292.7	1126.1	260316.6	1426756.9	6125.4

Source: Estimates based on primary survey data 2022-23

After the Green Revolution started in 1965, regardless of farm size, certain farm activities like planting and harvesting in Punjab have been done with farm machines. However, on average, machinery use is slightly different across farm sizes. Machinery costs showed an inverse relationship with farm size. Large farms showed the lowest machinery costs because larger farms tend to use machinery more efficiently and reduce their per hectare machinery costs (Xu et al., 2019). Moreover, large farms perform a cost-benefit analysis to ensure productivity and profitability before investing in farm machinery. However, small farmers do not follow such procedures much before buying farm machinery. Therefore, the variation in machinery costs is higher in small farms because they do not judiciously think about investing in machinery or going for the rent option, which can save their cost of cultivation (Singh et al., 2014).

3.4.4 Irrigation machine use and Irrigation machine costs per hectare of Net Sown Area

Punjab is the highest irrigated area across India. Groundwater is extensively used for

irrigation, making Punjab the most productive state in India. However, the continuous use of groundwater reduced the water table level in the state (Khara & Ghuman, 2023).

Table 3.4: Irrigation machine use (Whr/ha of Net Sown Area) & Irrigation machine costs per hectare (Rs. /ha of Net Sown Area)

Size group	Irrigation machine use (Whr/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	267.6	0.0	471.8	5471.7	2044.5
Small	259.2	0.0	496.4	5375.4	2074.1
Semi-medium	246.0	5.8	555.2	7642.8	3107.4
Medium	244.8	8.9	375.3	5185.7	2118.1
Large	225.7	11.4	367.3	2207.9	978.1
Overall	250.2	0.0	555.2	5470.2	2186.7
	Irrigation machine cost (Rs./ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	6821.7	0.0	22736.3	235238.6	3448.4
Small	5369.0	0.0	27988.4	211271.2	3935.0
Semi-medium	4619.3	525.8	35704.6	297649.8	6443.6
Medium	4273.7	277.1	17068.2	182926.8	4280.3
Large	3826.7	293.8	15040.5	74576.3	1948.9
Overall	4939.1	0.0	35704.6	217463.8	4402.9

Source: Estimates based on primary survey data 2022-23

Table 3.4 indicates that the increase in farm size reduced the irrigation use and costs per hectare. The reason for the inverse relationship is that large farmers use efficient irrigation machinery rather than small farms (Skaggs & Samani, 2005). They use high-power motors and advanced technology like drip irrigation and laser land

levelling that takes less time for irrigation. Large farms can spread their irrigation machinery expenses over a larger area, reducing irrigation costs in hectares. In addition, a significant variation in irrigation costs exists within farm sizes. This variation is maximum for semi-medium farms INR 6444 as some farmers spend less on irrigation, whereas some invest in hugely inefficient irrigation machinery. During the survey, farmers said they spent money on irrigation machinery depends on the water table level in their region. The noteworthy figure is zero irrigation machine cost on marginal and small landholdings which translates into reliance on rainwater.

3.4.5 Animal use and Animal costs per hectare of Net Sown Area

Animals were widely used in Indian agriculture, but since the 1980s, the use of animals has gone down drastically as machines have replaced them. Still, there is a need to analyze the animal use and cost with respect to various landholding sizes, as marginal and small farmers are using animals. The animal costs include farmers' expenditures on animal services, such as investments in animal infrastructure, wages paid to workers who handle animals, animal feed and medicine, and depreciation.

Table 3.5: Animal Use (Whr/ha of Net Sown Area) & Animal Costs per Hectare (Rs./ha of Net Sown Area)

Size group	Animal use (Whr/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	3.7	0.0	35.4	338.2	9264.3
Small	1.1	0.0	31.2	207.8	19117.4
Semi-medium	0.7	0.0	13.0	140.4	19855.0
Medium	0.2	0.0	2.1	33.3	13829.3
Large	0.1	0.0	3.2	13.5	10465.3
Overall	1.0	0.0	35.4	196.5	18861.3
Animal cost (Rs./ha of Net Sown Area)					

Marginal	455.4	0.0	4998.4	44895.5	9858.7
Small	122.7	0.0	2716.4	20473.1	16682.1
Semi-medium	73.1	0.0	1680.2	16650.1	22778.9
Medium	17.8	0.0	151.1	2444.6	13725.2
Large	15.9	0.0	485.6	1796.9	11335.2
Overall	119.1	0.0	4998.4	24361.2	20454.9

Source: Estimates based on primary survey data 2022-23

Table 3.5 shows that with the increase in farm size, animal use and costs per hectare would be reduced. Large farms prefer to depend more upon machines than animals. There is a considerable variation in animal costs in each group. This variability is the result of farming operations adopted by the farmers. Some farmers prefer to invest in animal sheds and be involved in the livestock business, whereas some prefer to deal with crop plantations only.

3.4.6 Seed use and Seed costs per hectare of Net Sown Area

Climate change forced farmers to adopt high-yield and pest-resistant varieties of seeds to increase productivity and profitability. However, this increased seed costs per hectare. Seed costs include the amount spent on purchasing seeds and expenditures incurred on seed treatment, transportation, and storage costs.

Table 3.6: Seed use (Kg/ha of Net Sown Area) & Seed Costs per hectare (Rs./ha of Net Sown Area)

Size group	Seed use (Kg/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	119.4	45.8	262.1	1471.1	1231.7
Small	117.8	38.6	308.8	1872.2	1588.9
Semi-medium	109.3	42.5	198.1	1361.8	1245.6

Medium	135.8	64.9	1414.9	11421.7	8409.9
Large	286.5	37.6	5321.4	22655.7	7907.3
Overall	129.7	37.6	5321.4	11506.3	8872.2
	Seed cost (Rs./ha of Net Sown Area)				
Marginal	5350.4	3071.8	11687.5	85247.8	1593.3
Small	4788.9	1500.0	10761.8	88890.2	1856.2
Semi-medium	4588.2	1263.0	9567.7	93185.1	2031.0
Medium	4626.1	2961.3	10830.7	89716.6	1939.4
Large	6828.4	1254.1	137331.8	439017.6	6429.3
Overall	4871.9	1254.1	137331.8	212067.8	4352.9

Source: Estimates based on primary survey data 2022-23

Table 3.6 depicts a positive link between farm size and seed costs. To increase per-hectare productivity, large farms involve themselves towards large-scale operations and high planting densities. It undoubtedly increased per-hectare productivity, but the cost of cultivation also went up. In addition, they use high-yield variety seeds, which are more expensive than traditional seeds. Higher cropping intensity and agronomic practices are also responsible for the high seed costs of large farms.

3.4.7 Fertilizers use and fertilizers costs per hectare of Net Sown Area

The high cropping intensity in Punjab promoted the use of fertilizers. The Green Revolution is the primary cause for farmers to use fertilizers, as high-yielding varieties of seeds required more water and the use of fertilizers.

Table 3.7: Fertilizers use (Kg/ha of Net Sown Area) & fertilisers use cost (Rs./ha of Net Sown Area)

Size group	Fertilizer use (Kg/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	427.2	135.0	1400.6	4609.5	1079.0
Small	418.9	95.7	685.4	4399.5	1050.2
Semi-medium	411.7	124.4	657.9	5378.8	1306.4
Medium	412.9	230.1	904.5	5033.0	1219.1
Large	436.3	152.4	1048.8	3175.3	727.7
Overall	417.0	95.7	1400.6	4579.2	1098.1
	Fertilizer cost (Rs./ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	8943.7	2480.4	16003.9	80926.5	904.8
Small	8731.4	2236.4	13794.1	108887.0	1247.1
Semi-medium	8324.6	3246.1	17706.3	144167.6	1731.8
Medium	8352.2	3893.0	13483.0	110220.1	1319.7
Large	9305.1	3230.2	31352.5	103161.2	1108.7
Overall	8553.7	2236.4	31352.5	111941.8	1308.7

Source: Estimates based on primary survey data 2022-23

In Punjab, most farmers prefer synthetic fertilizers like urea, DAP, and potash. On average, fertilizer use is consistent across landholding sizes. However, a high variation exists in fertilizer use and costs within each landholding size. These variations in fertilizer use and costs result from factors like type of fertilizer, crop type, farmers' experience, soil fertility level, and fertilizer availability. Crop types also influence fertilizer use and costs, such as crops like potatoes and vegetables requiring more fertilizer than fodder and cereal crops. Finally, government policies and the supply of fertilizer significantly contribute to the application of fertilizers. Farm size also influences the use and costs of fertilizers, as small farmers use less fertilizer but pay more on account of the lesser bargaining power of small farmers. The standard deviation is very high in fertilizer cost, as this is directly related to the subsidy received.

3.4.8 Farm Yard Manure Use and Costs per hectare of Net Sown Area

In 2022, the Indian government introduced directives on natural farming, which promote the use of organic fertilizer. The customers are also now more aware, thereby forcing the farmers to shift from synthetic fertilizers to farmyard manure.

Table 3.8: Farm Yard Manure use (Ton/ha of Net Sown Area) & cost per hectare (Rs. /ha of Net Sown Area)

Size group	Farm Yard Manure use (Ton/ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	46.8	0.0	1272.4	8605.9	18408.0
Small	48.9	0.0	541.9	5885.5	12034.8
Semi-medium	18.1	0.0	237.4	2749.7	15218.2
Medium	21.8	0.0	662.3	4501.0	20653.8
Large	8.5	0.0	168.3	579.0	6777.4
Overall	28.6	0.0	1272.4	5253.5	18378.5
	Farm Yard Manure costs (Rs. /ha of Net Sown Area)				
	Mean	Min	Max	Std	CV
Marginal	844.7	0.0	19793.3	140922.8	16683.3
Small	942.5	0.0	9483.9	110938.4	11770.4
Semi-medium	371.0	0.0	4069.5	54334.2	14645.4
Medium	435.8	0.0	10302.8	74482.4	17090.3
Large	168.8	0.0	2714.8	10671.4	6323.8
Overall	554.9	0.0	19793.3	90715.0	16346.9

Source: Estimates based on primary survey data 2022-23

The results in table 3.8 discuss the use and cost per hectare of farm yard manure. Farmers in Punjab prefer to use synthetic fertilizers and give farm yard manure as an optional choice. It is mainly limited to farmers who own their livestock, and most

livestock owners are small farmers compared to large farmers. Therefore, a farm yard manure cost is the maximum incurred by small farmers, and for large farmers, it is not very important, primarily used in combination with synthetic fertilizers. On average, farm yard manure (FYM) costs Rs. 554.94, with a high variability within all landholding sizes. This variation is a sign of agronomic practices followed by the farmers and their choice and availability of farm yard manure.

3.4.9 Insecticides Costs per hectare of Net Sown Area (Rs. /ha of Net Sown Area)

Pest attacks destroy a significant number of crops every year. Proper crop management and protection from external attacks are required to grow food for the entire world population. Several types of insecticides are available in the market, and most farmers in India, due to a lack of proper extension services, are misguided by shopkeepers into buying unnecessary insecticides that prove harmful to their crops.

Table 3.9: Insecticides cost per hectare (Rs. /ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	5218	1440.0	13387.5	97598.3	1870.3
Small	5025	1275.8	12991.6	126103.9	2509.8
Semi-medium	5810	499.5	14932.2	159942.9	2752.7
Medium	6380	1793.5	16155.5	154135.3	2416.1
Large	7129	1505.3	15210.7	80372.9	1127.3
Overall	5808	499.5	16155.5	130609.9	2248.7

Source: Estimates based on primary survey data 2022-23

Table 3.9 discusses the insecticide costs across the landholding size. Large farms utilize insecticides in abundance since managing pests became more difficult as farm sizes increased (Jørgensen et al., 2019). Large farmers should adopt Integrated Pest Management Strategies (IPM) to manage the cost of cultivation; that is, a holistic approach involving management strategies to minimize the impacts of pest attacks

while reducing the dependence on chemical insecticides. On average, they are paying around Rs. 5808.13 per hectare to manage pests using insecticides. The variation in insecticide costs is also high, indicating the level of pest attacks on farmers' crops. Lack of extension education also contributes to the increase in insecticide costs because farmers are unaware of the type of sprays they should prefer to maintain the yield rate.

3.4.10 Lease in Land Cost per hectare of Net Sown Area (Rs. /ha of Net Sown Area)

Farmers prefer to lease more land to gain economies of scale. However, land rent differs across the whole state due to the non-availability of the formal rent market. The main factors contributing to land rent are the location of the land, soil quality, distance from the market, and demand rates.

Table 3.10: Average Lease in Land cost (Rs. /ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	4394	0.0	90520.8	590120.3	13429.1
Small	4188	0.0	58543.8	556367.2	13284.6
Semi-medium	6966	0.0	69605.3	963703.1	13835.1
Medium	6213	0.0	65170.7	880444.0	14171.3
Large	11650	0.0	77079.7	531463.8	4562.1
Overall	6117	0.0	90520.8	730965.8	11950.3

Source: Estimates based on primary survey data 2022-23

As per table 3.10, farm size and land lease costs per hectare are positively correlated. The results are very much in line with the assumption that as the landholding size increases, the cost of leased-in land also increases. Ideally the marginal farmers should try to increase their land, but the cost of leasing does not allow them to rent more land. Although large farms even paid a high amount in leases in land costs, they remained profitable through their farm management practices and choice of cropping

pattern. The variations within the same farm size are high in lease land costs due to regional variation and its effect on land quality. For instance, the land lease cost is higher in central Punjab than in western Punjab.

3.4.11 Imputed Rent Cost per hectare Net Sown Area(Rs./ha of Net Sown Area)

To know the profitability of a farming business, imputed rent costs play a significant role. It is an opportunity cost associated with the use of land. The farmer decides, through imputed rent costs, that he should use his land for farming operations or lease it out for rental purposes. The decision on on-farm investment and resource allocation is also related to imputed rent costs.

Table 3.11: Imputed Rent cost per hectare of (Rs./ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	62627	10943.7	97329.0	762259.8	1217.2
Small	60899	0.0	85487.4	796144.7	1307.3
Semi-medium	60179	0.0	100342.4	1296171.2	2153.9
Medium	63824	3249.6	88982.9	964315.8	1510.9
Large	61358	6975.1	113120.4	566898.7	923.9
Overall	61754	0.0	113120.4	911760.7	1476.4

Source: Estimates based on primary survey data 2022-23

Table 3.11 discusses the mean imputed rent cost of around Rs. 61754.06. The imputed rent costs are almost the same for all landholding sizes, with slight variations. The marginal size group showed the maximum variation in imputed rent costs, which may be the location-specific nature of landholdings close to the market. The variation for imputed rent costs within groups is high because some farmers do not consider the imputed rent costs principle. In contrast, others study in detail to forecast the accurate profitability level.

3.4.12 Depreciation costs per hectare for Net sown Area (Rs. /ha of Net Sown Area)

In agricultural economics, depreciation is crucial in evaluating the precise estimation of productivity and profitability. With the help of depreciation, farmers can value and manage their fixed assets efficiently. It is calculated annually and helps determine overall operating expenses across the year.

Table 3.12: Depreciation cost per hectare (Rs. /ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	12387	250.0	60089.2	625631.8	5050.9
Small	12229	484.0	97548.6	930735.2	7611.1
Semi-medium	12029	1556.3	154709.4	1309689.2	10888.1
Medium	9628	1501.7	104511.0	748047.3	7769.1
Large	9165	1216.7	43064.9	224296.7	2447.2
Overall	11288	250.0	154709.4	846699.3	7501.1

Source: Estimates based on primary survey data 2022-23

Table 3.12 indicated that, on average, farmers pay Rs. 11288 per hectare on the wear and tear of farm machinery, which is depreciation. As depreciation costs of large farms spread across a greater area, therefore depreciation costs per hectare decrease as farm size increases. Although they use the latest and most modern equipment, which results in more depreciation, they manage with their scale. In contrast, small farmers have high depreciation costs, which may result from using obsolete farm machinery or not using fixed assets properly.

3.4.13 Fixed Capital Costs per hectare of Net Sown Area (Rs. /ha of Net Sown Area)

Fixed capital costs deal with the purchase, maintenance, and depreciation of fixed assets like land, buildings, machinery and equipment, and renovations of farming infrastructure. Fixed capital costs help farmers understand their fixed asset costs and

motivate them to use farm equipment efficiently, which reduces their per-hectare costs, promoting their productivity and profitability.

Table 3.13: Fixed Capital cost per ha (Rs. /ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	428301	6363.3	1616415.4	17938173.5	4188.2
Small	575594	4275.0	4246287.0	42451009.7	7375.2
Semi-medium	512235	32151.6	3571475.1	37164019.4	7255.3
Medium	478924	88005.8	2661911.9	22243768.4	4644.5
Large	477118	97690.0	1517605.1	7284317.5	1526.7
Overall	500888	4275.0	4246287.0	28395076.3	5669.0

Source: Estimates based on primary survey data 2022-23

Table 3.13 indicates that farmers are investing Rs. 500887 on average in fixed capital assets. Large farms showed the lowest fixed capital costs for spreading their fixed costs across the land and achieving economies of scale. In addition, large farms did not show much variance in fixed capital costs because almost all large farms have the same investment in their fixed assets. Other farms showed maximum variance except for large farms, indicating that some farmers prefer to own their fixed capital assets like tractors, discs and cultivators, Happy Seeders, rotavators, etc. However, others prefer to rent from Agriculture Machinery Center (AMC) and other private dealers.

3.4.14 Other Costs per hectare of Net Sown Area (Rs./ha of Net Sown Area)

Other costs refer to miscellaneous costs that do not fall under the main production cost categories. These costs include transportation, extension services, fuel costs, etc.

Table 3.14: Other cost per ha (Rs./ha of Net Sown Area)

Size group	Mean	Min	Max	Std	CV
Marginal	168	0.0	5132.0	25586.0	15191.9
Small	116	0.0	2932.8	17361.0	15003.7
Semi-medium	121	0.0	2105.3	20389.0	16838.8
Medium	75	0.0	939.0	10212.7	13658.1
Large	64	0.0	1118.6	5069.1	7912.1
Overall	111	0.0	5132.0	17348.2	15661.3

Source: Estimates based on primary survey data 2022-23

Table 3.14 indicates that, on average, farmers incur Rs. 111 per hectare on other costs. Unlike primary costs such as machines, fertilizers, etc., with the increase in farm size, other costs come down per hectare due to operation efficiency and resource management. On the other hand, small farms paid the maximum for other costs because of their inefficiencies. Small farmers' maximum variation in other costs is operational inefficiencies and the need for more management. These problems of small farmers need to be addressed to reduce their primary and miscellaneous costs.

3.5 Conclusion

After 1991, the cultivation costs increased at an accelerated rate due to the withdrawal of subsidies by the government on farm inputs. Farmers in Punjab state started leasing their farms rather than cultivating crops on them due to the escalating cost of farming. Marginal and small farmers are at the top of the list for renting out their farms. It requires a complete cost component analysis of various farm inputs across farm size groups. As per our study area, Punjab, input use and production costs are influenced by farm size. Large farms, for their ability to invest in modern technology, reduced their per-hectare expenses on farm inputs. Resources are utilized more expertly when technology is accessible, and economies of scale are possible due to the spreading of costs over a larger output.

First and foremost, farm inputs whose costs have an inverse relationship with farm sizes, like labour, machine costs, farm yard manure, animal costs, irrigation machine costs, depreciation, fixed capital costs, and other costs. Labour is one of the main components of crop cultivation. The labour shortage in the agriculture sector increases the cost of cultivation for the farm sizes that depend upon labour for farming operations. Large farms have a minimum per hectare labour cost of Rs.22151, whereas small farms pay Rs.31285 because they use more machines for farming operations and thus pay less than others. The use of machines increased their cost of consumption of fixed capital per hectare, but the ability to spread the machinery and depreciation costs across large areas resulted, on average, in large farms paying only Rs.9165 for depreciation, whereas small farms pay around Rs.12386. Large farmers do not depend upon animals and farm yard manure for farming operations; thus, animal costs are only Rs. 15 for them, whereas for small farms, it is around Rs. 455. In addition, with the increase in farm size, other costs or miscellaneous expenses have come down.

The second category was a positive relationship between farm size and farm input costs. The farm inputs, like seed use, insecticides, leased land, and fixed capital costs, showed a positive relationship with farm size. Large farmers must pay more for seeds, as they use high-quality seeds in large amounts compared to others and pay around Rs.6828 per hectare. Similarly, for insecticides, Rs.7129 per hectare is quite more than other categories. Large farms maintained a significant fixed capital stock and spent more per hectare. Furthermore, leased land costs are high for large farms because they even pay more to lease fertile lands. The last category revealed farm inputs having no correlation with the size of farms. Farm inputs like fertilizers and imputed rent costs did not show any variation, and almost each farm size paid the same on average, around Rs. 9000 for fertilizers and Rs. 61734 for imputed rent costs. The above results showed that larger farms in Punjab generally have lower average costs per unit of output than smaller farms. Economies of scale, operational efficiency, better management practices, and proper resource allocation are the main reasons that favour large farms. Therefore, farmers in Punjab prefer to expand their farming operations by buying additional land plots or leasing land.

In addition, the cost difference of input use is not only related to the landholding sizes; the variation in input costs is also exhibited within size groups. Except for large farms, all other landholding sizes showed high variations in using farm inputs due to following different types of agronomy practices and management strategies. Large farms showed consistency within the group for farm input use and costs because most large farms followed similar agronomic practices. The outcome produced using the combination of various farm inputs, called the value of crop output, is almost the same for each landholding size, suggesting that farm size does not impact the value of crop output, which is called productivity per hectare; however, the variation in farm inputs used and costs affects their cost of cultivation and profit.

CHAPTER IV

RELATIONSHIP BETWEEN FARM SIZE, PRODUCTIVITY, AND PROFITABILITY IN PUNJAB AGRICULTURE

4.1. Introduction

The entire purpose of doing agriculture is to maximize profits. The size of the farm significantly affects its productivity, posing the question of whether there is a relationship between farm size, productivity, and profitability. In the previous chapter, the cost of cultivation across landholding size was analyzed. The results showed that government policies impacted the cost of cultivation. The input use and the production costs influenced the farm size, as larger landholdings allow farmers to invest more in mechanization. In this chapter, an inquiry was made about whether landholding size impacted productivity and profitability. In the first part, the literature review has been done, followed by the methodology used in the chapter, and the last part discusses the relationship between farm size, productivity, and profitability. The analysis is based on the primary survey conducted in the year 2022-23.

4.2. Literature Review

Since the commencement of the Green Revolution in Punjab, the region's agricultural output has almost doubled. The integration of technology with government initiatives yielded positive results, thus making Punjab the granary of the country (Singh, 2022). However, the overuse of modern farm inputs has raised cultivation costs and negatively impacted the sustainability of farming, particularly for small and marginal farmers. This has prompted a debate concerning bringing down the cultivation costs to further boost productivity and profitability. The factors influencing farm productivity are input costs, labour costs, land costs, capital costs, and operational costs. Utilizing farm inputs significantly enhances farm productivity manifold, like the use of high-yield variety seeds, which increased per hectare productivity in Punjab compared to the national average. The use of HYV seeds requires a high dosage of nitrogen (N), phosphorus (P), and potassium (K) to enhance the soil

nutrient level, and the increased availability of these nutrients directly correlates with higher yields per hectare (Wahyuni et al., 2024). Likewise, each year, the use of pesticides in Punjab saves a huge portion of yield from pest attacks, which increased per-hectare productivity in Punjab more than in other states of India (Tudi et al., 2021). The expansion of the area covered by planned modern irrigation infrastructure and the government policies of free electricity and subsidies for purchasing efficient irrigation equipment, etc., increased per-hectare productivity in Punjab (Kaur et al., 2015). Apart from the basic farm inputs, farm productivity depends upon the labour in Punjab. With the structural transformation in Punjab, agricultural labour shifted from agriculture to the non-farm sector with attractive wage rates (Singh, 2020; Sharma, 2023). Shifting of labour introduced mechanization in Punjab agriculture, and the productivity of labour increased, which reduced labour costs and enhanced efficiency. Regardless, the farm size transition to mechanized farming requires initial capital investment, which can be a barrier for smallholder farmers. Land and capital costs are also important in determining farm productivity. Land costs involve rents paid or purchase price for agricultural land. Economies of scale through optimal utilization of resources are possible for large landholdings. In contrast, small farms in Punjab deal with land fragmentation and suffer from inefficiency and high cultivation costs (Lu et al., 2018). Capital costs involve investment in farm machinery, technology adoption, and other farm infrastructure. The level of capital costs directly depends upon the access to credit facilities. The majority of financial institutions, including banks, have complicated requirements and collateral for providing credit facilities. Marginal farmers are unqualified for these requirements, which forces them to rely upon non-institutional sources of credit (Kumar & Kaur, 2017; Pandey, 2022). Finally, and above all, operational costs also influence farm productivity, including day-to-day expenses incurred during farming activities such as fuel for machinery and maintenance costs. Sound management of operational costs is integral for preserving efficiency and productivity.

The interesting dualism here is that increased cost on inputs positively impacted productivity; however, profitability was negatively impacted. It was observed that in order to control food inflation, the government does not allow a rise in agriculture

output prices to correspondingly rise in farm input prices like seeds, fertilizers, and pesticides (Rivai, 2022). It adversely affected the net profit margin of farmers. Farmers involuntarily invest in expensive farm machinery, which makes their farming operation more expensive due to the non-availability of farm labour during peak season. Therefore, many small and marginal farmers are leaving agriculture in Punjab due to the non-lucrative nature of farming for them. This increased the reverse tenancy, and large farmers are getting benefits from the economies of scale and are able to spread both their fixed and variable costs and maintain their venture's profitability. In addition, these farms are able to maintain their connections with wholesale markets and earn surplus profits (Lee et al., 2020). They follow marketing channels and strategies to improve their sales and earn healthy returns. Thus, farm size in Punjab has been increasing and showing a stark contrast to the pictures in other Indian states (Bera, 2015). However, the government needs to intervene to safeguard the interests of small and marginal farmers, as the lion's share of the Punjab population relies on agriculture for their livelihood.

4.3 Database and Methodology

Variables included in the study

The variables we included to study to explore the relationship between farm size, productivity and profitability are:

Cost A1: Cost A1 including the cost of the components as listed below:

- Cost on Labour use (Rs /per ha of net cropped area)
- Cost on Machine use (Rs./per ha of net cropped area)
- Cost of Irrigation Machine use (Rs. /per ha of net cropped area)
- Cost on Animal use (Rs/per ha of net cropped area)
- Cost on Seed use (Rs./per ha of net cropped area)
- Cost on Fertilizers use (Rs./per ha of net cropped area)
- Cost on Farm Yard Manure (Rs/ per ha of net cropped area)
- Cost on Insecticide use (Rs./per ha of net cropped area)

- Depreciation (Rs. /per ha of net cropped area)
- Other Costs (Rs./ per ha of net cropped area)

2. Cost A2:

It includes Cost A1+ Rent paid for leased in land.

3. Cost B1:

Cost A1+ Interest on value of owned fixed capital assets.

4. Cost B2:

Cost B1+ Imputed Rent of own land.

One –Way Analysis of Variance (One Way- ANOVA)

The limitation of the *t*-test and *z*-test in comparing more than two groups is addressed by Analysis of Variance (ANOVA), which enables simultaneous comparison of multiple group means (Statistics Solutions, 2024). In this study, one-way ANOVA is employed to examine the effect of farm inputs on productivity and profitability across five landholding categories. In one-way ANOVA, the F-statistic is computed as:

$$F = \frac{MST}{MSE}$$

where the **Sum of Squares Between groups (SSB)** measures variation between group means and the grand mean:

$$SSB = \sum_{i=1}^k n_i (\bar{X}_i - \bar{X})^2$$

The **Mean Square for Treatment (MST)** is calculated as:

$$MST = \frac{SSB}{k - 1}$$

The **Sum of Squares Error (SSE)** captures within-group variation:

$$SSE = \sum (X_{ij} - \bar{X}_i)^2$$

The **Mean Square Error (MSE)** is given by:

$$MSE = \frac{SSE}{N - k}$$

These components together determine whether differences in group means are statistically significant.

Post-Hoc Tests

Post-hoc tests are multiple-comparison procedures used after a significant ANOVA F-statistic to know which specific group means differ, while meticulously controlling the family wise Type I error rate arising from repeated pair wise comparisons. These procedures adjust critical values or comparison thresholds to maintain the experiment-wise α -level (Juarros-Basterretxea et al., 2024). Common methods used to perform post-hoc are Bonferroni adjustment, Fisher's LSD, Tukey's Studentized Range Test, Scheffé's method, and Dunnett's correction.

In this study, Tukey's Studentized Range Test was used. This test evaluates all pairwise contrasts using the Studentized Range Statistic (q) and estimates significance based on the Honest Significant Difference (HSD), which shows the minimum mean separation required for statistical significance (Nanda et al., 2021).

Formula (Tukey's HSD)

$$\text{HSD} = q_{\alpha, k, df_{\text{error}}} \sqrt{\frac{\text{MSE}}{n}}$$

A pairwise mean difference is significant when:

$$|\bar{X}_i - \bar{X}_j| \geq \text{HSD}$$

4.4 Results & Discussions

4.4.1 Relationship between farm size and productivity

The value of crop output involves the financial value of the product generated. It helps us to know the region's agriculture level. The crop output value is calculated through agricultural productivity and crop yield. For the productivity method, we need to compare the market value of the final output to the input used. For the crop yield

method, we measure the value of crop output by the agricultural production harvested per unit of land area.

Table 4.1: Analysis of Variance of productivity (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7892354205	1973088551	1.15	0.3342
Error	403	693588459544	1721063175		
Corrected Total	407	701480813749			

Source: Estimation based on survey data 2022-23

Table 4.2: Results of Post Hoc test (Tukey's) on productivity (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95 % Confidence Limits		Significance
Marginal – Small	6698	-11166	24562	
Marginal - Semi-Medium	8047	-9653	25746	
Marginal – Medium	1300	-16453	19054	
Marginal – Large	-3883	-21691	13925	
Small – Marginal	-6698	-24562	11166	
Small - Semi-Medium	1349	-16462	19160	
Small – Medium	-5397	-23262	12467	
Small – Large	-10581	-28499	7338	

Semi-Medium – Marginal	-8047	-25746	9653	
Semi-Medium – Small	-1349	-19160	16462	
Semi-Medium – Medium	-6746	-24446	10954	
Semi-Medium – Large	-11930	-29684	5825	
Medium – Marginal	-1300	-19054	16453	
Medium – Small	5397	-12467	23262	
Medium - Semi-Medium	6746	-10954	24446	
Medium – Large	-5183	-22992	12625	
Large – Marginal	3883	-13925	21691	
Large – Small	5183	-12625	22992	
Large - Semi-Medium	10581	-7338	28499	
Large – Medium	11930	-5825	29684	
Number of Observations	408			
F Statistics	1.15			

Source: Estimation based on survey data 2022-23

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and *.**

Table 4.1 and Table 4.2 show that the value of crop output across the landholding sizes is almost the same. This proved that farm size has no relationship with the value of crop output (Sheng & Chancellor, 2018). The post-hoc test showed that marginal farms, due to high cropping intensity, produced more output than small, semi- medium, and medium farms. Therefore, the value of crop output of marginal farms is more than other landholding sizes except large farms. Large farms have better access to the market and get better prices due to their connections with wholesale markets, whereas marginal farmers struggle to obtain fair prices for their smaller volumes.

4.4.2 Relationship between farm size and cost of cultivation

Cost A2+ Family Labour (Rs/ha of NSA): The cost of cultivation determines the financial viability of farming operations and the cropping pattern (Ruma et al., 2023). In agriculture, we include variable and fixed costs when calculating the cost of cultivation. Variable costs involve seeds, fertilizers, and labour expenses whereas fixed costs comprise land rent and machinery depreciation. In addition, the Government of India uses the cost of cultivation to calculate the Minimum Support Price (MSP). Cost A2+ Family Labour measures the Minimum Support Price (MSP) in India. Cost A2+ Family Labour metrics include paid-out costs and the economic contribution of family members. However, the National Commission on Farmers (NCF) headed by M.S. Swaminathan, supported that MSP should be calculated at 50 per cent above comprehensive costs (C2) (Geetha & Mahesh, 2019).

Table 4.3: Analysis of Variance of cost (Cost A2+Family Labour) of cultivation (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	179763030690	44940757672	25.38	<.0001
Error	403	713593508219	1770703494.3		
Corrected Total	407	893356538909			

Source: Estimation based on survey data 2022-23

Table 4.4: Results of Post Hoc test (Tukey's) on cost (Cost A2+Family Labour) of cultivation (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal - Small	39858	21738	57978	***
Marginal - Semi-Medium	50570	32616	68523	***
Marginal - Medium	58891	40883	76899	***
Marginal - Large	51127	33064	69190	***
Small - Marginal	-39858	-57978	-21738	***
Small - Semi-Medium	10711	-7354	28777	
Small – Medium	19033	913	37153	***
Small – Large	11269	-6906	29444	
Semi-Medium - Marginal	-50570	-68523	-32616	***
Semi-Medium - Small	-10711	-28777	7354	
Semi-Medium - Medium	8321	-9632	26275	

Semi-Medium - Large	558	-17451	18567	
Medium - Marginal	-58891	-76899	-40883	***
Medium - Small	-19033	-37153	-913	***
Medium - Semi-Medium	-8321	-26275	9632	
Medium - Large	-7764	-25827	10300	
Large - Marginal	-51127	-69190	-33064	***
Large – Small	-11269	-29444	6906	
Large - Semi-Medium	-558	-18567	17451	
Large – Medium	7764	-10300	25827	
Number of observations	408			
F-Statistics	25.38***			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23 w

Table 4.3 and Table 4.4 discuss the cost of cultivation between the landholding sizes. The overall F-statistics and p-value < .0001 indicate that the cost of cultivation between the five landholding groups differs. The results of Tukey's post hoc test also supported that a significant difference exists in the cost of cultivation across landholding sizes. Marginal farms bear the maximum cultivation costs compared to the remaining landholding sizes. High-input agricultural practices, including chemical fertilizers, pesticides, and hybrid seeds, are part of the Green Revolution strategies. No doubt, this reduced the productivity difference across landholding sizes but made farming unaffordable for marginal farmers. Unlike large farms, the benefits of economies of scale are unavailable for marginal farms, resulting in high per-hectare costs (Duffy, 2009; Singh & Singh, 2018). Marginal farmers also discriminated against credit availability due to a lack of collateral securities, which resulted in their cost of cultivation due to their dependence on non-institutional sources of credit.

Apart from marginal farms, small farms also showed a statistically significant difference in the cost of cultivation compared to medium farms due to resource access. The access level of resources for medium farms is relatively higher than for small farms. This access reduces the per hectare cost of cultivation of medium farms.

4.4.3 Relationship between farm size and Labour Costs (Rs/ha of NSA)

Labour is an essential and significant component of the total costs. While working on the level of productivity and profitability across landholding sizes, we must understand the labour costs efficiently because they, directly and indirectly, affect the level of productivity and profitability (Pawłowska & Jaroszevska, 2020). To calculate productivity across landholding sizes, we incorporate metrics such as labour hours per hectare or output per labour hour (Shanmugan & Baria, 2019). Similarly, the proper total cost structure must be evaluated to work with profitability, and labour costs must represent a significant share of total costs.

Table 4.5: Analysis of Variance of labour use costs (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	3250065142	812516285	13.84	<.0001
Error	403	23655954648	58699639		
Corrected Total	407	26906019790			

Source: Estimates based on the primary survey 2022-23

Table 4.6: Results of Post Hoc test (Tukey's) on cost of labour use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal – Small	3835	536	7134	***
Marginal - Semi-Medium	6790	3522	10059	***
Marginal – Medium	7036	3757	10314	***
Marginal – Large	7449	4161	10738	***
Small – Marginal	-3835	-7134	-536	***
Small - Semi-Medium	2955	-334	6244	
Small – Medium	3200	-99	6500	
Small – Large	3614	305	6923	***
Semi-Medium - Marginal	-6790	-10059	-3522	***
Semi-Medium - Small	-2955	-6244	334	
Semi-Medium - Medium	245	-3024	3514	
Semi-Medium - Large	659	-2620	3938	
Medium – Marginal	-7036	-10314	-3757	***
Medium – Small	-3200	-6500	99	
Medium - Semi-Medium	-245	-3514	3024	
Medium – Large	414	-2875	3703	
Large – Marginal	-7449	-10738	-4161	***
Large – Small	-3614	-6923	-305	***
Large - Semi-Medium	-659	-3938	2620	
Large – Medium	-414	-3703	2875	
Number of Observations	408			
F Statistics	13.84***			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

Table 4.5 and Table 4.6 show that the labour cost is not the same across the landholding sizes. With the increase in farm size, the labour costs start declining. Marginal farms showed statistically significant higher costs than other landholding sizes. Marginal farms paid the maximum for labour per hectare. Marginal farms are not suitable for mechanical operations due to their size restrictions. Therefore, marginal farms are basically labour intensive by nature and demand more labour usually seasonal workers, which drives up labour costs because they pay higher wages to attract them during peak seasons (Foster & Rosenzweig, 2017).

4.4.4 Relationship between farm size and machine use Costs (Rs/ha of NSA)

With the advent of the Green Revolution, the use of machines in agriculture has increased manifold. The various farm practices, like winnowing, threshing, sowing, etc., have been shifted from manual to mechanical (Parayil, 1992). However, understanding machinery costs is essential for costs and earning sufficient returns. When deciding to invest in a particular piece of farm machinery, we must evaluate the total cost of ownership, including maintenance charges like depreciation, insurance, repairs, etc. If machinery ownership is not feasible, we could shift towards rental machinery models to reduce the cost of cultivation (Singh, 2017).

Table 4.7: Analysis of Variance of cost of machine use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	139254291945	34813572986	86.76	<.0001
Error	403	161715738696	401279748.62		
Corrected Total	407	300970030640			

Source: Estimates based on the primary survey 2022-23

Table 4.8: Results of Post Hoc test (Tukey's) on cost of machine use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal – Small	33558	24932	42184	***
Marginal - Semi-Medium	42512	33965	51058	***
Marginal – Medium	48357	39784	56929	***
Marginal – Large	50447	41848	59046	***
Small – Marginal	-33558	-42184	-24932	***
Small - Semi-Medium	8954	354	17554	***
Small – Medium	14799	6173	23425	***
Small – Large	16889	8237	25541	***
Semi-Medium - Marginal	-42512	-51058	-33965	***
Semi-Medium - Small	-8954	-17554	-354	***
Semi-Medium - Medium	5845	-2702	14391	
Semi-Medium - Large	7935	-638	16508	
Medium – Marginal	-48357	-56929	-39784	***
Medium – Small	-14799	-23425	-6173	***
Medium - Semi-Medium	-5845	-14391	2702	
Medium – Large	2090	-6509	10689	
Large – Marginal	-50447	-59046	-41848	***
Large – Small	-16889	-25541	-8237	***
Large - Semi-Medium	-7935	-16508	638	
Large – Medium	-2090	-10689	6509	
Number of Observations	408			
F Statistics	86.76***			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

The cost of machine use varied significantly across land size in Punjab, as shown by Tables 4.7 and 4.8. There is a significant difference between the marginal landholding and all the other three sizes of landholding for machine use costs. Similarly, small landholding also has a significant difference with the other four groups. This divergence resulted from differences in farm area and production volume across landholding sizes. Both marginal and small farm size groups paid statistically significant higher machine use costs than other landholding size groups. It was observed during our survey that marginal farms pay more than small farms because they solely depend upon the rental market for machinery, and due to limited land area, machine operators charge them more than small farms. Marginal farms' dependence upon the rental market for machinery increases their per-hectare costs of machine use compared to semi-medium, medium, and large farms because these farms use their own machinery rather than renting from the market. Likewise, small farms paid more machinery costs because the majority of small farmers in Punjab own their tractors and other farm machinery, which makes their farming operations less economical and less efficient than medium and large farms.

4.4.5 Relationship between farm size and Irrigation machine use Costs (Rs/ha of NSA)

The availability of irrigation facilities positively impacts the productivity of farms because the yield per hectare of irrigated crops is almost twice that of rain-fed crops (Jaramillo et al., 2020). This increased per-hectare productivity would stimulate the profitability level as well. The initial investment, maintenance costs, replacement, power consumption, labour use and potential returns should be evaluated before investment in irrigation machinery like tube wells operated by diesel and electricity. Moreover, the Agro-climatic region must be considered while deciding about irrigation costs. The zone having the issue of water scarcity should consider water- saving technologies like drip irrigation and sprinkler systems for efficient utilization of water (Noreldin et al., 2016; Singh et al., 2018).

Table 4.9: Analysis of Variance of cost of Irrigation use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	504921663	126230416	7.24	<.0001
Error	403	7027643764	17438322		
Corrected Total	407	7532565427			

Source: Estimates based on the primary survey 2022-23

Table 4.10: Results of Post Hoc test (Tukey's) on Irrigation machine use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal-Small	1172.7	-625.5	2970.9	
Marginal-Semi Medium	2142.1	360.4	3923.8	****
Marginal-Medium	2648.9	861.8	4435.9	****
Marginal-Large	3110.3	1317.7	4902.8	****
Small-Marginal	-1172.7	-2970.9	625.5	
Small-Semi-Medium	969.4	-823.4	2762.2	
Small-Medium	1476.1	-322.1	3274.3	
Small-Large	1937.6	133.9	3741.2	****
Semi-Medium-Marginal	-2142.1	-3923.8	-360.4	****

Semi-Medium-Small	-969.4	-2762.2	823.4	
Semi-Medium-Medium	1476.1	-1274.9	2288.4	
Semi-Medium-Large	1937.6	-819	2755.4	
Medium-Marginal	-2142.1	-4435.9	-861.8	***
Medium-Small	-969.4	-3274.3	322.1	
Medium-Semi-Medium	1476.1	-2288.4	1274.9	
Medium-Large	461.4	-1331.1	2254.0	
Large-Marginal	-3110.3	-4902.8	-1317.7	***
Large-Small	-1937.6	-3741.2	-133.9	***
Large-Semi-Medium	-968.2	-2755.4	819.0	
Large-Medium	-461.4	-2254.0	1331.1	
Number of Observations	408			
F Statistics	7.24**			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

Tables 4.9 and 4.10 show that the cost of irrigation machine use varies significantly across landholding size in Punjab. There is a significant difference between the marginal landholding and all the other three sizes of landholding. Similarly, small landholding also has a significant difference with the large landholding size. The significant difference between irrigation costs across landholding sizes is due to government subsidies on electricity used for pumping water and financial support for installing water-saving irrigation systems. Farmers during the survey opened up about the assistance provided by the government for adopting modern irrigation techniques

due to water table issues in Punjab and said that the majority of schemes are not meant for marginal and small farms. They need to invest by taking loans from outside sources. Thus, per hectare, irrigation cost is higher for marginal farms than for medium and large farms. Similarly, small farms also showed a statistically significant difference in irrigation cost and paid more than large farms on account of the non-spreading of irrigation machinery costs across large areas.

4.4.6 Relationship between farm size and Animals use Costs (Rs/ha of NSA)

The animal-related costs have reduced their share in the total cultivation costs with the involvement of mechanization in farming operations (Lohan et al., 2015; Shrivastava et al., 2021). Now marginal farmers depend on machines to perform their agricultural operations timely to increase per-hectare profitability through machinery rental models (Aundhakar, 2023). However, animal use costs matter somewhere, which is why they are included in the cost of cultivation.

Table 4.11: Analysis of Variance of cost of Animal use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	3624247.72	906061.93	4.59	0.0012
Error	403	79598128.68	197513.97		
Corrected Total	407	83222376.40			

Source: Estimates based on the primary survey 2022-23

Table 4.12: Results of Post Hoc test (Tukey's) on cost of Animal use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal-Small	91.37	-100.00	282.75	

Marginal-Semi-Medium	178.44	-11.17	368.06	
Marginal-Medium	244.07	53.88	434.25	***
Marginal-Large	243.80	53.03	434.58	***
Small-Marginal	-91.37	-282.75	100.00	
Small-Semi-Medium	87.07	103.73	277.87	
Small-Medium	152.69	-38.68	344.07	
Small-Large	152.43	-39.53	344.39	
Semi-Medium-Marginal	-178.44	-368.06	11.17	
Semi-Medium-Small	-87.07	-277.87	103.73	
Semi-Medium-Medium	65.62	-123.99	255.24	
Semi-Medium - Large	65.36	-124.84	255.56	
Medium-Marginal	-244.07	-434.25	-53.88	***
Medium-Small	-152.69	-344.07	38.68	
Medium-Semi-	-65.62	-255.24	123.99	

Medium				
Medium- Large	-0.26	-191.04	190.51	
Large- Marginal	-243.80	-434.58	-53.03	***
Large-Small	-152.43	-344.39	39.53	
Large-Semi Medium	-65.36	-255.56	124.84	
Large - Medium	0.26	-190.51	191.04	
Number of Observations	408			
F Statistics	4.59***			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

Tables 4.11 and 4.12 show that the statistically significant difference prevails across landholding sizes for the animal cost per hectare. As farm size increases, animal costs go down. Marginal farms spent the most on animal costs and showed statistically significantly higher costs on animals than medium and large farms. The socio-economic characteristics of farmers across landholding sizes decide the animal cost (Yang et al., 2022; Rah & Choi, 2023). Large farms usually have infrastructure like barns and fencing and contacts with vets. These facilities for the animals make them healthier and more productive and reduce per-hectare animal costs compared to small and marginal farms.

4.4.7 Relationship between Farm Size and Seed Use Costs (Rs/ha of NSA)

The adoption of high-quality seeds leads to a positive impact on productivity and profitability. The productivity of crops increased due to reduced crop failure by introducing high-quality seeds that withstand adverse weather conditions or pest invasion (Elias, 2018; Bailly & Roldan, 2023). The yield per hectare of high-quality seeds is almost double that of a traditional variety (Yoshinaga et al., 2013). Profitability also escalated with high-quality seeds because these varieties can induce the efficient

utilization of fertilizers and pesticides. Proper estimation of seed costs requires considering the seeding rate and the price of seed treatment costs.

Table 4.13: Analysis of Variance of cost of seed use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	240008049	60002012	1.26	0.2864
Error	403	19240249111	47742554		
Corrected Total	407	19480257160			

Source: Estimates based on the primary survey 2022-23

Table 4.14: Results of Post Hoc test (Tukey's) on seeds use costs (Rs./ha of net sown area) among Farm size group

Size-Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal-Small	280	-2695	3256	
Marginal-Semi-Medium	578	-2370	3526	
Marginal-Medium	590	-2367	3547	
Marginal-Large	-1480	-4446	1486	
Small-Marginal	-280	-3256	-2695	
Small-Semi-Medium	298	-2668	3264	
Small-	310	-2666	3285	

Medium				
Small-Large	-1760	-4745	1224	
Sem-Medium-Marginal	-578	-3526	2370	
Semi-Medium-Small	-298	-3264	2668	
Semi-Medium-Medium	12	-2936	2959	
Semi-Medium-Large	-2058	-5016	899	
Medium-Marginal	-590	-3547	2367	
Medium-Small	-310	-3285	2666	
Medium-Semi-Medium	-12	-2959	2936	
Medium-Large	-2070	-5036	896	
Large-Marginal	1480	-1486	4446	
Large-Small	1760	-1224	4745	
Large-Semi-Medium	2058	-899	5016	
Large - Medium	2070	-896	5036	
Number of Observations	408			

F Statistics	1.26***
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Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

Tables 4.13 and 4.14 show that the seed costs do not have statistically significant differences across landholding sizes. Post-hoc test followed by one-way ANOVA did not find any pair that showed a statistically significant difference in seed costs. The seed costs across the landholding sizes are exact because the majority of interviewed farmers reported that they used the seed rate and variety prescribed by Punjab Agriculture University. In addition, the prices of seed packets are almost the same everywhere; even private dealers cannot sell seeds for more than MRP as per Punjab Government orders (Mahal, 2022).

4.4.8 Relationship between Farm size and Fertilizers use Costs (Rs/ha of NSA)

To maintain global food security, intensive farming practices need to be followed. However, intensive farming requires supplanting soil with artificial nutrients. Fertilizers are pivotal to preparing soil to grow multiple crops annually by providing the necessary nutrients. The fertilizer prices keep fluctuating due to geopolitical tensions like the Russia-Ukraine war (Shahini et al., 2022; Hassen & Bilali, 2022). Thus, the cost of cultivation has been increasing, and farmers should follow precision farming practices to utilize fertilizers efficiently (Ren et al., 2021).

Table 4.15: Analysis of Variance of cost of fertilizers use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	57768433	14442108	2.28	0.0598
Error	403	2549445563	6326168		
Corrected Total	407	2607213995			

Source: Estimates based on the primary survey 2022-23

Table 4.16: Results of Post Hoc test (Tukey's) on fertilizers use costs (Rs./ha of net sown area) among Farm size group

Size-Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal-Small	154.9	-928.2	1238	
Marginal-Semi-Medium	596.9	-476.2	1670.0	
Marginal-Medium	643.4	-432.9	1719.8	
Small-Marginal	-357.4	-1437.1	722.2	
Small-Semi-Medium	-154.9	-1238.0	928.2	
Small-Medium	442.0	-637.8	1521.8	
Small-Semi-Medium	488.6	-594.5	1571.6	
Small-Large	-512.3	-1598.7	574.0	
Semi-Medium-Marginal	-596.9	-1670	476.2	
Semi-Medium-Small	-442	-1521.8	637.8	
Semi-Medium-Medium	46.6	-1026.5	1119.7	
Semi-Medium-Large	-954.3	-2030.7	122.1	
Medium-Marginal	-643.4	-1719.8	432.9	
Medium-Small	-488.6	-1571.6	594.5	
Medium-Semi-Medium	-46.6	-1119.7	1026.5	
Medium-Large	-1000.9	-2080.5	78.8	
Large-Marginal	357.4	-722.2	1437.1	
Large-Small	512.3	-574	1598.7	

Large-Semi-Medium	954.3	-122.1	2030.7	
Large-Medium	1000.9	-78.8	2080.5	
Number of Observations	408			
F Statistics	2.28**			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***.

Source: Estimates based on the primary survey 2022-23

Tables 4.15 and 4.16 show that the fertilizers cost almost the same across the landholding sizes. Post-hoc tests followed by one-way ANOVA did not find any pair that showed a statistically significant difference in fertilizer costs. During the survey, it was found that the fertilizer costs are the same across landholding sizes because farmers adopt similar agronomic practices and follow almost the same fertilizer quantity per hectare; over and above that, the fertilizer control order of 1985 ensures that the central government will fix fertilizer prices for fair distribution of fertilizers (Ministry of Agriculture and Rural Development, 1985).

4.4.9 Relationship between Farm Size and Farmyard Manure Use Costs (Rs/ha of NSA)

Farmyard manure is a perfect substitute for synthetic fertilizers. The application of farmyard manure provides soil essential nutrients like nitrogen (N), phosphorus (P), and potassium (K). Farmyard manure can replace synthetic fertilizers and reduce the cost of cultivation due to continuous increases in fertilizer prices. However, the issue is managing farmyard manure cost-effectively. Particular farmyard manure costs include transportation charges, storage, and application on-field expenses (De Rosa et al., 2021). Furthermore, farmers also need to manage the timely application to get maximum nutrient uptake by crops while reducing the effects of leaching. To reduce the cost of cultivation, a farmer should compare the cost of synthetic fertilizers with farmyard manure before selecting fertilizer. Most farmers prefer the combination of both farmyard manure and chemical fertilizers (Nisar et al., 2022).

Table 4.17: Analysis of Variance of cost of farm yard manure use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	25517053	6379263	2.11	0.0784
Error	403	1216499482	3018609		
Corrected Total	407	1242016534			

Source: Estimates based on the primary survey 2022-23

Table 4.18: Results of Post Hoc test (Tukey's) on farm yard manure use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal – Small	29.4	-718.8	777.5	
Marginal - Semi-Medium	459.5	-281.8	1200.7	
Marginal - Medium	375.8	-367.7	1119.3	
Marginal – Large	646.0	-99.8	1391.9	
Small – Marginal	-29.4	-777.5	718.8	
Small - Semi-Medium	430.1	-315.8	1176.0	
Small – Medium	346.4	-401.7	1094.6	
Small – Large	616.7	-133.8	1367.1	
Semi-Medium - Marginal	-459.5	-1200.7	281.8	
Semi-Medium - Small	-430.1	-1176.0	315.8	
Semi-Medium - Medium	-83.7	-824.9	657.6	
Semi-Medium - Large	186.6	-557.0	930.1	
Medium - Marginal	-375.8	-1119.3	367.7	
Medium – Small	-346.4	-1094.6	401.7	
Medium - Semi-Medium	83.7	-657.6	824.9	
Medium – Large	270.2	-475.6	1016.0	

Large – Marginal	-646.0	-1391.9	99.8	
Large – Small	-616.7	-1367.1	133.8	
Large - Semi-Medium	-186.6	-930.1	557.0	
Large – Medium	-270.2	-1016.0	475.6	
Number of Observations	408			
F Statistics	2.11**			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Tables 4.17 and 4.18 show that the farmyard manure cost is the same irrespective of the farm size group. It is validated by the post-hoc test followed by one-way ANOVA, as not a single pair showed a statistically significant difference in farmyard manure cost per hectare. The principal reason behind the similarity of farmyard manure costs was the availability in the local market. Moreover, it was observed during interviews with farmers that using farmyard manure is restricted to the number of farmers who own their livestock.

4.4.10 Relationship between Farm Size and Insecticides & Pesticide use Costs (Rs/ha of NSA)

High-quality seeds have resistance to stand against the insects and pests' invasion, but still, insecticides are required to bring the crops to their maturity. Pest invasion is the biggest reason for the loss of crop output per hectare. Insecticides are essential in maintaining agricultural productivity by directly controlling crop yield and profitability. The shifting of global attention towards sustainable agriculture practices brought forward the concept of integrated pest management (IPM). Integrated Pest Management (IPM) is a holistic process that involves using present and extensive information on the life cycles of pests and their interaction with our environment (Green et al., 2020). Farmers limit the application of the IPM process due to a lack of proper technical training and the interference of the pesticide industry (Parsa et al., 2014).

Table 4.19: Analysis of Variance of cost of pesticides use (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	40086382	10021596	1.46	0.2121
Error	403	2756995653	6841180		
Corrected Total	407	2797082035			

Source: Estimates based on the primary survey 2022-23

Table 4.20: Results of Post Hoc test (Tukey's) on pesticides use (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95 % Confidence Limits		Significance
Marginal – Small	199.4	-926.8	1325.7	
Marginal - Semi-Medium	-95.1	-1211.1	1020.8	
Marginal – Medium	-335.3	-1454.6	784.0	
Marginal – Large	-717.2	-1840.0	405.5	
Small – Marginal	-199.4	-1325.7	926.8	
Small - Semi-Medium	-294.6	-1417.5	828.4	
Small – Medium	-534.7	-1661.0	591.6	
Small – Large	-916.7	-2046.4	213.0	
Semi-Medium – Marginal	95.1	-1020.8	1211.1	
Semi-Medium – Small	294.6	-828.4	1417.5	
Semi-Medium – Medium	-240.2	-1356.1	875.8	
Semi-Medium – Large	-622.1	-1741.5	497.3	
Medium – Marginal	335.3	-784.0	1454.6	

Medium – Small	534.7	-591.6	1661.0	
Medium - Semi-Medium	240.2	-875.8	1356.1	
Medium – Large	-381.9	-1504.7	740.8	
Large – Marginal	717.2	-405.5	1840.0	
Large – Small	916.7	-213.0	2046.4	
Large - Semi-Medium	622.1	-497.3	1741.5	
Large – Medium	381.9	-740.8	1504.7	
Number of Observations	408			
F Statistics	1.46			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Table 4.19 and Table 4.20 show that the use of insecticides is the same across the five landholding groups. Insecticide costs are uniform across landholding sizes due to the standardized nature of insecticides, which follow a uniform pricing model for all landholding sizes. The post-hoc test did not show any pair that is statistically significant and showed a significant spending difference on insecticides and pesticides.

4.4.11 Relationship between farm size and Land lease in Cost (Rs/ha of NSA)

Leasing land is an efficient method to reduce fixed-cost expenditure, and farmers can expand their operations to increase their productivity and profitability. Lease payment is made annually, irrespective of the crop yield or market condition. The tenure of the lease is the main determinant in deciding the productivity and profitability of a farming operation (Place, 2009; Lawry et al., 2016). The productivity of land increases with long-term tenure because it improves stability, and farmers are willing to invest in land improvement technology, which escalates their profits. With the increase in the demand for agricultural land, especially in the productive region of Punjab, where alternative professions are not available, land rent is booming and negatively affecting the profitability of farms. Farmers try to diversify their cropping patterns by shifting from low-value to high-value crops.

Table 4.21: Analysis of Variance of cost of lease in land (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	4666689899.2	1166672474.8	4.34	0.0019
Error	403	108402535700	268988922.33		
Corrected Total	407	113069225599			

Source: Estimates based on the primary survey 2022-23

Table 4.22: Results of Post Hoc test (Tukey's) on cost of lease in land (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal – Small	380	-6683	7442	
Marginal - Semi-Medium	-2061	-9058	4936	
Marginal – Medium	-1183	-8201	5836	
Marginal – Large	-8923	-15963	-1882	***
Small – Marginal	-380	-7442	6683	
Small - Semi-Medium	-2441	-9482	4601	
Small – Medium	-1562	-8624	5500	
Small – Large	-9302	-16386	-2218	***
Semi-Medium – Marginal	2061	-4936	9058	
Semi-Medium – Small	2441	-4601	9482	
Semi-Medium – Medium	879	-6119	7876	

Semi-Medium – Large	-6862	-13881	158	
Medium – Marginal	1183	-5836	8201	
Medium – Small	1562	-5500	8624	
Medium - Semi-Medium	-879	-7876	6119	
Medium – Large	-7740	-14780	-700	***
Large – Marginal	8923	1882	15963	***
Large – Small	9302	2218	16386	***
Large - Semi-Medium	6862	-158	13881	
Large – Medium	7740	700	14780	***
Number of Observations	408			
F Statistics	4.34**			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Table 4.21 and Table 4.22 show that there are statistically significant differences in lease costs per hectare among the farm size groups. The post-hoc test followed by the one-way ANOVA showed a statistically significant cost difference in marginal and large, small and large, and medium and large landholding sizes. Large farms paid a higher lease in land cost than other landholding sizes. It was observed while interviewing farmers that large farms in Punjab take advantage of economies of scale by expanding their operations. Therefore, they can cultivate more land efficiently and earn higher profits that help them to afford the higher cost of leasing land.

4.4.12 Relationship between farm size and Depreciation Cost (Rs/ha of NSA)

Depreciation costs help farmers make provisions for the replacement and maintenance of assets. Efficient management of depreciation enables maximization of per-hectare productivity and profitability. With the accurate assessment of depreciation costs, farmers can quickly replace obsolete assets and invest in technology that promotes productivity and profitability (Beloiev et al., 2020). Estimating depreciation costs involves identifying fixed assets, determining an asset's life, and choosing a

depreciation method like the straight-line or declining balance method. Finally, we need to calculate annual depreciation expenses.

Table 4.23: Analysis of Variance of cost of cost of deprecation of farm building and implements (Rs./ha of net sown area) among Farm size group

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	67155727	16788932	0.09	0.9866
Error	403	78167279999	193963474		
Corrected Total	407	78234435727			

Source: Estimates based on the primary survey 2022-23

Table 4.24: Results of Post Hoc test (Tukey's) on cost of deprecation of farm building and implements (Rs./ha of net sown area) among Farm size group

Size Comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal - Small	121	-5876	6118	
Marginal - Semi-Medium	-583	-6525	5359	
Marginal - Medium	412	-5547	6372	
Marginal - Large	592	-5386	6571	
Small - Marginal	583	-5359	6525	
Small - Semi-Medium	704	-5276	6683	
Small – Medium	995	-4947	6937	
Small – Large	1175	-4785	7135	
Semi-Medium - Marginal	583	-5359	6525	
Semi-Medium - Small	704	-5276	6683	
Semi-Medium - Medium	995	-4947	6937	
Semi-Medium - Large	1175	-4785	7135	

Medium - Marginal	-412	-6372	5547	
Medium - Small	-291	-6289	5706	
Medium - Semi-Medium	-995	-6937	4947	
Medium - Large	-995	-6937	4947	
Large - Marginal	-592	-6571	5386	
Large – Small	-471	-6487	5544	
Large - Semi-Medium	-1175	-7135	4785	
Large – Medium	-180	-6158	5798	
Number of Observations	408			
F Statistics	0.09			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Table 4.23 and Table 4.24 show that farm size did not affect the depreciation costs per hectare. The post-hoc test followed by the one-way ANOVA did not find any statistically significant difference in depreciation cost between any pair of farm size groups. During the survey, it was observed that irrespective of farm size, the main farm equipment were tractors, harvesters, and irrigation systems. It leads to similarity in depreciation rates because these assets have similar usage patterns and life expectancies. In addition, the method to calculate depreciation costs is also the same. Therefore, depreciation cost remained the same for each landholding size in Punjab.

4.4.13 Relationship between farm size and Other minor Cost (Rs/ha of NSA)

Other costs refer to miscellaneous expenditures that do not fall into the category of variable costs but indirectly support the production process. These costs are part of the cost of production to correct the estimation of the total cost.

**Table 4.25: Analysis of Variance of other minor cost (Rs./ha of net sown area)
among Farm size group**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	742988.79	185747.20	1.19	0.3162

Error	403	63094421.05	156561.84		
Corrected Total	407	63837409.84			

Source: Estimates based on the primary survey 2022-23

Table 4.26: Results of Post Hoc test (Tukey's) on other minor cost (Rs./ha of net sown area)among Farm size group

Size-comparison	Difference between Means	Simultaneous 95% Confidence Limits		Significance
Marginal-Small	36.17	-134.21	206.56	
Marginal-Semi-Medium	50.91	-117.91	219.73	
Marginal-Medium	101.90	-67.43	271.23	
Marginal-Large	115.77	-54.08	285.62	
Small-Marginal	-36.17	-206.56	134.21	
Small-Semi-Medium	14.74	-155.14	184.61	
Small-Medium	65.72	-104.66	236.11	
Small-Large	79.59	-91.31	250.49	
Semi-Medium-Marginal	-50.91	-219.73	117.91	
Semi-Medium-Small	-14.74	-184.61	155.14	
Semi-Medium-Medium	50.99	-117.83	219.80	
Semi-Medium-Large	64.86	-104.48	234.20	
Medium-	-101.90	-271.23	67.43	

Marginal				
Medium-Small	-65.72	-236.11	104.66	
Medium-Semi-Medium	-50.99	-219.80	117.83	
Medium-Large	13.87	-155.98	183.72	
Large-Marginal	-115.77	-285.62	54.08	
Large-Small	-79.59	-250.49	91.31	
Large-Semi-Medium	-64.36	-234.20	104.48	
Large-Medium	-13.87	-183.72	155.98	
Number of Observations	408			
F Statistics	1.19			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Tables 4.25 and 4.26 show that other minor costs are almost the same across farm size groups. It was validated both by a one-way ANOVA test, and then the post-hoc test did not find any statistically significant difference in other costs across the farm size group. During the survey, it was observed that a majority of other minor costs involve labour intensive and farm inputs like fuel for transportation that do not change with farm size, and large farmers do not get the benefit of economies of scale. Therefore, other minor costs remain almost the same for farm-size groups in Punjab.

4.4.14 Relationship between farm size and Profitability on Cost A2+ Family Labour (Rs/ha of NSA)

To gain insights into the economic viability of farming operations, the farmers need to evaluate the level of profitability. Profitability on Cost A2+ Family Labour (Returns on Cost A2+ Family Labour) can be calculated by considering total revenues generated from farming operations against total costs incurred, including both A2 costs (paid-out costs) and imputed family labour costs. Therefore, farmers prepare their financial plans and decisions regarding resource allocation, cropping patterns, and expenses on farm inputs like fertilizers, seeds, and pesticides according to the maximum share of the total revenue as a profit (Muzhinji & Ndou, 2022).

Table 4.27: Analysis of Variance of profitability on Cost A2+ Family Labour (Rs/ha of NSA) among Farm size group.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	176837184710	44209296178	14.47	<.0001
Error	403	1.2313121E12	3055365045.7		
Corrected Total	407	1.4081493E12			

Source: Estimates based on the primary survey 2022-23

Table 4.28: Results of Post Hoc test (Tukey's) on Profitability on Cost A2+ Family Labour (Rs/ha of NSA) among Farm size group.

Size-Comparison	Difference between Means	Simultaneous 95 % Confidence Limits		Significance
Marginal-Small	-33160	-56962	-9358	***
Marginal-Semi-Medium	-42523	-66106	-33936	***
Marginal-Medium	-57590	-81245	-33936	***
Marginal-Large	-55010	-78738	-31283	***
Small-Marginal	33160	9358	56962	***
Small-Semi-Medium	-9363	-33094	14368	

Small-Medium	-24430	-48232	-628	***
Small-Large	-21850	-45724	2025	
Semi-Medium-Marginal	42523	18940	66106	***
Semi-Medium-Small	9363	-14368	33094	
Semi-Medium-Medium	-15067	-38651	8516	
Semi-Medium-Large	-12487	-36144	11169	
Medium-Marginal	57590	33936	81245	***
Medium-Small	24430	628	48232	***
Medium-Semi-Medium	15067	-8516	38651	
Medium-Large	2580	-21147	26308	
Large-Marginal	55010	31283	78738	***
Large-Small	21850	-2025	45724	
Large-Semi-Medium	12487	-11169	36144	
Large-Medium	-2580	-26308	21147	
Number of Observations	480			
F Statistics	14.47***			

Note : Significant at the 10%, 5%, and 1% level are indicated by *, **, and ***

Source: Estimates based on the primary survey 2022-23

Table 4.27 and Table 4.28 show that the level of profitability is not the same across the

landholding sizes. Marginal and small farms are the least profitable landholding sizes. With the increase in farm size, the level of profitability increases. Thus, marginal and small farms earn less than other landholding sizes. One of the primary reasons for less profitability of marginal and small farms is escalation in farm input prices, which has not been coordinated by an analogous increase in crop prices, leading to reduced profit margins. Moreover, high dependency on non-institutional sources of credit increased debt traps on marginal and small farms that reduced their share of their annual income.

4.5 Conclusion

The connection between farm size and productivity is a complex task that involves research conducted over the past few decades. Estimations explain the complexity of this relationship. The need for proper and reliable data has been diverting us towards misleading pathways. Therefore, the data collection should follow systematic approaches and methodologies. Productivity is a ratio of outputs to inputs. While estimating productivity per hectare, we need to properly assess the agricultural production of the main crops, minor crops, and by-products. The lack of proper accounting for minor crops and by-products can lead to underestimation or overestimation. We should follow micro-based measures to collect data to make comparisons of productivity across different farm size categories. Agriculture is a nature-affected activity, and productivity depends upon natural conditions like climate, soil characteristics, and water availability. Thus, data collection should align with the agro-climatic zones. Farm-level productivity requires collecting data on all the output produced using different inputs. The quality of the inputs used for the production should be included during the data collection, including owned farms, leased land, family labour, hired labour, quality and source of seeds, owned and rental machinery, and irrigation pumps. The socio-economic characteristics, cost of cultivation, and types of crops produced influence productivity. By converting output and input units into monetary values, value-based productivity is estimated to make comparisons possible across farm sizes. Finally, productivity is estimated using gross output, defined as the production value. Profitability estimation involves subtracting the value of inputs purchased from the farm output, with depreciation deducted to arrive at the net operating income. A one-way ANOVA followed by Tukey's post-hoc test used to know the impact of farm size on productivity and profitability is statistically significant. The

findings of this statistical analysis suggested that farm size does not impact productivity in Punjab. Farm size affects cultivation costs, with an inverse relationship observed. As farm size increases, the cost of cultivation goes down due to the application of economies of scale. The returns on Cost A2+ Family Labour (profitability) showed a positive relationship with the farm size, as larger farms earned more returns than small-sized farms due to fewer paid-out costs per hectare. Moreover, farm size influences the use of farm inputs, either positively or negatively. Labour costs and farm size showed a statistically significant inverse relationship, with labour costs per hectare decreasing as farm size increased. With the increase in farm size, labour costs per hectare come down. Machine costs per hectare are also affected by the farm size. The increase in farm size reduced per-hectare machinery costs. Irrigation costs exhibited a negative relationship with the farm size; the increase in farm size reduced per-hectare irrigation costs. Animal costs per hectare are reduced with the farm size. Lease in land costs shared an inverse relationship with farm size. Small farms paid less and were more consistent on leases in land than large farms. However, farm size did not show any statistically significant relationship with seed, fertilizer, farmyard manure, depreciation, and other costs. These farm inputs' quantity and costs are affected by factors other than farm size. Thus, estimating the association between farm size, productivity, and profitability is an intricate task involving several statistical tests and proper estimation.

CHAPTER V

AGRICULTURAL PRODUCTION AND PROFITABILITY IN PUNJAB

5.1 Introduction

The preceding chapters have already established the importance of agriculture for the economic development of a country. In India, several policies promote this sector, resulting in tremendous improvement in the production of key crops. Since the inception of the Green Revolution, science, particularly genetics, has played a significant role in developing pest-resistant varieties of seeds (Varshney et al., 2011). Increasing production is one of many solutions needed in the current world, where most countries are grappling with hunger. The countries have to focus on the productivity of farms. When we are discussing overall production and productivity, the profitability of farms is also important. The government's Viksit Bharat @2047 document focuses on increasing farmers' income, with a commitment to doubling the income of farmers by 2030. One way of increasing farmers' income is to lessen the cost of production by providing subsidies and strengthening backward linkages. The second way is to increase the productivity of land. There are various methods to improve soil productivity, such as better-quality seeds, fertilizers, insecticides, pesticides, and farm machines. This chapter identifies the factors affecting production and profitability across the five landholding sizes.

This chapter is divided into two sections; the first one deals with the factors of production dealing with productivity, while the second section discusses the production factors influencing profitability per hectare. The decision about the factors of production affecting the productivity and profitability was taken through the descriptive statistics, Pearson correlation coefficient, and multiple regression analysis.

5.2 Literature Review

Food security for the world's ever-growing population is a challenging task. Two alternatives are available: first, increase the area under production, and second, increase the productivity of the current farmlands. The first alternative is not viable in

the present scenario, as it could disturb the existing ecosystem and increase significant greenhouse gas emissions (Fargione et al., 2008). Therefore, worldwide efforts are focused on increasing productivity. Most countries worldwide have begun to implement measures to improve food crop productivity. Studies conducted worldwide explore the factors that increase the productivity of crops (Anik et al., 2017; Fuglie, 2017; Rahman et al., 2022). The first and foremost emphasis in literature is on Agriculture Research and Development Programs. Studies from the countries found a positive relationship between research and development investment and productivity (Mohan, 1974; Piesse & Thirtle, 2010). However, the benefit level of research and development varied with the source of research and development. It was found that public expenditure benefits are more significant than private expenditure for ordinary people. The main reason for supporting public expenditure was to prevent monopoly pricing and ease knowledge and technology flow among small and marginal farmers (Gerpacio, 2003). On the other hand, we must pay attention to the role that the private sector plays. Private-sector investment in research and development has surpassed public-sector investment since 2010. Private expenditure focuses on improving the quality of agricultural inputs like seeds, chemicals, and machinery to target productivity (Fuglie, 2016). Currently, public and private expenditure is required in equal measure to deal with productivity challenges and reduce inequalities in technology access across landholding sizes (Ballabh, 2007; Spielman et al., 2010).

After the completion of a particular research project, the central issue involves disseminating the outcome of a research project to the targeted population, which is farmers. Extension services are equally crucial to research and development, helping farmers to adopt fruitful farm practices. Extension agents from state-owned agricultural universities, cooperative societies, and employee of private brand contact farmers to provide them guidance and services (Danso-Abbeam et al., 2018; Van Crowder, 1987). Afrianto et al. (2022), the Internet has been playing an active role in imparting knowledge to farmers through mobile applications. In India, applications like IFFCO Kisan Agriculture, Kisan Jagran, Pusa Krishi, etc., are well-known farm applications. Apart from investment in research and development and providing

extension services to forward the outcome of research work to the targeted population, the state is responsible for providing infrastructure facilities to farmers. Infrastructure also plays a vital role to improve productivity. Studies presented in the literature showed the positive association between productivity and infrastructure (Adepoju & Salman, 2013). The availability of highways and roads helps farmers acquire agricultural inputs and sell their outputs quickly (Mamatzakis, 2003). Furthermore, the government adopts various policies to promote productivity, such as subsidies and minimum support prices (MSP) for farmers. However, it is observed that certain subsidies have an inverse effect on agricultural productivity through allocative and technical inefficiencies, like free electricity for farmers (Sidhu et al., 2011), whereas Minimum Support Price (MSP) has been promoting mono-cropping practices that reduced the per hectare productivity (Wang et al., 2014). Oluwatusin and Shittu (2014) mentioned the socio-economic characteristics like farmer age, education, household size, experience, landholding size, farm income, extension education adopted, and credit availability that influence agriculture productivity. These factors affect the farm productivity and determine the type of farming practices and crops the farmer grows (Mazvimavi & Twomlow, 2009; Jara-Rojas et al., 2012).

The profitability is also essential for maintaining the sustainability of farmers. Therefore, the incumbent government has set up a doubling farmers' income committee to find ways to increase farmers' income (Chand, 2017). It has been observed from the literature that the main factor that influence the profitability in agriculture is the size of farms, which determines the scale of operation, and the output price that farmers receive from the sale of products in the market (Tey & Brindal, 2014). In addition to this, socio-economic characteristics also influence the profitability of an enterprise because profitability depends upon farm management, and farm management depends upon the socio-economic characteristics of the farmer (Mishra et al., 2012). Profitability is the biggest concern for small and marginal farmers. Numerous studies highlight that the cultivation costs of these farmers are exceptionally high, and their profits are not enough to manage their household expenses, forcing them to seek non-farm employment along with the farming profession (Meert et al., 2004). Large-scale farmers are also experiencing certain

constraints, like climate change, that are reducing their per-hectare profitability even at large farms. The solutions to this problem are crop diversification and improving efficiency. The profitability of farms depends upon the efficiency level of farmers using farm inputs. Efficiency can be improved by reducing the wastage of inputs and reducing the cultivation costs. The integration of information technology in the agricultural sector has improved efficiency and reduced the wastage of farm inputs, thereby lowering the cultivation costs and ameliorating the profitability of farmers (Izmailov, 2019; Saiz-Rubio & Rovira-Más, 2020; Ali et al., 2023). Precision farming is a globally accepted method that contributes to the efficient utilization of farm inputs.

Changes in cropping patterns are another alternative to increase per-hectare profitability, before the Green Revolution, Punjab was producing 14 major crops, which were rice, millets, maize, wheat, barley, rapeseed and mustard, gram, mash, moong, arhar, groundnut, sugarcane, American cotton and desi cotton that accounted for 85-90 per cent in total production, where apparent diversification was evident. However, agriculture soon changed after the Green Revolution, with the area under wheat and rice expanding approximately to 90.13 per cent (Singh, 2022). In comparison, other crops were reduced considerably to 9.87 per cent in total production. This happened due to increased crop productivity with new technology, improved seed fertilisers, and more widespread use of irrigation (Murgai, 2001). However, it led to severe issues that raise a question about the sustainability of agriculture, such as land, water and environmental degradation (Bhullar & Mohan, 2015). These unsustainable agriculture practices results stagnation in agriculture sector the income level of farmers came down due to stagnant productivity on one side and increasing cost of cultivation on another. Farmers were forced to shift from the agriculture sector to another profession to earn stable earnings for their families.

5.3 Database and Methodology

Seventeen variables were identified to analyse productivity and thirteen variables to analyse profitability (Table 5.1).

Table 5.1: Identification of variables to analyse Productivity & Profitability

Dependent Variables	Dependent Variables
Value of Output per hectare	Profitability

Independent Variables	Independent Variables
Labour Cost per hectare	Returns Cost A2 per hectare
Machine Cost per hectare	Small Dummy
Irrigation Cost per hectare	Semi-Medium Dummy
Animal Cost per hectare	Medium Dummy
Seed Cost per hectare	Large Dummy
Fertilizers Cost per hectare	Cropping Intensity per hectare
Farm Yard Manure (FYM) Cost per hectare	Age Year
Insecticides Cost per hectare	Schooling Year
Lease in Land Cost per hectare	Household Members
Imputed Rent Cost per hectare	Zone 1 Dummy
Depreciation Cost per hectare	Zone 2 Dummy
Fixed Capital Cost per hectare	Leased In Dummy
Other cost per hectare	Fragments
Cropping Intensity	
Schooling Year	
Tractor No.	
Combine No.	

Source: Primary Survey conducted in 2022-23

Descriptive Analysis & Inferential Statistics

Descriptive analysis was carried out to get an overall view of the variables. Four descriptive tools were used: mean, standard deviation, minimum, and maximum. As this chapter deals with factors of production and profitability, correlation and multiple regression were used.

Pearson Correlation Coefficient

The Pearson correlation coefficient was used to measure the strength and direction of the linear relationship between diverse factors of production. Moreover, it would also help to explore the factors that are more promising towards productivity and profitability.

$$r = \frac{n(\sum XY)^2 - (\sum X)(\sum Y)}{\sqrt{[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]}}$$

Multiple Regression Analysis

Multiple regression used to understand the relationship between multiple independent variables and a dependent variable because in agriculture many farm inputs work cooperatively to influence production and profitability. Moreover, it helps to find out the effect on each independent factor separately on productivity and profitability.

For Productivity Analysis

VOP = Value of Product

$$\text{VOP} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \epsilon$$

Whereas

β_0 = Slope;

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}, \beta_{16}, \beta_{17}$ are known as slopes and ϵ is an error term.

X_1 = Labour Cost per hectare; X_2 = Machine Cost per hectare; X_3 = Irrigation Cost per hectare Cost; X_4 = Animal Cost per hectare; X_5 = Seed Cost per hectare; X_6 =

Fertilizer cost per hectare; X_7 = Farm Yard Manure (FYM) cost per hectare; X_8 = Insecticides Cost per hectare; X_9 = Lease in Land Cost per hectare; X_{10} = Imputed Rent Cost per hectare; X_{11} = Depreciation Cost per hectare; X_{12} = Fixed Cost per hectare; X_{13} = Other Cost per hectare; X_{14} = Cropping Intensity; X_{15} = Schooling Year; X_{16} = Tractor No.; X_{17} = Combine No.

For Profitability Analysis:

$$\text{Profitability} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + W + \epsilon$$

Whereas

β_0 = Slope;

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}$ are known as slopes and ϵ is an error term.

X_1 = Small Dummy; X_2 = Semi-Medium Dummy; X_3 = Medium Dummy; X_4 = Large Dummy; X_5 = Cropping Intensity per hectare; X_6 = Age Year; X_7 = Schooling Year; X_8 = Household Members; X_9 = Zone 1 Dummy; X_{10} = Zone 2 Dummy; X_{11} = Leased in Dummy; X_{12} = Fragments.

Model Specification Test (SPEC)

Heteroskedasticity may produce unreliable statistics inference. Therefore, it is important to detect the presence of heteroskedasticity presence and in our research work we used Model Specification Test (SPEC) to check whether regression model follows the assumption of constant error variance.

Formula

After the calculation of the original regression, we have calculated the SPEC test statistic as:

$$LM = n \cdot R^2$$

Where:

- n = number of observations
- R^2 = R-square from the auxiliary regression of squared residuals on the

explanatory variables

5.4 Results & Discussions

5.4.1 Value of crop output (productivity) Analysis per hectare

Descriptive Statistics

Table 5.2: Descriptive statistics of the variables used to analyse the Productivity

Variables	N	Mean	Std Dev	Minimum	Maximum
Value of crop output(Rs/ha of NSA)	408	211713	41516	40343	495723
Labour Cost(Rs/ha of NSA)	408	24635	8131	2744	63080
Machine Cost(Rs/ha of NSA)	408	23159	27193	1126	260317
Irrigation machine cost (Rs/ha of NSA)	408	5010	4302	0	35705
Animal Cost(Rs/ha of NSA)	408	109.61	452.19	0	4998
Seed Cost(Rs/ha of NSA)	408	5215	6918	1254	137332
Fertilizer Cost (Rs/ha of NSA)	408	8800	2531	2236	31353
Farm Yard Manure cost (Rs/ha of NSA)	408	524.83	1747	0	19793
Insecticides cost(Rs/ha of NSA)	408	6107	2622	499.47	16155
Lease in Land cost(Rs/ha of NSA)	408	7603	16668	0	90521
Imputed Rent (Rs/ha of NSA)	408	61802	18890	0	113120
Depreciation cost(Rs/ha of NSA)	408	10361	13864	250	154709
Fixed capital cost (Rs/ha of	408	467537	471684	4275	4246287

NSA)					
Other cost (Rs/ha of NSA)	408	114.07	396.04	0	5132
Cropping Intensity (%)	408	196.09	25.786	50	286.1
Schooling Years	408	8.76	4.21	0	18
Tractor No	408	0.82	0.649	0	4
Combine No	408	0.02	0.197	0	3

Source: Estimates based on the primary survey 2022-23

Table 5.2 depicts the quantitative description of variables included in the model that influence productivity level. On average, the value of crop output per hectare was Rs. 211713. The standard deviation is relatively high (Rs. 41516), depicting that there is a significant variation in the value of crop output. The maximum and minimum statistical methods further justified disparity in crop output across landholding sizes. The disparity in crop output value is the outcome of the socioeconomic characteristics, crop diversification, efficient farm management, and irrigation facilities (Kingra et al., 2018; Prabhjyot-Kaur et al., 2021; Saeed et al., 2021). The machine costs and fixed capital costs per hectare showed the maximum variability between farms. This variation is the result of the scale of operations, types of machines, cropping patterns, ownership of machines, and access to credit (Sarkar, 2020).

Pearson Correlation Coefficient

Table 5.3: Descriptions of variables used in Table 5.4

S.NO	Variables	Descriptions
1	VAR1	Value of crop output per hectare
2	VAR2	Labour cost per hectare
3	VAR3	Machine Cost per hectare
4	VAR4	Irrigation Cost per hectare
5	VAR5	Animal Cost per hectare
6	VAR6	Seed Cost per hectare

7	VAR7	Fertilizers Cost per hectare
8	VAR8	Farm Yard Manure Cost per hectare
9	VAR9	Insecticides Cost per hectare
10	VAR10	Leased in land cost per hectare
11	VAR11	Imputed Rent Cost per hectare
12	VAR12	Depreciation Cost per hectare
13	VAR13	Fixed Capital cost per hectare
14	VAR14	Other Cost per hectare
15	VAR15	Cropping Intensity
16	VAR16	Schooling Year
17	VAR17	Tractor No
18	VAR18	Combine No.

Source: Primary Survey conducted in 2022-23

Table 5.4: Pearson Correlation Coefficient to determine factors of production

Variable	VAR1	VAR2	VAR3	VAR4	VAR5	VAR6	VAR7	VAR8	VAR9	VAR10	VAR11	VAR12	VAR13	VAR14	VAR15	VAR16	VAR17	VAR18
VAR1	1 (<.0001)																	
VAR2	0.205 (<.0001)	1 (<.0001)																
VAR3	-0.028 (0.566)	0.537 (<.0001)	1 (<.0001)															
VAR4	0.176 (0.00)	0.137 (0.006)	0.191 (0)	1 (<.001)														
VAR5	-0.098 (0.047)	0.31 (<.0001)	0.516 (<.0001)	-0.027 (0.592)	1 (<.0001)													
VAR6	0.311 (<.0001)	0.33 (<.0001)	0.024 (0.631)	-0.013 (0.787)	0.039 (0.43)	1 (<.0001)												
VAR7	0.521 (<.0001)	0.318 (<.0001)	0.121 (0.015)	0.099 (0.047)	0.018 (0.721)	0.543 (<.0001)	1 (<.0001)											
VAR8	-0.024 (0.623)	0.323 (<.0001)	0.313 (<.0001)	0.045 (0.363)	0.237 (<.0001)	0.011 (0.831)	0.072 (0.146)	1 (<.0001)										

VA R9	0.39 ($<.0001$)	-0.04 (0.417)	-0.153 (0.002)	0.19 (0)	-0.033 (0.501)	0.034 (0.488)	0.242 ($<.0001$)	-0.034 (0.497)	1 ($<.0001$)								
VA R10	0.011 (0.82)	0.043 (0.389)	0.016 (0.753)	0.106 (0.033)	-0.066 (0.183)	0.01 (0.848)	0.06 (0.226)	-0.075 (0.132)	0.037 (0.452)	1 ($<.0001$)							
VA R11	0.683 ($<.0001$)	-0.011 (0.822)	-0.118 (0.017)	0.042 (0.401)	-0.064 (0.198)	0.113 (0.023)	0.244 ($<.0001$)	-0.003 (0.944)	0.338 ($<.0001$)	-0.64 ($<.0001$)	1 ($<.0001$)						
VA R12	-0.055 (0.268)	0.335 ($<.0001$)	0.268 ($<.0001$)	0.11 (0.026)	0.22 ($<.0001$)	0.018 (0.711)	0.106 (0.032)	0.312 ($<.0001$)	-0.082 (0.096)	0.101 (0.042)	-0.198 ($<.0001$)	1 ($<.0001$)					
VA R13	-0.041 (0.406)	0.318 ($<.0001$)	0.17 (0.001)	0.124 (0.012)	0.1 (0.044)	0.067 (0.176)	0.137 (0.006)	0.277 ($<.0001$)	-0.088 (0.075)	0.114 (0.022)	-0.216 ($<.0001$)	0.833 ($<.0001$)	1 ($<.0001$)				
VA R14	0.111 (0.025)	0.093 (0.06)	0.062 (0.213)	0.12 (0.015)	-0.008 (0.865)	-0.007 (0.895)	0.061 (0.217)	0.021 (0.667)	-0.052 (0.294)	-0.041 (0.408)	0.105 (0.035)	-0.027 (0.584)	0.035 (0.486)	1 ($<.0001$)			
VA R15	0.69 ($<.0001$)	0.427 ($<.0001$)	0.141 (0.004)	0.103 (0.038)	0.086 (0.081)	0.28 ($<.0001$)	0.495 ($<.0001$)	0.093 (0.06)	0.209 ($<.0001$)	0.026 (0.6)	0.455 ($<.0001$)	0.108 (0.029)	0.087 (0.079)	0.13 (0.008)	1 ($<.0001$)		
VA R16	0.082 (0.1)	0 (0.993)	-0.115 (0.02)	-0.17 (0.001)	-0.007 (0.895)	0.091 (0.068)	0.155 (0.002)	0.066 (0.185)	0.007 (0.885)	0.007 (0.893)	0.03 (0.547)	0.04 (0.425)	0.034 (0.493)	-0.009 (0.856)	0.062 (0.21)	1 ($<.0001$)	
VA R17	0.054 (0.274)	-0.126 (0.011)	-0.377 ($<.0001$)	-0.071 (0.152)	-0.193 ($<.0001$)	0.23 ($<.0001$)	0.12 (0.015)	-0.04 (0.418)	0.037 (0.453)	0.157 (0.001)	-0.111 (0.025)	0.152 (0.002)	0.299 ($<.0001$)	0.046 (0.358)	-0.02 (0.695)	0.115 (0.02)	1 ($<.0001$)
VA R18	0.054 (0.279)	-0.053 (0.289)	-0.082 (0.099)	0.005 (0.913)	-0.03 (0.544)	-0.018 (0.714)	0.031 (0.529)	-0.038 (0.45)	0.128 (0.01)	0.113 (0.023)	-0.007 (0.891)	0.02 (0.691)	0.045 (0.36)	-0.022 (0.653)	-0.012 (0.81)	0.046 (0.356)	0.053 (0.284)

Source: Primary Survey conducted in 2022-23

Table 5.4 is a correlation matrix (18X18) that depicts the association between factors of productions and value of output per hectare.

1. Value of Crop Output per Hectare (Per Hac of NSA)

The value of crop output per hectare shows several important associations with key agricultural inputs. It demonstrates a positive link with labour expenditure, with the correlation estimated at $r = .20$ and statistical significance at $p < .001$, suggesting that greater use of skilled labour contributes to higher productivity (Kloeker et al., 2019). Seed expenditure shows a moderate correlation with output value, indicated by a coefficient of .31, which is statistically significant at the 1% level ($p < .001$), reflecting the productivity gains from high-quality seed varieties. Fertilizer use exhibits a strong positive linear association, with the analysis yielding $r = .54$ and a highly significant probability value ($p < .001$), aligning with the central role of fertilizers in intensive farming systems (Paul et al., 2022). Insecticide spending also shows a moderate relationship with crop output, reflected by a correlation of .39 and a statistically meaningful p-value ($p < .001$), as effective pest management helps prevent yield losses (Ali et al., 2023). Imputed rent shows a robust positive association with output, where

the correlation reaches .68 and the relationship is highly significant ($p < .001$), highlighting the importance of fertile land and modern inputs (Grover & Sharma, 2011). The strongest linkage is observed with cropping intensity, for which the correlation coefficient is .69, with significance recorded at $p < .001$, confirming that more frequent cropping substantially boosts output (Wu et al., 2018).

2.Labour Cost per Hectare (Rs./ha of NSA)

Compared to capital-intensive agricultural systems in countries such as the United States, Canada, and Australia, Indian agriculture remains fundamentally labour driven. Consequently, labour accounts for the largest proportion of the total cost of cultivation (Kumar & Sachdeva, 2016). The correlation results further highlight the centrality of labour in shaping multiple dimensions of the production environment. Labour cost exhibits a modest yet statistically significant association with the value of crop output ($r = .20$; $p\text{-value} < .001$). Although mechanization has expanded, the timely execution of farm operations continues to rely heavily on labour, influencing overall crop performance (Tudor et al., 2022). A strong positive relationship is observed between labour and machine costs, with the correlation coefficient estimated at 0.53 and the relationship significant at the $< .001$ probability level. This pattern suggests complementarity: machinery enhances efficiency, but skilled operators are indispensable for its effective use (Flug & Hercowitz, 2000; Hazarika, 2015; Rajkhowa & Kubik, 2021). Despite increasing mechanization, several regions and farm categories continue to depend on animal power where machines are impractical or economically unviable. This sustained dependence explains the observed link between labour and animal-related costs (Rahman & Miah, 2011; Mota-Rojas et al., 2021). Labour cost is moderately and favourably correlated with seed expenditure, with the analysis yielding $r = .33$ and a $p = .0001$. Labour-intensive activities—such as seed selection, preparation, sowing, and transplanting, particularly in crops like paddy and potatoes—underpin this relationship (Amuthaselvi, 2021). The association between labour and fertilizer expenses is also substantial. The correlation is .32, with the significance level reported as $p < 0.0001$, indicating that fertilizer application—whether synthetic or organic—remains highly labour demanding. FYM handling, transport, and application are inherently labour intensive. Accordingly, labour cost demonstrates a notable correlation of $r = .32$, and the association is highly significant ($p\text{-value} = .0001$),

underscoring the manual nature of FYM-based nutrient management (Daadi&Latacz-Lohmann, 2021). Depreciation cost shows a positive and statistically robust connection with labour expenditure; the coefficient reaches 0.33, accompanied by a $p < 0.0001$. Increased depreciation reflects greater investment in machinery, which necessitates skilled operators and technicians for maintenance and repairs (Ibendahl, 2015). Labour cost is also linked to fixed capital investment, as evidenced by a correlation of $r = .32$ and statistical significance at $p\text{-value} < .0001$. As Punjab's farmers expand fixed capital investments, the demand shifts from unskilled labour to a more skilled workforce (Ilyin et al., 2020). A moderate and statistically meaningful relationship exists between labour cost and cropping intensity, with a coefficient of .43 and the association significant at $p < .001$. Higher cropping intensity naturally elevates labour requirements for planting, maintenance, and harvesting (Dahlin &Rusinamhodzi, 2019).

3. Machine Cost per Hectare (Rs./ha of NSA)

The inception of the Green Revolution in the Indian economy caused some changes. People have shifted from manual farming to mechanized operations (Suresh, 2022), which increased the share of machine costs in the total cost of cultivation. It benefits farmers because they can perform their farming operations on time and can handle multiple cropping cycles within a single year. Machine cost shares the correlation with the following other cost components: Machine cost showed a strong positive and significant association with labour cost ($r = 0.54$). Although mechanization enhances productivity, it also demands skilled operators and regular maintenance, increasing labour expenses. Moreover, the shift of workers from agriculture to non-farm jobs has led to labour scarcity, pushing up wage rates and labour costs per hectare. Machine cost showed a positive association with animal cost, with a correlation coefficient of 0.52 ($p < 0.0001$). Farmers often use machines alongside animals for livestock tasks, so machine expenses rise as livestock numbers increase (Akram et al., 2020). Machine cost showed a significant positive link with FYM cost, with a correlation coefficient of 0.31. Applying and incorporating FYM often requires specialized equipment, which raises machinery expenses when farmers use farmyard manure (Suleiman, 2022). Machine cost showed a positive association with depreciation cost, with a correlation coefficient of 0.27 ($p < 0.0001$). Frequent use of machinery leads to wear and tear, increasing the need for depreciation to replace outdated equipment. Machine cost

displayed a negative link with tractor numbers, indicated by a correlation coefficient of -0.38 and a significance level below 0.0001 . The shift towards advanced multifunctional tractors reduces the requirement for multiple smaller tractors, resulting in fewer tractors even as machinery expenses rise.

4.Irrigation Cost per hectare (Rs./ha of NSA): The agriculture sector of Punjab depends mainly upon groundwater, as Punjab has a semi-arid climate with limited rainfall. Thus, irrigation costs are included while determining the cost of cultivation. However, irrigation costs shared no statistically significant correlation with other factors of production.

5.Animal Cost per hectare (Rs./ha of NSA)

Animal costs involve feeding, veterinary care, and infrastructure for animals. It exhibited the close relationship with the cost components like Animal cost showed a positive link with labour cost, with a correlation coefficient of 0.31 ($p < 0.0001$). Livestock activities are labour-intensive—requiring workers for feeding, milking, cleaning, and general management—and additional skilled labour for specialized tasks can further raise labour expenses (Bendahan et al., 2018). Animal cost showed a positive association with machinery cost, reflected in a correlation coefficient of 0.52 . Both crop and livestock systems increasingly rely on mechanization to maintain efficiency under changing climatic conditions (Pampori& Sheikh, 2023). Animal cost had a positive link with FYM cost, indicated by a correlation coefficient of 0.23 ($p < 0.0001$). Higher livestock numbers increase FYM availability, encouraging farmers to use organic manure over synthetic fertilisers (Chaudhary et al., 2022). A positive relationship was observed between animal cost and depreciation cost, with a correlation coefficient of 0.22 . Modern machinery used in livestock operations undergoes wear over time, raising depreciation charges (Langemeier, 2016). Animal cost showed a negative association with tractor numbers, with a correlation coefficient of -0.19 ($p < 0.0001$). As farmers invest more in livestock, the demand for additional tractors and related implements tends to decline.

6.Seed costs (Rs/ha of NSA)

Seed expenditure showed the following associations with key cost components: Seed cost had a positive link with output value, with a correlation coefficient of 0.31 ($p < 0.0001$). Better-quality seeds generally enhance yield potential (Kozulina et al., 2023). A moderate positive association was observed, with a correlation coefficient of 0.33 ($p < 0.0001$). High-yielding varieties often demand extra crop care such as irrigation, pest control, and field management, increasing labour requirements (Goyari & Sharma, 2008). Seed cost showed a strong positive link with fertilizer cost, indicated by a correlation coefficient of 0.54 ($p < 0.0001$). because hybrid and improved seeds require a high dose of nutrients (fertilizers) than conventional seeds (Santana et al., 2017). Seed cost showed a positive association with cropping intensity, reflected in a correlation coefficient of 0.28. Regions with higher cropping intensity require more frequent seed use across multiple seasons (Mondal et al., 2015). Seed cost also displayed a positive link with tractor numbers, indicated by a correlation coefficient of 0.23. High-value seeds often require modern machinery for timely sowing and field preparation, increasing the demand for tractors and related equipment (Pebrian, 2021).

7.Fertilizer Costs (Rs./ha of NSA):

Modern farming practices encompass specific inputs that explicitly and implicitly increase productivity per hectare. Fertilizers are either one of them. Fertilizers shared an association with the following cost components: Fertilizers shared correlation with value of crop output by the coefficient of correlation value 0.52. The primary reason for the increase in the value of crop output is cropping intensity (Paul et al., 2022). Fertilizer and seed costs have shown similar upward growth trends because they are complementary to each other. Thus, fertilizer cost showed a notably significant correlation ($p < .0001$) with seed cost and a coefficient of association $r = .54$. Farmers who use fertilizers and modern seeds to ameliorate per-hectare productivity also pay equal attention to safeguarding their produce from the attacks of insects and pests. Thus, insecticides were positively correlated with fertilizer costs ($r = .24$, $p < .0001$). Fertilizer costs also correlated with imputed rent costs. The coefficient of correlation was .24 with $p < .000$ between fertilizer costs and imputed rent costs, showing that increased fertilizer uses uplifts per hectare yield, thereby increasing imputed rent. Fertilizers and cropping intensity exhibited a strong correlation ($r = .49$) significant at $< .0001$, indicating that soil needs nutrients to support multiple cropping patterns

(Quddus et al., 2022).

8. Farmyard Manure Costs (FYM) (Rs./ha of NSA):

The amalgamation of farmyard manure and inorganic fertilizers works best to enhance soil fertility. Therefore, farmers prefer to use farm yard manure and it is associated with other cost components: The notable correlation of farmyard manure is identified with labour cost ($r = .32$ and $p < .0001$) on account of the labour-intensive nature of applying farmyard manure compared to inorganic fertilizers. It involves higher immediate labour costs, mainly when manure must be applied per agronomic practices (Daadi&Latacz-Lohmann, 2021). The use of farmyard manure entails the requirement of specific equipment designed to deal with farmyard manure efficiently and sustainably (Korra et al., 2020). Consequently, a positive correlation between machine costs and farmyard manure is indicated by a coefficient $r = .31$ linked with a significant value of p . The shifting of people's demand towards organic food items increased the demand for farmyard manure. Thus, the increase in demand for farmyard manure is positively correlated with animal costs, represented by a correlation coefficient $r = .23$ with significant p value less than .0001. It is pivotal to highlight that the machinery used for organic manure is expensive and requires more maintenance due to adverse environmental conditions, which lead to high corrosion rates and corresponding increased depreciation costs. Thus, the coefficient of correlation is .31 with $p < .0001$ that exists between farmyard manure and depreciation costs. Farmers must invest in specialized infrastructure, such as storage units and composting areas, which could initially increase fixed capital costs (Stroescu et al., 2022). Hence, a significant association between farmyard manure and fixed capital cost ($r = .27$).

9. Insecticides Cost (Rs./ha of NSA):

Insect and pest attacks destroy a huge amount of farm production each year. Therefore, globally, the use of insecticides has been increasing to address this hassle. It increases the insecticide's share in the total cost of cultivation and shared the association with other costs: The use of insecticides reduced the loss of crops from the attacks of insects and pests, thereby increasing the value of crop output (Misra et al., 2021). Consequently, a positive correlation with correlation value 0.39 between insecticide use and the value of the product. The increased use of nitrogen-based fertilizers that

help to increase soil nutrients, but it also invites invasions of insects and pests. Thus, a moderate association exhibited between insecticide costs and fertilizer costs, where $r = .24$, significant at 1 per cent. With the use of insecticides, the destructions of crops got reduced as the attacks of pests and insects got reduced. Therefore, it also increased imputed rent cost because increased per- hectare productivity escalates land value. Therefore, the coefficient $r = .34$ between insecticide and imputed rent costs significantly less than 1 per cent. Insecticide cost is also positively correlated with cropping intensity with a correlation coefficient of .20 and $p\text{-value} < .0001$. With the increase in cropping intensity, farmers have less time for natural pest management and depend upon insecticides (Schreinemachers&Tipraqsa, 2012).

10. Lease in Land Costs (Rs./ha of NSA

The lease in land costs relates to the rental payment paid by the farmers who do not own their land and lease it from others for farming practices. It is associated with these cost components: The skyrocketing rental value of farms in Punjab negatively impacts the imputed rent costs because the increased lease in land costs demotivates owners to invest in their land and latterly reduces their imputed rental value (Shyian et al., 2020). Therefore, a negative correlation exists between lease in land costs and imputed rent costs ($r = -.64$, $p < .0001$). The imputed rent costs refer to an opportunity cost that a farmer foregoes for cultivating their own land. The associated cost components were: Imputed rent costs exhibited the strongest positive correlation with the value of crop output, having a coefficient of correlation $r = .68$ ($p < .0001$). The non-existence of a formal rental market in Punjab relies on the value of crop output to estimate imputed rental costs. High per-hectare productivity in Punjab increased output value, following increased imputed rental costs (Sachdeva et al., 2017). Imputed cost shared a significant positive association with the fertilizers cost with having association value 0.24 because with the use of fertilizers, per hectare value of crop increased that positively effects imputed rent costs. Insecticide costs exhibited a moderate correlation with imputed rent cost with coefficient 0.34. Imputed rent costs are negatively associated with leased-in land costs as farmers preferred to cultivate their land, where they could invest in cost-saving technologies and increase their yield per hectare. Thus, the correlation coefficient $r = -.64$ with a $p\text{-value} < .0001$ between these two. With the increase in

imputed costs, the depreciation cost came down (Erenstein et al., 2007). Hence, the coefficient of correlation $r = -.19$ with a $p\text{-value} < .0001$ between imputed rent and depreciation costs. Increase in imputed rent cost motivates farmers to invest more in fixed capital assets. Therefore, correlation coefficient $r = -.21$ and a $p < .0001$ between imputed rent costs and fixed capital costs due to the spreading of fixed capital costs across multiple crops. Farmers strive to grow more crops to improve productivity, which raises their cropping intensity. Therefore, a positive correlation exists between imputed rent costs and cropping intensity with a coefficient value of $r = .45$ and $p < .0001$.

11. Depreciation Cost (Rs./ha of NSA):

It is essential to maintain a depreciation record to accurately estimate the benefits that are brought in using that particular asset. It is related with others cost components as under: It should be noted that the mechanization process does not underrate the labour requirement. Hence, moderate positive correlation between depreciation costs and labour costs exists ($r = .33$ with $p < .0001$). However, skilled labour has replaced unskilled labour to work with machines. Depreciation cost also shared a positive correlation with machinery costs with a coefficient of correlation ($r = 0.26$ with $p\text{-value} < 0.0001$, as with the increase in machines for farming operations, the depreciation also increased. Depreciation costs also correlated with the animal costs with a correlation coefficient is $.22$ and a $p < .00001$ due to the capital investment required for livestock operations like animal shelters that depreciate with time. Farmyard manure costs correspondingly and exhibited correlation coefficient ($r = .31$ having a $p\text{-value} < .0001$ between depreciation costs and farmyard manure. With the increase in depreciation costs, the imputed rent costs got reduced, and the correlation coefficient ($r = -.19$ $p < .0001$) between depreciation costs and imputed rent costs because the depreciation of assets due to continuous usage reduces imputed rent values. Mechanization of agriculture made farmers invest in fixed capital, which includes machinery, buildings, and farm equipment (Peng et al., 2022). Thus, a positive correlation exists between depreciation costs and fixed capital costs with coefficient $r = .83$, $p < .0001$.

12. Fixed Capital Cost per hectare (Rs./ha of NSA):

Fixed capital cost refers to the cost of using assets that are not used up during production of goods and services and can be used multiple times. Therefore, fixed capital cost shares association with other factors of production costs positively and negatively. With the increase in fixed capital, the labour cost also increased, as with the increase in investment in fixed capital such as in farmland, machinery, and other infrastructure, farmers need to hire more labour to deal with their increased investment (Elzbieta & Dziwulski, 2021). Thus, the correlation coefficient between fixed costs and labour costs exhibited $(r) = 0.32$ with the $p\text{-value} < 0.000$. The increase in fixed capital refers to the addition of machinery, which can be tractor equipment and irrigation machines like tube wells and sprinklers. Hence, a positive correlation is shared between fixed costs and machine costs with correlation coefficient $.17$ and $p\text{-value} < .0001$. Fixed capital costs also influence farmyard manure costs because the farmers need to invest in sustainable practices and make composting plots to prepare farmyard manure, which increases farmyard manure costs per hectare. The correlation coefficient between fixed capital costs and farm yard manure is 0.28 . Increases in fixed costs have a negative correlation with imputed rent costs with a correlation coefficient $(r) = -0.21$ with a $p\text{-value} < 0.0001$. An increase in fixed capital cost suggested that farmers allocated their resources towards more capital goods like machinery and farm equipment to operate on the same farm efficiently rather than investing in new land. It negatively affected their imputed rent costs per hectare. Increases in machines and other farm infrastructure correspondingly increase depreciation costs because more fixed assets imply more depreciation. Thus, the correlation between fixed capital costs and depreciation costs are positive with a coefficient of correlation $(r = .83, p < .0001)$. A tractor is an example of a fixed capital cost for agriculture. Therefore, the number of tractors and the fixed capital cost per hectare shared a positive correlation with each other $r = .30$ with $p < .0001$ (Akram et al., 2020).

13. Other costs (Rs. /ha of NSA):

While calculating the cost of cultivation, we divided costs into different categories like direct operating costs (seeds, fertilizers, insecticides, and irrigation costs), fixed costs (land costs, machinery deposits, and insurance), and variable costs (labour costs, fuel and oil, and repairs). Imputed costs (interest charges, depreciation) and miscellaneous costs (marketing costs, crop insurance premium). The deep analysis of these costs

would help to understand the overall cost structure of farming operations. Therefore, other costs/miscellaneous costs are calculated while dealing with the total cost of cultivation. Although costs paid on miscellaneous expenses do not share any statistically significant correlation with other factors of production used in our study.

14.Cropping Intensity:

It refers to how intensely farmer use his land to grow multiple crops. It is related with a number of other cost components like: The per-hectare productivity of Punjab is the highest, which is supported by the positive association between cropping intensity and the value of crop output with $r = .69$ (Singh et al., 2011; Kaur & Chauhan, 2024). Increased cropping intensity also intensified the demand for labour, with a significant ($p < .0001$) positive correlation between cropping intensity and demand for labour where coefficient $r = .43$, since labour is required for implementing intensive cropping strategies (Dahlin & Rusinamhodzi, 2019). A high cropping intensity is not possible without the contribution of high yield variety seeds. Thus, seed costs shared a positive correlation with cropping intensity, having a correlation coefficient $r = .28$ with a p -value $< .0001$. Increased cropping intensity also escalated the demand for fertilizers with coefficient of association $r = .49$, $p < .0001$ because high cropping intensity leads to the depletion of soil nutrients at a faster rate. To restore soil nutrients, farmers need to depend on fertilizers. Cropping intensity also increases the rate of insecticide application to save the crop from insects and pests and escalates insecticide costs. Thus, the correlation coefficient (r) = .20 with a p -value $< .0001$ between cropping intensity and insecticide costs. Cropping intensity promotes imputed rent cost through increase in value of crop output. They shared a high positive correlation with each having value 0.45 significant at $< .0001$.

15.Schooling Year:

Education is a tool that can increase the analytical power of an individual. Therefore, while considering the cost of cultivation, the education/schooling years are kept in mind. The number of years of formal education plays an important role in a farmer's capability to perform his farming operations efficiently. However, schooling years do not show any statistically significant correlation with the factors of production used in our Endeavour.

16.Tractor Number:

Advancements in agriculture have led the way for farmers to pin their hopes on mechanical power for agricultural operations. Tractors are among the most crucial farm machinery (Gulati & Juneja, 2020). It is associated with these cost components: With the increase in the number of tractors, economies of scale are achieved, and machinery costs per hectare are reduced. Thus, a negative correlation coefficient ($r = -.38$, $p < .0001$) between tractor number and machine costs. Advanced technology use in agriculture stressed the use of machines, leading to a fall in the dependence on livestock for labour and income generation (Chen & Lan, 2020). Thus, the tractor number negatively correlates with animal cost ($r = -.19$, $p < .0001$). The shifting of the seed-sowing task from labour to tractors increased seed costs (Dawid et al., 2022). Thus, with the increase in the number of tractors, the seed cost per hectare also increased, and the low ($r = .23$) but significant ($p < .0001$) correlation between them. Increase in tractor number also leads to increased fixed capital costs due to the requirement of investment in tractor components and other tools and machinery necessary for their working (Parashunath et al., 2017). Therefore, moderate correlation between tractor number and fixed capital costs with coefficient $r = .30$ and a p -value $< .0001$.

17.Combine Number: During harvesting periods, farmers use combined harvesters that can simultaneously reap, thresh, and winnow. The choice of ownership of a combine depends upon its ownership costs, operating costs, and the efficiency of the combine corresponding to the areas of harvest. However, the combined number did not show any statistically significant correlation with other production factors from the data collected from our primary survey.

Regression Analysis

Table 5.5: Regression Analysis of factors of production

Variables	Coefficient	Std Error	t Value	$P_r > t $	Variance

					Inflation
Intercept	-7342.51	7140.82	-1.03	0.305	0.00
Dummy for Small Size of landholding Group	3922.81	2738.53	1.43	0.153	2.54
Dummy for Semi-Medium of landholding Group	5763.45	2941.33	1.96	0.051	3.01
Dummy for Medium of landholding Group	7546.69	3109.76	2.43	0.016	3.33
Dummy for large size of landholding Group	12210.00	3255.26	3.75	0.000	3.62
Labour Cost (Rs/ha of NSA)	0.76	0.13	5.68	<.0001	2.52
Machine Cost (Rs/ha of NSA)	0.09	0.05	1.78	0.076	3.75

Irrigation machine cost(Rs/ha of NSA)	0.47	0.18	2.65	0.008	1.25
Animal Cost (Rs/ha of NSA)	-2.52	1.93	- 1.31	0.192	1.63
Seed Cost (Rs/ha of NSA)	0.45	0.13	3.56	0.000	1.64
Fertilizers Costs(Rs/ha of NSA)	1.18	0.40	2.95	0.003	2.17
Farm Yard Manure(Rs/ha of NSA)	-1.36	0.45	- 3.01	0.000 5	1.33
Insecticides cost (Rs/ha of NSA)	-0.17	0.35	- 0.49	0.621	1.82
Leased in Land cost (Rs/ha of NSA)	1.44	0.08	18.0 2	<.000 1	3.83
Imputed Rent Cost (Rs/ha of NSA)	2.31	0.08	29.5 6	<.000 1	4.67
Depreciation Cost	-0.16	0.10	- 1.62	0.105	3.76

(Rs/ha of NSA)					
Fixed Capital Cost (Rs/ha of NSA)	0.01	0.00	2.15	0.052	3.71
Other Costs (Rs/ha of NSA)	-2.05	1.83	- 1.12	0.265	1.03
Cropping Intensity(%)	114.08	44.01	2.59	0.010	2.76
Age of head	-123.88	65.06	- 1.90	0.058	1.51
Schooling Years	-37.55	191.48	- 0.20	0.845	1.39
Dependent person as % total number of family	-35.10	36.83	- 0.95	0.341	1.10
Dummy for Paddy/Maize-Wheat Crop	10526.00	2232.32	4.72	<.0001	2.49
Dummy for Paddy-Wheat Crop	12372.00	2096.71	5.90	<.0001	2.18
Dummy if some portion of	5571.21	2333.17	2.39	0.017	2.40

land leased in					
Number of Observations	408				
R ²	0.896				
Adjusted R ²	0.889				
F-Statistics	137.87***				

1. Intercept

The result indicates that the value of crop output is Rs. -7342.51 when all independent variables are equal to zero. However, it is not statistically significant because the p-value > 0.05 and the standard error is high with low |t| value.

2. Model fit

The high Adjusted R² = 0.89 and the high F-value suggests that the model fit is good and it explains the variability in value of crop output efficiently.

3. Dummy for Small Size of Land holding Group

The value of the coefficient for the dummy of the small size of the landholding group = 3922.81 indicated that, keeping other independent variables constant, the small size group was related to an increase of Rs.3922.81 in the value of crop output compared to the marginal size group. The p-value > 0.05, a low t-value (1.43), and a standard error (2738.53) revealed that there was high variability in the estimate.

4. Dummy for Semi-medium size of land holding Group

Likewise, to the small dummy, this variable compared the semi-medium group against the marginal landholding group (reference). The coefficient (5763.45) indicated that, keeping other independent variables constant, the semi-medium-size group is related to an increase of Rs.5763.45 in the value of crop output compared to the marginal-size group. A high standard error (2738.53), low t-value (1.96), and high p-value (0.051) suggested that semi-medium landholding size is not statistically significant in

affecting the value of crop output. Although the issue of multicollinearity does not exist, as $VIF < 5$.

5. Dummy for medium size of land holding Group

The coefficient of dummy for the medium-size landholding group (7546.69) suggested that, keeping other independent variables constant, the medium-size group is related to an increase of Rs.7546.69 in the value of crop output compared to the marginal landholding group (reference category). The result was not statistically significant, as the t-value is low (2.43) and the p-value is high (>0.05).

6. Dummy for large size of land holding Group

The coefficient (12210.00) indicated that, keeping other independent variables constant, the large size group is related to an increase of Rs. 12210 in the value of crop output compared to the marginal size group.

7. Labour cost (Rs./ha of NSA)

The coefficient of labour costs = 0.76, showing that an increase in labour costs would result in an increased in the value of crop output by Rs. 0.76, while all other variables remain constant. The relationship between labour cost and the value of crop output is statistically significant with very low dubiety, as the standard error = 0.13, a high t-statistic (>5), and a small p-value ($< .0001$). Moreover, the level of multicollinearity is moderate ($VIF = 2.52$).

8. Machine cost (Rs./ha of NSA)

The coefficient of machine costs = 0.09 revealed a positive relationship between machine costs and the value of crop output. Considering all other variables constant, for every one-unit increase in machine costs, the value of crop output increases by Rs. 0.09. Although its statistical significance is weak due to a low t-value = 1.78 and a high p-value = 0.076. The standard error of 0.05 indicates moderate precision in estimation. The $VIF = 3.75$ suggests a moderate level of multicollinearity.

9. Irrigation Machine cost (Rs./ha of NSA)

The coefficient of irrigation machine costs = 0.47 suggested that irrigation machine costs showed a positive relationship with the value of crop output. Assuming all other variables are constant, a one-unit increase in irrigation machine costs would increase

the value of crop output by Rs. 0.47. The result was statistically significant because the p-value was low ($p = 0.008$). The standard error = 0.18 depicted reasonable precision in estimation. The VIF = 1.25, which does not pose any concerns regarding multicollinearity.

10. Animal cost (Rs./ha of NSA)

The coefficient of animal costs = -2.52 suggested that a negative relationship existed between animal costs and the value of crop output. However, the relationship was not statistically significant .

11. Seed cost (Rs./ha of NSA)

The coefficient of seed costs = 0.45 indicated a positive relationship between seed costs and the value of crop output; a one rupee increase in seed costs would result in an increase in the value of crop output of approx. Rs. 0.45. The small standard error of 0.13 and high t-value (3.56), accompanied by a low p-value (0.000) and a VIF ($1.64 < 5$), exhibited a statistically significant positive relationship between seed costs and the value of crop output.

12. Fertilizers cost (Rs./ha of NSA)

The coefficient of fertilizer costs = 1.18 indicated that for every one-unit increase in fertilizer costs, there was an expected increase of Rs. 1.18 in the value of crop output, assuming all other variables remain constant. The result represented precise estimation with the high t-value (2.95), the p-value was $0.003 < 0.05$, and the standard error was low (0.40). Furthermore, a low VIF of 2.17 represents no concern about multicollinearity.

13. Farm Yard Manure Cost (Rs./ha of NSA)

The negative coefficient of farm yard manure cost (-1.36) indicated that a one-unit increase in farmyard manure costs leads to a decrease in the value of crop output by Rs.1.36, holding other variables constant. The result is statistically significant, as $p\text{-value}=0.003<0.05$ and $|t|=-3.01$, which is high and represents strong evidence that FYM costs have a real effect on the value of crop output rather than being due to

sampling error. The VIF=1.33, which represents the absence of the problem of multicollinearity.

14. Insecticides Costs (Rs./ha of NSA)

The coefficient of insecticide costs = -0.17 suggested that an increase in insecticide costs may reduce the value of crop output by Rs 0.17. Although, the result was not statistically significant.

15. Leased-in-land Costs (Rs./ha of NSA)

The coefficient for leased-in land costs = 1.44 indicated a positive relationship between leased-in land costs and the value of crop output; for every one-unit increase in leased-in land costs, there was an average increase of Rs. 1.44 in the value of crop output, holding all other variables constant. The result was statistically significant because of a very low p-value (<0.0001) and a high $|t|$ -value (18.02). Moreover, the precision of this estimate was supported by its small standard error (0.08) and moderate VIF (3.83), showing the problem of multicollinearity was not severe.

16. Imputed rent own land cost (Rs. /ha of NSA)

The coefficient of imputed rent costs = 2.31 indicated a positive relationship between imputed rent costs and the value of crop output, with every one-unit increase in imputed rent costs correspondingly increasing the value of crop output by Rs. 2.31. The result was significant, as the p-value is < 0.0001 and there was a very large $|t|$ -value (29.56) and a small standard error (0.08), which indicated precise estimation. The VIF value was 4.67, which showed an acceptable level of multicollinearity.

17. Depreciation of farm building and implement cost (Rs. /ha of NSA)

The coefficient for depreciation costs (-0.16) suggested a negative relationship between depreciation costs and the value of output. The result was not statistically significant, as the p-value is > 0.05 . Therefore, we can say depreciation costs did not affect the value of crop output despite a moderate standard error (0.10).

18. Fixed capital cost (Rs./ha of NSA)

The coefficient of fixed capital costs = 0.01 suggested a statistically significant positive relationship between fixed capital costs and the value of crop output. The

result was statistically significant because the $p\text{-value} < 0.05$ and the standard error (0.00). Moreover, $VIF=3.71$ represented an acceptable level of multicollinearity.

19. Other cost (Rs./ha of NSA)

The coefficient for —other costs $\parallel = -2.05$ suggested a negative relationship between other costs and the value of crop output. However, the result was not statistically significant, as the $p\text{-value} > 0.05$ ($p = 0.265$). Thus, other costs did not show a meaningful impact on the value of crop output.

20. Cropping Intensity (Per cent)

The coefficient for cropping intensity = 114.08 suggested that a one-unit increase in cropping intensity results in an increase in the value of crop output by Rs.114.08 due to the positive relationship between cropping intensity and the value of crop output. The result was statistically significant as the $p\text{-value}$ is < 0.05 . However, the standard error of 44.01 showed moderate variability around its estimates. The $VIF=2.76$ exhibited an acceptable level of multicollinearity.

21. Age of head (in Year)

The coefficient for age of head = -123.88 suggested that a negative relationship exists between age of head and value of crop output. As age increases by one year, the value of the crop would decrease by Rs.123.88, holding all other variables constant. This relationship was not statistically significant, as the $p\text{-value}$ was high and the $|t|\text{-value}$ was low. The multicollinearity did not exist due to low VIF (1.51).

22. Schooling years of head

The coefficient of schooling years = -37.55 suggested a negative relationship with the value of crop output. This result was not statistically significant due to a very high $p\text{-value}$ ($P = 0.845$), a small $t\text{-statistic}$ (-0.20), and a large standard error (191.48). Moreover, multicollinearity does not exist, as $VIF = 1.39$.

23. Dependent person as percentage of total member in family

The coefficient of dependent persons as a percentage of total members in a family is -35.10, suggested that if one dependent person increased in a family, the value of crop output would decrease by Rs.35.10. However, this effect is not statistically

significant, as the p-value = 0.341, the standard error is high at 36.83, and the |t|-value is low at -0.95.

24. Dummy for Paddy/Maize- Wheat Crop Zone

The coefficient for —paddy/maize-wheat crop zone (10526) indicated that the value of crop output increases by an average of Rs10,526 compared to the reference zone (cotton/paddy-wheat zone), keeping other variables constant. This effect is statistically significant ($P=0.0001$), as evidenced by a large absolute t-statistic ($|t|=-4.72$). Additionally, with $VIF=2.49$, there are no concerns about multicollinearity affecting this result significantly.

25. Dummy for Paddy-Wheat Crop Zone

As the paddy-wheat crop zone increased, the value of crop output increased by an average of Rs. 12,372 compared to the reference category. It was statistically significant at $p < 0.01$, and the relatively small standard error (2,093.71). The $VIF = 2.18$ indicates the non-problematic level of p multicollinearity.

26. Dummy if some portion of land leased in

The coefficient of dummy, if some portion of land leased, increased the value of crop output by an average of Rs. 5,571, holding all other variables constant. This effect was statistically significant at a p-value of 0.017 and with a relatively low standard error, indicating reasonable precision. The VIF value of 2.40 shows no serious multicollinearity concerns.

SPEC test for factors of production

Table 5.6: SPEC test for factors of production

Degree of freedom	Chai square value	Pr>ChiSq
111	108.37	0.5530

Since the p-value > 0.05 , therefore we fail to reject the null hypothesis of homoskedasticity. Thus, the model does not show the evidence of heteroskedasticity and the error variance is constant.

5.4.2 Return on Cost (Profitability) Analysis

Profitability is indispensable for farmers' survival in the agricultural sector. However, over the past ten decades, profitability has been declining, which has resulted in farmers in Punjab either migrating to foreign countries or selling their lands and adopting an alternative profession other than agriculture (Dutta, 2012). Although those who decided to continue in agriculture due to lacking job opportunities in other sectors have protested the guaranteed MSP. In addition, MSP should be calculated as per the recommendations of the Swaminathan Commission, and it should be at least 50 percent more than the C2 cost of production to make farming a viable profession (Swaminathan, 2017). However, it has not been implemented by India's government yet despite massive protests by farmers across India. Profitability (return on costs) can be increased in several ways, from modern marketing methods to the adoption of crop diversification. In this chapter, we analyzed the factors identified from literature and during our data collection that statistically significantly promote returns on costs (profitability) per hectare.

Descriptive Statistics

Table 5.7: Descriptive statistics of the variables used to analyse the Profitability

Variable	N	Mean	Std Dev	Minimum	Maximum
Return on Cost A2+ Family labour cost (Rs./ha of NSA)	408	120075	58820	-241114	358508
Dummy for Small Size of Land holding Group	408	0.20	0.40	0	1
Dummy for Semi- Medium Size of Land holding Group	408	0.20	0.40	0	1
Dummy for Medium Size of Land holding Group	408	0.20	0.40	0	1
Dummy for Large Size of Land holding Group	408	0.20	0.40	0	1
Cropping Intensity (%)	408	196.09	25.79	50	286
AgeYear	408	49.54	12.90	20	81
Schooling_year	408	8.76	4.21	0	18

Family Size (No.)	408	5.83	2.39	1	17
Dummy for Paddy/Maize- Wheat Crop Zone	408	0.37	0.48	0	1
Dummy for Paddy- Wheat Crop Zone	408	0.36	0.48	0	1
Dummy if some portion of land leased in	408	0.29	0.45	0	1
Fragment (No)	408	7.00	3.46	0	23

Source: Author's Estimation

Table 5.7 describes the descriptive statistics of the variables involved in our analysis that we claimed affect profitability. Our analysis found that returns to farmers varied from negative to positive, and the maximum return was Rs.3,58,508 per hectare. The average return was Rs. 1,20,075 per hectare. The majority of farms in Punjab were semi-medium and medium-sized farms. The average cropping intensity was 196.09 percent, higher than the national average. Socio-economic characteristics revealed that the average farmer age in Punjab was 49.5 years, and their school years were 8.75 years. The average number of household members was 5.83. On the other hand, on average, fragment numbers were 7.

Table 5.8: Descriptions of variables used in Table 5.9

S.NO	Variables	Description
1	VAR1	Return on Cost A2+ Family labour cost (Rs./ha of NSA)
2	VAR2	Dummy for Small Size of Land holding Group
3	VAR3	Dummy for Semi- Medium Size of Land holding Group
4	VAR4	Dummy for Medium Size of Land holding Group
5	VAR5	Dummy for Large Size of Land holding Group
6	VAR6	Cropping Intensity (%)
7	VAR7	AgeYear
8	VAR8	Schooling_year

9	VAR9	Family Size (No.)
10	VAR10	Dummy for Paddy/Maize- Wheat Crop Zone
11	VAR11	Dummy for Paddy- Wheat Crop Zone
12	VAR12	Dummy if some portion of land leased in
13	VAR13	Fragment (No)

Pearson Correlation Coefficient

Table 5.9: Pearson Correlation Coefficient Analysis for Returns on Costs (Profitability).

Variable	VAR1	VAR2	VAR3	VAR4	VAR5	VAR6	VAR7	VAR8	VAR9	VAR10	VAR11	VAR12	VAR13
VAR1	1 (<.0001)												
VAR2	-0.038 (0.447)	1 (<.0001)											
VAR3	0.042 (0.398)	-0.25 (<.0001)	1 (<.0001)										
VAR4	0.17 (0.001)	-0.248 (<.0001)	-0.253 (<.0001)	1 (<.0001)									
VAR5	0.147 (0.003)	-0.246 (<.0001)	-0.252 (<.0001)	-0.25 (<.0001)	1 (<.0001)								
VAR6	0.254 (<.0001)	-0.009 (0.849)	-0.012 (0.805)	0.017 (0.737)	-0.025 (0.609)	1 (<.0001)							
VAR7	-0.124 (0.012)	0.147 (0.003)	0.019 (0.709)	-0.084 (0.092)	-0.12 (0.015)	-0.043 (0.387)	1 (<.0001)						
VAR8	0.092 (0.062)	0.004 (0.943)	-0.004 (0.934)	0.122 (0.014)	0.105 (0.034)	0.062 (0.21)	-0.366 (<.0001)	1 (<.0001)					
VAR9	0.067 (0.18)	0.04 (0.419)	-0.122 (0.014)	0.051 (0.306)	0.22 (<.0001)	0.016 (0.753)	0.096 (0.054)	-0.093 (0.059)	1 (<.0001)				
VAR10	-0.252 (<.0001)	-0.005 (0.916)	0.006 (0.902)	-0.002 (0.97)	0.003 (0.955)	0.064 (0.198)	0.269 (<.0001)	-0.038 (0.441)	0.052 (0.296)	1 (<.0001)			
VAR11	0.245 (<.0001)	0.002 (0.964)	0.001 (0.981)	0.006 (0.907)	-0.015 (0.76)	0.006 (0.904)	-0.088 (0.077)	0.125 (0.012)	-0.043 (0.386)	-0.572 (<.0001)	1 (<.0001)		

VAR12	-0.334 ($<.0001$)	-0.015 (0.755)	0.04 (0.418)	-0.01 (0.846)	0.089 (0.072)	-0.029 (0.559)	-0.088 (0.078)	-0.022 (0.653)	-0.005 (0.926)	0.175 (0.00)	-0.04 (0.425)	1 ($<.0001$)	
VAR13	-0.288 ($<.0001$)	-0.19 (0.00)	-0.002 (0.966)	0.138 (0.005)	0.375 ($<.0001$)	0.095 (0.056)	-0.045 (0.37)	0.143 (0.004)	0.128 (0.01)	0.355 ($<.0001$)	-0.163 (0.001)	0.414 ($<.0001$)	1 ($<.0001$)

Source: Estimation based on primary survey 2022-23.

1. Return Cost A2 + family labour cost (Rs/ha of NSA):

Return Cost A2+family labour cost (Rs/ha of NSA) the profitability of agricultural operations is observed by their returns relative to costs. Higher returns over costs represent profitability. It is related with the cost components. Cropping Intensity (VAR 6) the return on costs positively correlates with cropping intensity, with a coefficient (r) of .25 and $p < .0001$. It suggests that growing multiple crops by the farmers through crop rotation and adopting modern agricultural technologies and farm inputs such as fertilizers, pesticides, and high-yield variety (HYV) seeds increases their returns per hectare (Zhao et al., 2019). Dummy for Paddy maize wheat crop zone (VAR 10) Profitability is negatively correlated ($r = -.25$, $p < .0001$) with the paddy maize wheat crop zone 1, due to soil degradation and resource depletion. Dummy for Paddy Maize Wheat Crop Zone (VAR 11) Return on costs (profitability) showed a positive correlation with Paddy and wheat crops zone return on cost, with a correlation coefficient of .24 ($p < .0001$). Economies of scale are the primary reason for positive correlation due to mono cropping patterns. Moreover, the inputs required for both paddy and wheat cultivation is similar, allowing for the distribution of fixed costs over a larger area and output. Dummy if some portion of land leased in (VAR 12) Returns on costs negatively associated with leasing land having a correlation value of -.33 with $p < .0001$ on account of the lack of a formal land rental market. Farmers think twice before adopting new technology on leased land because it is expensive and they are not sure how long they will retain the land due to the lack of a formal land market (Ruzzante et al., 2021). Fragmentation (VAR 13) the return on cost exhibited a negative correlation with return on cost, with Pearson's r of -0.28 ($p < .0001$), because modern agriculture depends upon machinery for various practices, from cultivation to harvesting. Fragmentation leads to increased operational costs and reduced returns per hectare (Wang et al., 2020).

2. Dummy for Small Size of Land holding Group

Dummy for Small Size of Land holding Group A landholding having an area between 1–2 hectares is considered a small-sized farm. The close and significant correlation with other variables were Dummy for Semi-Medium Landholding group (VAR 3) Small farms shared a negative correlation with semi-medium farms ($r = -.25$) because semi-medium farms have better access to resources like agricultural credit, seeds, fertilizers, pesticides, and advanced technology. The accessibility of these resources increased the per-hectare productivity compared with small farms. Therefore, they are more profitable than small farms. Dummy for Medium Landholding group (VAR 4) Small farms had a negative correlation with medium farms, with the Pearson's r was $-.25$ and $p < .0001$ because medium farms are more profitable in Punjab on account of their high bargaining power. Moreover, medium farms can be involved in contract farming to increase their per-hectare profitability, which is impossible for small farms because of their limited production capacity. Dummy for Large Landholding group (VAR 5) Small farms also shared an inverse correlation with large farms, having a correlation value r of $-.24$ because the introduction of technology under the Green Revolution made small farms infeasible (Schmook et al., 2022; Pingali, 2012).

3.Dummy for Semi-Medium Landholding:

A landholding having an area between 2–4 hectares is considered a semi-medium-sized farm. Significant and correlated variables were Dummy for small size landholding farms group (VAR2) Semi-medium farms showed a negative correlation with small-sized landholdings ($r = -.24$) for lower profitability of small farms in Punjab compared to semi-medium farms. The main reasons for low profitability were the high input costs and low productivity (Singh & Singh, 2017). Dummy for medium size landholding farms group (VAR4) Semi-medium farms showed a negative correlation with medium farms with a Pearson's coefficient $r = -.25$ and $p < .0001$, for efficiency in the use of farm inputs compared to medium farms (Singh et al., 2017). Dummy for large size landholding farms group (VAR5) Semi-medium farm also revealed a negative correlation with large farms with Pearson correlation value -0.25 because large farms receive special perks from the government in the form of subsidies to invest in advanced technology that can increase per hectare productivity compared to semi-medium farms.

4.Dummy for Medium Landholding Size:

A landholding having an area between 4–10 hectares is considered a medium-sized farm. The association with other variables were Dummy for small size landholding farms group (VAR2) A negative correlation between medium-sized farms and small farms with correlation coefficient (r) = -0.25 with a p -value < 0.0001. It indicated to the problems of small farms in Punjab, such as indebtedness, inequalities, and low returns that make small farms less competitive than medium farms (Saini et al., 2022). Dummy for semi-medium size landholding farms group (VAR3) Dummy for semi-medium size landholding farms group (VAR3) Medium farms shared a negative correlation with semi-medium farms with the r value of -0.25 on account of yield variations for difference in technical efficiency (Dagar et al., 2021). Dummy for large size landholding farms group (VAR5) Medium farms showed a significant negative correlation coefficient (r) = -.25 with large farms group. It was due to the advantage of economies of scale taken by the large farms (Janus & Markuszewska, 2017; Allahyari et al., 2018; Nguyen & Warr, 2019).

5.Dummy for Large Size of Landholding Group:

Farms having an area more than 10 hectares are considered large farms. It is correlated with the following variables. Dummy for small size landholding farms group (VAR2) Large landholding size shared a contrary significant correlation with small-size landholding, having a Pearson r is -.24, showing that small farms are decreasing in Punjab and the lion's share of small farmers are leasing out their land to large farmers. Dummy for semi-medium farms group (VAR3) with the semi-medium farms, large farms express a negative correlation r of -.25 with a p -value < .0001 because large farms have more connections in the market (Gohain, 2018). Therefore, large farms earn more profits than semi-medium farms. Dummy for medium farms group (VAR3) Large farms also showed a negative correlation with medium farms (r = -.25) because large farms have more access to resources in Punjab than medium farms (Singh, 2002). Family size number (VAR 9) A positive correlation exists between large farms and household members with a correlation coefficient r = .22 and p -value < .0001 because a joint family is able to manage large farm operations economically (Ayaz & Mughal, 2022). Cropping Intensity (VAR6) the level of cropping intensity is satisfactory in large farms, and the coefficient of correlation between large farms and cropping intensity is .25 with p less than 1. Fragmentation (VAR13) Large farms and fragmentation were positively associated and coefficient of correlation is 0.37.

6. Cropping Intensity:

Cropping intensity in Punjab is the highest across India. With the increase in cropping intensity, farmers are getting better returns on investment because they are growing multiple crops across the year due to various support provided by the state government, like subsidies for seeds, fertilizers, and irrigation facilities, which have led to increase per hectare productivity and better returns on costs (Kaure et al., 2015). Therefore, the coefficient $r = .25$ with a $p\text{-value} < .0001$ between cropping intensity and returns on costs.

7. Age Year:

The age of the farmers, measured in years, was examined in relation to variables such as schooling years and agro-climatic zones. A negative association was observed between farmers' age and their years of schooling ($r = -.36$, $p < .0001$), which aligns with the understanding that formal education was not widely prioritized in earlier decades (Sharma, 2017). In contrast, societal attitudes toward education have evolved significantly over time (Liu & Cheng, 2021). Additionally, farmer age showed a positive correlation with the paddy/maize–wheat crop zone ($r = .27$, $p < .0001$), indicating that this zone has a relatively higher proportion of experienced, older farmers.

8. Schooling Year:

Schooling year relates with the number of years a person attended a formal education institution. It was observed that school year is inversely correlated with farmer age. The correlation coefficient between them was 0.36 with $p\text{-value} < .0001$.

9. Household Member/Family Size (No.):

Household size refers to the total number of family members in farming household and was examined in relation to landholding size. A positive and significant association was observed between family size and large landholdings ($r = .22$, $p < .0001$). This relationship is consistent with earlier findings that large farms in Punjab are predominantly managed by joint families, which enables them to efficiently handle extensive farm operations (Kaur et al., 2020).

10. Dummy for Paddy/Maize-Wheat Crop Zone:

This zone related with other variables like return on cost $A2 + \text{family labour cost}$ (VAR1), age (VAR7), the paddy–wheat crop zone dummy (VAR11), and

fragmentation (VAR13). Fragmentation and age contribute to a reduction in per-hectare returns on costs in the paddy/maize–wheat crop zone, having a correlation coefficient of $r = -0.25$ with a p -value $< .0001$. Age is another constraint. During the interview process with the farmers in the paddy/maize–wheat crop zone, it was found that most of the farmers belong to the older age category, which makes it difficult for them to adopt modern technology in farming. Thus, there is a moderate correlation between the paddy/maize–wheat crop zone and age, with Pearson's $r = .27$ and $p < .0001$. Returns on costs in the paddy–wheat crop zone are notably lower compared to the paddy/maize–wheat crop zone, and therefore a negative correlation was exhibited between them ($r = -0.57$, $p < .0001$). The paddy/maize–wheat crop zone is also encountering difficulties that reduce its return on costs (profitability), with fragmentation serving a primary role. The correlation between the paddy/maize–wheat crop zone and fragmentation is $r = .35$ with $p < .0001$.

11. Dummy for Paddy- Wheat Crop Zone:

Paddy–wheat crop zone refers to the central Punjab, and the relationship with other variables is explained through return on cost A2 + family labour cost (VAR1) and the dummy for the paddy/maize–wheat crop zone. It showed a more positive return per hectare than the reference category (cotton/paddy–wheat zone), with a coefficient of $r = .24$ and $p < .0001$, mainly due to its high per-hectare productivity. A negative correlation was exhibited between the paddy–wheat crop zone and the paddy/maize–wheat crop zone because of variation in per-hectare productivity, with $r = -.57$ and $p < .0001$.

12. Dummy if some portion of land leased in:

This variable is correlated with the following other variables, including return on cost A2 + family labour cost (VAR1) and fragmentation (VAR13). In Punjab, the demand for land for agricultural purposes is more than the supply, resulting in relatively high rental values. This reduces per-hectare returns for farmers, and therefore a negative association exists between leased land and returns on costs, with a coefficient of $r = -.33$, significant at the 1 per cent level. The leased-in land is also correlated with fragmentation due to reverse tenancy, and thus a positive correlation exists between leased land and fragmentation, with Pearson's $r = .41$ and $p < .0001$.

13. Fragmentation:

Fragmentation refers to farmers owning multiple land plots that are not contiguous and are dispersed across a broad geographical area, and it is linked with the following cost components: return on cost A2 + family labour cost (VAR1), the dummy for large landholding size (VAR5), the dummy for leased-in land (VAR12), and the dummy for the paddy/maize–wheat crop zone (VAR10). During the survey, it was observed that farmers whose land was scattered over a wide area had to undertake much additional work to manage their land effectively and adopt modern production techniques (Tan et al., 2007). This reduced their per-hectare return on cost, reflected in a correlation of $r = -.29$, significant at the 1 per cent level. It was also found that large farms were more affected by fragmentation because they were inclined to lease additional land to increase their productivity (Niroula & Thapa, 2005), resulting in a correlation coefficient of .37 between them. Fragmentation further promoted leased-in land, with a correlation of $r = .41$, as more scattered landholdings increased the incidence of reverse tenancy and large farmers leased in land to achieve economies of scale. The problem of land fragmentation also varied by zone, and the value of the correlation coefficient between fragmentation and the paddy/maize–wheat crop zone was $r = .35$, $p < .0001$, indicating that fragmentation is considerably more significant in this zone than in others.

Regression Analysis

Table 5.10: Regression Analysis of factors of profitability.

Variables	Coefficient	Std Error	t Value	P _r > t	Variance Inflation
Intercept	8082.44	19795.00	0.410	0.683	0.000
Dummy for Small size of land holding group	47830.00	6606.19	7.240	<.0001	1.726
Dummy for Semi-Medium size of	68193	6560.57	10.390	<.0001	1.750

landholding size					
Dummy for Medium size of landholding size	89430.00	6958.01	12.850	<.0001	1.951
Dummy for large size of landholding group	105257.00	7608.31	13.380	<.0001	2.312
Cropping Intensity (%)	700.40	78.82	8.890	<.0001	1.034
Age Year	-449.44	181.19	-2.480	0.014	1.368
Schooling	-921.06	547.27	-1.690	0.092	1.317
Family Size(No)	-254.42	888.41	-0.290	0.775	1.131
Dummy for Paddy/Maize-Wheat crop	10599.00	5760.32	1.840	0.067	1.936
Dummy for Paddy-Wheat Crop zone	25285.00	5207.86	4.860	<.0001	1.569
Dummy if some portion of land leased in	-26151	4992.89	-5.240	<.0001	1.286
Fragment No.	-8725.41	792.85	-11.010	<.0001	1.887
Number of Observations	408				
R ²	0.544				
Adj R ²	0.530				
F-Statistics	39.26***				

Interpretation:

1.Intercept: The intercept coefficient = -7342.51 represents the forecasted value of the return on cost (profitability) when all independent variables are considered zero. However, the result is not precise due to a large standard error (7140.82), and it is not statistically significant based on its t-value (-1.03) and p-value (0.305).

2.Model fit: The high Adjusted $R^2 = 0.53$ and the high F-value = 39.26 suggested that the model fit is good and it explains the variability in returns on Costs A2 (probability) efficiently.

3.Dummy for Small Size of Land holding Group:

The dummy variable for Small Size of Landholding Group has a promising result on the return on cost (profitability). The profitability increased by Rs.47,830 compared to its reference category (marginal landholding). Additionally, statistically significant ($p < 0.001$), high t-value (7.240), and allow Variance Inflation Factor (VIF)=1.726 specify no multi collinearity issues with other independent variables in the model. The standard error (6606.19) shows reasonable precision of the results.

4.Dummy for Semi-Medium Size of Landholding Group:

The dummy variable for-semi-medium size of landholding group II suggested a statistically significant positive relationship between semi-medium size of landholding group and returns on costs (profitability). The returns on costs (profitability) increased by Rs.68,193 compared to the reference group (marginal landholding group). The result is validated with the large t-value (10.390) and low p-value (0.0001). Furthermore, the VIF (1.750) ensured that the problem of multicollinearity does not exist.

5.Dummy for Medium Size of Landholding Group:

The coefficient for Dummy for Medium Size Landholding Group II indicated that profitability increased by Rs.89,430 compared to the reference group (marginal landholding group), keeping other variables constant. The results are statistically significant as a very small p-value (< 0.0001), encouraged by a high t-value (12.850). The VIF value (1.951) confirms a minimal multicollinearity issue.

6.Dummy for Large Size of Landholding Group:

The dummy variable for-Large Size of Landholding Group II has a statistically significant favorable effect on the return on costs (profitability). It is escalated by Rs.105,257 compared to reference landholding groups (marginal landholding size). The low p-value ($<.0001$), low standard error (7608.31), and high t-value (13.830) validated a reliable result. Furthermore, multicollinearity does not concern any issue, as VIF (2.312) <5 .

7.Cropping Intensity (per cent):

The coefficient for cropping intensity (700.40) suggested a strong positive and statistically significant relationship between cropping intensity and return on costs (profitability). A high t-value accompanied by a low p-value ($p<0.0001$) and a low standard error (78.82) justified that the estimation is precise and significant. Moreover, 0000000VIF (1.034) exhibits that multicollinearity is not a matter of concern as VIF <5 .

8.Age Year: Age year has a statistically significant negative effect on the return on costs (profitability) because for every one-year increase in age, there is an estimated decrease in return on cost (profitability) by Rs. 449.44. The precision of estimation is verified by a low standard error (181.19). Furthermore, VIF=1.368 suggested the problem of multicollinearity does not exist.

9.Schooling Years: The coefficient (-921.06) indicates that each additional year of schooling decreases the return on costs (profitability) by Rs.921. However, this result is not statistically significant, as the p-value >0.05 , accompanied by a low t-value and a large standard error (545.27).

10.Family Size (No.): The negative coefficient (-254.42) indicates an inverse relationship between family size (No.) and the return on costs (profitability). However, the result is not statistically significant as the p-value >0.05 and the t-value is (-0.290). Thus, we do not have enough evidence to support that family size significantly impacts return on costs (profitability).

11.Dummy for Paddy/ Maize- Wheat Crop Zone: The results suggested that potential benefits from being in a paddy/maize-wheat crop zone with an estimated increase of returns on costs (profitability) of Rs. 10,599 compared to the reference

category (cotton/paddy-wheat crop zone). However, $p\text{-value} > 0.05$ and a high standard error cast doubt on the precision of estimation.

12.Dummy for Paddy-Wheat crop Zone: The dummy variable for the paddy-wheat crop zone has a significant positive impact on returns on costs (profitability) compared to the reference category (Cotton/Paddy-wheat zone) by Rs. 25285. The estimation is precise and statistically significant, as $p\text{-value} < .0001$ And the $t\text{-value}$ (4.860) is high. Moreover, the standard error is also low (5207.86), and the problem of multicollinearity does not exist as $VIF = 1.569$.

13.Dummy if some portion of land leased in: The coefficient (-26151.00) of Dummy is if some portion of land is leased in, suggesting that the increase in the portion of leased-in land results in a significant negative impact on returns on costs (profitability). The result is statistically significant as the $p\text{-value} < .0001$ and the high $|t|$ -value (-5.240). Precision of the estimate was also validated from a small standard error (4992.89).

14.Fragment No.: The regression analysis suggested fragmentation statistically significantly negatively impacts returns on costs (profitability) by Rs.8725.41 with each fragment. The low $p\text{-value}$ ($p < .0001$) and high $|t|$ value (-11.010) represents statistically significant results. Additionally, a low standard error (792.85) represents the precision of estimation. Further, multicollinearity is not an issue as $VIF (1.887) < 5$.

SPEC test for Profitability as:

Table 5.11 SPEC test for profitability

Degree of freedom	Chi square value	Pr>Chi Sq
66	61.20	0.6444

There is no evidence of heteroskedasticity in the model. We compared the LM statistic (61.20) against a chi-square distribution with 66 degrees of freedom. Since the $p\text{-value} = 0.6444$, which is much greater than 0.05, therefore, we fail to reject the null hypothesis of homoskedasticity.

5.5 Conclusion

The role of factors of production is essential to improve per hectare value of crop output

(productivity) and returns on costs per hectare (profitability). In this chapter, we studied certain variables (factors of production) to know their contribution towards the increase in per hectare value of crop output and returns on costs. These variables are identified from the literature and data collection process. We applied multiple regression analysis to justify the inclusion of each variable in the model. It involves descriptive analysis, Pearson Correlation Coefficient, and regression analysis to justify the model selection. Both R-square & Adj R-square are used to know the fit of the model, and the values corresponding to these two are pretty high, which confirms that the model fit is good to explain the variance in value of crop output and returns on costs (Rs/NA). Overall, the F-value is also relatively high for both the value of crop output and returns on costs. A p-value < 0.0001 suggested that all the independent variables included in the model explained the variance in the dependent variable. The results of multiple regression suggested that the value of crop output is statistically significantly affected by the variables (factors of production) like labour costs, lease-in-land costs, imputed rent costs, and zone. A unit increase of these variables positively increases the value of crop output. Likewise, returns on costs (profitability) are also influenced statistically by the factors of production (variables) like small-size landholding, semi-medium-size landholding, medium-size landholding, large-size landholding, cropping intensity, Paddy-Wheat crop zone, leased-in land costs, and fragment. Except for variables such as lease in land and fragment, all the other variables contribute positively towards returns on costs (profitability). Unit increases in these variables positively contribute towards returns on costs (profitability). However, with a unit increase in lease in land cost and fragmentation, the returns on costs (profitability) go down. These production factors are part of the micro-level analysis. However, the decisions taken by the government for the agriculture sector also affect the level of value of crop output (productivity) and returns on costs (profitability). It involves schemes started by the government to promote per-hectare productivity, like the National Mission for Sustainable Agriculture (NMSA) for promoting agricultural productivity in rainfed areas, Pradhan Mantri Krishi Sanchi Yojana for extending the coverage of irrigation to every farm by improving water use efficiency, the Soil Health Card (SHC) Scheme, and the Agriculture Technology Management Agency (ATMA).

Like productivity promotion schemes, the government also introduced schemes related

to promoting the returns on cash (profitability). It involves schemes like the Doubling Farmer's Income program alongside existing policies like the E-NAM trading portal, Paramparagat Krishi Vikas Yojana for organic farming, Pradhan Mantri Fasal Bima Yojana for disaster losses, Pradhan Mantri Kisan Samman Nidhi Schemes, and the Micro Irrigation Fund to enhance agricultural production and farmer incomes. In addition, specific schemes have been started targeting Punjab only, like the Punjab Land Leasing and Tenancy Bill and the East Punjab Holdings (Consolidation and Prevention of Fragmentation Act, 1948). These schemes targeted all the possible ways to increase the farmers' income. Crop diversification must be widespread, and farmers should be encouraged to grow high-value crops like horticulture, floriculture, and medicinal plants.

CHAPTER-VI

CONCLUSION & SUGGESTIONS

6.1 Conclusion

Structured Transformation in the Indian economy shifted the government's attention towards the service sector, contributing to the country's GDP of around 54.72 per cent during 2023-24 (Government of India et al., 2024). However, the role of the agriculture sector cannot be denied because it is still contributing significantly towards employment, Rural Development, poverty alleviation, and India's export earnings. Therefore, the government of India has been assigning the lion's share of the budget to agriculture policies that can promote inclusive growth and Development. The formulations of these inclusive policies require a detailed study of farmers belonging to different farm size categories and the relationship between farm size, productivity, and profitability.

Punjab is one of the most important agricultural states, contributing massively to India's food granary. Around 30.50 per cent of wheat and 21.18 per cent of rice contributed from the Punjab 1.53 per cent of the total geographical area of India. (Directorate of Statistics, 2022). Productivity per hectare is the principal reason behind Punjab's massive contribution to the country's food basket. States like Haryana and Uttar Pradesh are Punjab's main wheat production competitors. Uttar Pradesh surpassed Punjab and became the biggest wheat producer in India, but it still lags behind Punjab for productivity per hectare. Likewise, West Bengal is the primary rice-producing state. It even has less per hectare productivity than Punjab—high productivity per hectare results from state fertile land and favourable climate conditions. In addition, the role of the Punjab government and farmers should not be neglected. Punjab farmers are the pioneers in adopting and learning modern farming practices like yielding a variety of seeds, fertilisers and pesticides. On the other hand, the Minimum Support Policy and Direct Benefit Transfers provided by the Punjab government further encouraged farmers to invest in farm machinery and groundwater sources of irrigation to increase their productivity and profitability (Kaur et al., 2015; Dhawan et al., 2019).

Food security is the primary concern across the world due to the growing population. It raises the need to explore the relationship between farm size, productivity, and profitability and learn about the farming operations that could help achieve growth with sustainability. Furthermore, studying different farm sizes and their impact on productivity and profitability can help make investment decisions for efficiency improvement across landholding sizes. In the current global scenario, land allocation towards agriculture is not possible, and the only way out is to increase productivity per hectare. Therefore, stress should be placed on policies and management practices that reduce resource wastage and produce maximum output with minimum farm inputs. With the introduction of the Green Revolution, farm inputs increased almost doubled. Water is the chief farm input among them; the use of groundwater increased, which reduced the water table and made the land infertile. Thus, reducing the water productivity gap is essential and can also lessen the yield gap (Zheng et al., 2018). In addition, land management and stress management policies should be implemented to ameliorate productivity. These policies involve steps like land consolidation, land ownership, and conservation practices ranging from inter-cropping to no-tillage practices (Hiironen & Riekkinen, 2016; Miah et al., 2023). Productivity escalation also requires investment in the agriculture sector, both by private and public sectors (Usman et al., 2024). Research and development should be conducted to find methods to reduce per-hectare farm inputs, like precision farming practices. Moreover, farmers should teach such practices using extension services to motivate them to adopt innovation to reduce their wastage and increase their per-hectare productivity and profitability (Raji et al., 2024). Last but not least, government support towards small and marginal farmers is also pivotal for their survival. The government should provide them with subsidies and other benefits because it is believed that 35 per cent of global food is produced by farms smaller than 2 hectares (Lowder et al., 2021). However, the biggest concern for these farms is not productivity but profitability due to limited market access. They do not easily find buyers even if they follow a niche strategy to sell their produce at a reasonable rate due to a lack of social connections. The government should promote Self-help Groups and cooperative farming to open market doors for them with protection (Bizikova et al., 2020).

The present study had four broad objectives:

1. To examine the Socio-economic characteristics across landholding sizes in the state of Punjab.
2. To estimate input use and the cost of production across farm size.
3. To analyze the relationship between farm size, productivity, and profitability.
4. To determine the factor of Production and Profitability.

Socio-economic characteristics include several factors that affect farming operations, productivity, sustainability, and profitability. It includes the study of demographic profiles of farmers, such as age, gender, education level, religion, and marital status. It also encompasses economic status, resource access, social networks, extension services, and technology adoption. Socio-economic characteristics like education, age, access to resources and adoption of extension services improve productivity through proper resource allocation across farm sizes (Nouman et al., 2013; Mwololo et al., 2019; Bahua, 2024). Likewise, socio-economic characteristics like market access, social networks, and technology adoption influence profitability (Songsermsawas, 2015; Simon et al., 2021). Understanding socio-economic characteristics helps us determine solutions to revamp productivity and profitability across landholding sizes. Thus, the first objective is to examine the Socio-economic characteristics across landholding sizes in Punjab. The analysis has shown a detailed understanding of Punjab state agriculture's social and economic situations. The social characteristics found that Punjab agriculture is dominated by males irrespective of farm size, and the participation of females is absent. Therefore, feminization in agriculture needs to be promoted in Punjab. Another shortcoming of Punjab agriculture society, irrespective of farm size, is the young generation's disengagement from agriculture. Punjab youth prefer to settle down in foreign countries or search for jobs in the service sector (Chahal et al., 2014). Likewise, marital status is an independent factor that does not affect farm size. However, farm size also plays an important role in the Punjab society. The level of education is directly related to farm size. Large farmers are more educated than small farmers due to their access to education (Arora, 2024). Furthermore, the family size and dependency level also had

an inverse relationship with farm. The economic characteristics of Punjab's agrarian society favoured farm size and suggested that the economic conditions of farmers are influenced by farm size. Moreover, the ownership of farm implements shows the dominance of large farms. It indicates the prevalence of inequalities in ownership of farm machinery. Therefore, the large farms are the principal owners of farm machinery like rotavators, Happy Seeder and combine harvestors. The inequalities are not limited to farm machinery ownership; large farmers enjoy good access to resources like credit, agricultural inputs and technology (Chandio et al., 2018). It further increases the productivity and profitability gap between large and small farmers. The involvement of socio-economic characteristics helps to design policies at the farm level and at the state level that would target growth with equality.

In agriculture, productivity refers to the ratio of agricultural outputs to inputs. Therefore, studying the input use and input costs across farm sizes is important. Furthermore, it helps us estimate the returns on costs, called profitability. Many farm inputs are involved in farm production, like land, labour, fertilizers, pesticides, seeds, and machines. The per-hectare use of these farm inputs directly affects productivity across farm sizes. Comparing the level of input use across farm sizes helps to know which landholding sizes adopt best farm practices through optimum resource allocations. It also helps to set up benchmarks that other farmers should imitate across landholding sizes. Likewise, profitability is influenced by the farm inputs costs per hectare. By examining the input costs across farm sizes, we could inform about the costs and benefits of each size group. For example, large farms have high fixed costs per hectare, whereas small farms have high variable costs per hectare. Farmers should make investment decisions to maximize their returns on costs per hectare by considering all these input cost analyses. Moreover, the analysis of input use and input costs across landholding sizes helps policymakers understand the challenges faced by farmers of different farm sizes. It would guide them in implementing support and subsidies per the farmer's requirements. Thus, the second objective of our study is to estimate input use and the cost of production across farm size. Using descriptive statistics like mean, range, standard deviation, coefficient of variation. We worked on the input use and input costs across the landholding sizes. Our results suggested that

due to economies of scale and better management practices, the efficient use of farm inputs is possible in large farms. Farm input costs that showed significant reduction with the increase in farm size are labour, machine, and depreciation. Input costs that increased with farm size were seeds, insecticides, and leased land costs. Farm inputs are not influenced by farm size and are incurred by every landholding size, like fertilizer costs and farm yard manure and imputed rent costs. The cost difference of Input use is not only related to the land holding sizes; the variation in input costs is also exhibited within size groups. Except for large farms, all other landholding sizes showed high variations in using farm inputs due to following different types of agronomy practices and management strategies. Large farms showed consistency within the group for farm inputs use and costs because most large farms followed similar agronomic practices. The outcome produced using the combination of various farm inputs, called the value of crop output, is almost the same for each landholding size, suggesting that farm size does not impact the value of crop output, which is called productivity per hectare—however, the variation in farm inputs use and costs effect on their cost of cultivation and profitability.

To ensure food security and rural development, we must explore the relationship between farm size, productivity, and profitability. Therefore, we explored this relationship as our third objective. Beginning with farm size, the most economically viable landholding size needs to be explored. Large farms are generally believed to be more economically viable regarding land holdings due to economies of scale. On the other hand, small farms have high input costs, but they can also be economically viable if they grow labour-intensive, high-value crops. Likewise, the second variable, productivity, can be measured as the crop output value or yield per hectare. Several studies in the literature that supported a positive relationship between farm size and productivity suggested that large farms are more productive due to their access to technology, management practices, and market access. In contrast, the studies that advocated an inverse relationship between farm size and productivity suggested that small farms are more productive due to their intensive farming approach—the last variable, profitability, defines the ability to sustain farming operations. Economies of scale are helping large farms to save costs, but they have high labour management

costs, risk management costs, and logistic costs. On the other hand, small farms can be turned into profitable ventures by concentrating on niche markets. This analysis used One-way Anova followed by Tuckey's Post hoc test to explore the relationship between farm size, productivity, and profitability. Our results suggested that the relationship between farm size and productivity is neutral. Productivity is not affected by the size of farms in Punjab. On the other hand, farm size impacts the cost of cultivation. As farm size increases, the cost of cultivation goes down. It increases the return on cost A2+ family labour (profitability) for large farms, making them more profitable. That is why farmers in Punjab prefer large-sized landholdings.

Besides, it explores the relationship between farm size, productivity, and profitability. There is a need to identify the factors of production and profitability to help farms effectively maximize their profits. There are four main factors of production use in agriculture: land, labour, capital and technology. Analyzing each production factor helps farmers make their farming operations more productive and profitable. Inquiring about land use patterns helps farmers decide about policies like crop rotation, soil management, and sustainable practices that positively impact their per- hectare productivity. Similarly, by inspecting labour input, the efficiency of farming operations can be increased manifold through labour management and training. Escalation of per-hectare productivity and profitability also require an understanding of investment requirements on farms in farm infrastructure and technology farms. The lack of proper estimation of capital investment adversely affects productivity and profitability. On top of that, the management skills of farmers are most important in increasing per-hectare productivity and profitability. Farmers must be aware of the current market conditions, consumer preferences, and schemes the government has started to help them. In addition to factors of production, profitability analysis is also important, as well as the factors that increase the level of profitability. The farm inputs need to increase due to adverse climate changes, which escalated the cost of cultivation and reduced per-hectare profitability. Therefore, exploring the factors that significantly impact profitability relative to farm size helps farmers allocate their resources efficiently even under limited capital and land availability constraints. Therefore, our fourth and last objective is to determine the factors of production and

profitability. In our fourth objective, we used Multiple Regression analysis to identify the factors of production and profitability. The results suggested that the value of crop output (productivity) is positively and negatively affected by several factors of production. The factors of production that positively affect the productivity per hectare are labour costs, lease in land costs, imputed rent costs and Zone. A unit increase in these above-mentioned factors positively increases the value of crop output.

On the other hand, profitability (Returns on costs) is also influenced statistically by the certain factors like the size of holdings; with the increase in the size of holdings, cropping intensity and Zone positively affect profitability. A unit increase in these factors increases returns on costs significantly. In contrast, factors like a lease in land costs and fragmentation are negatively associated with the returns on costs. The role of government policies and schemes should also not be neglected. These policies and schemes also affect the returns on costs per hectare. Thus, productivity and profitability are the outcomes of farm-related practices and government participation.

6.2 Suggestions

Strengthening Technology Access for Small and Marginal Farmers: The results predicted from the study indicate that the adoption of modern agronomic practices across farm sizes, which include mechanization on a rental basis and the use of high-yielding variety (HYV) seeds, fertilizers, and pesticides, helps to reduce production disparities, resulting in neutralizing the effect of farm size on productivity. Consequently, policy interventions are needed to focus on equitable access to these technologies for small and marginal farmers in India. This can help to curtail the higher cost of cultivation and remediate the profitability level.

1.Strengthening Technology Access for Small and Marginal Farmers: The results predicted from the study indicate that the adoption of modern agronomic practices across farm sizes, which include mechanization on a rental basis and the use of high-yielding variety (HYV) seeds, fertilizers, and pesticides, helps to reduce production disparities, resulting in neutralizing the effect of farm size on productivity. Consequently, policy interventions are needed to focus on equitable access to these technologies for small and marginal farmers in India. This can help to curtail the higher cost of cultivation and remediate the profitability level.

2.Strengthen Region-Specific Advisory Support:

Farmers in the paddy/maize–wheat zone have high levels of experience, which strongly boosts output (about 15.95 for medium farms and 18.03 for large farms). This suggests that extension services should build on the region’s existing expertise and design advisory programme tailored to local cropping patterns and conditions.

3.Promoting Cropping Intensity Through Tactical Subsidy Support:

The results shown in our research work exhibited that cropping intensity employs a strong positive effect on value of crop output (Productivity), with regression coefficients of around 0.594 for medium farms and 0.545 for large farms. These results indicate that policies targeted at enhancing cropping intensity can considerably improve farm productivity. Punjab’s long-standing action plans of providing a liberal number of subsidies on fertilizers and irrigation inputs appear to be effective in this regard, as they enable farmers to adopt more intensive cropping practices. Strengthening and better targeting such subsidies—especially for resource-constrained farms—may further raise profitability and ensure more efficient utilization of agricultural land.

4.Improve Education and Skill Development for Young Farmers:

The regression results advise a negative and statistically significant coefficient for age (-0.160), whereas years of schooling reveal a positive effect on output (0.163). These uncovering highlight the importance of strengthening educational and skill-enhancement initiatives targeted at younger farmers. Programs such as vocational training, digital literacy workshops, and extension-driven skill development may therefore play a vital role in boosting productivity outcomes.

5.Prioritize Investment in Irrigation Infrastructure: Irrigation machinery costs showed a positive and statistically significant effect on value of crop output (like, 0.195 for large farms). This highlights the need to further develop and expand irrigation facilities, because reliable water access supports healthier crop growth and greater yield stability.

6. Improvement of Market Linkages and Input Procurement for Smaller Farms through FPOs: The study shows that large farmers are reducing their cost of

cultivation through economies of scale. This benefit is completely absent for small and marginal farmers. Therefore, the statistically significant difference exists between marginal and large farms on account of cost of cultivation. Marginal farms on average spend Rs.51127 more on cost of cultivation than large farms per hectare. Likewise, small farms spend Rs.19033 more on cultivation costs than medium farms. No doubt, the Punjab government has established FPOs (Farmer Producer Organizations) to help small and marginal member farmers reap the benefits of bulk purchase. However, these FPOs have weak market linkages and bargaining power due to limited organizational capacity and competition from large players, resulting in weak price capture. Therefore, attention needs to be paid to the organization a capacity of FPOs through capacity-building initiatives focused on professional management, marketing skills, and negotiation techniques.

7.Develop Infrastructure and Support Services by Agro-Climatic Zones: The study suggested that Agro-climatic zones affect the level of productivity and profitability. Therefore, the government should implement policies and infrastructure development according to zones to harness local advantages and address region-specific challenges.

8.Focus on Factors of Production that Affect Profitability: It was observed from the present study that farming is not a lucrative profession for farmers in Punjab. This promotes the depeasantization of the state. Additionally, this study also highlighted, through empirical evidence, the factors that positively affect profitability, such as farm size, cropping intensity, zone, and schooling years, and the factors such as fragmentation, age of farmer, and leased-in land that negatively influence profitability. Therefore, interventions are needed to optimize factors that positively impact profitability and stress the need to deal with factors that reduce per hectare profitability. For example, land pooling can help to increase operational efficiency and profitability of farmers by consolidating their fragmented landholdings into large, contiguous parcels. It would help him to adopt modern farming practices which was difficult earlier.

9.Tailored mechanization and agronomic technologies: Our study results showed that Punjab has a large number of small and scattered land plots (fragmentation).This results in the inefficient use of farm machinery, increases the cost of cultivation, and

reduces profitability. The results of regression analysis showed that per hectare profitability is negatively affected by the fragmentation. Each fragmented piece of land owned by farmer reduces profitability by Rs.8725.41 controlling other variables in the model. The result is statistically significant as the standard error is 792.85, which is low and absolute value of t is high 11.010. Therefore, we should follow the strategies China has adopted because most of the landholdings in China are also small and fragmented, such as two-wheel tractors and mini-combine harvesters.

10.Crop Diversification and Market Linkages: Our results show that Punjab follows mono cropping practices, which have had devastating effects not only on the state water table but also on productivity and profitability. Small and marginal farmers have been suffering the most, as confirmed by the study through a post-hoc test on per-hectare profitability across farm sizes. Profitability has a big difference between small and large farms, marginal and large farms, and small and medium farms. Therefore, small farmers should diversify their cropping patterns to include high-value and niche crops with better market access.

11.Strengthening land tenure security for smallholder farmers: The results predicted by the study suggested that small farms have high variations in fixed capital costs, which is the result of insecure tenancy and reverse tenancy practices in Punjab. Therefore, it is suggested that land tenure security for smallholders be strengthened. Formalizing tenancy rights motivates small farmers to invest in land and adopt modern technology, which positively affects productivity and profitability in Punjab. Additionally, promoting cooperative models for resource sharing and credit access can help small farmers reduce their cultivation costs.

CHAPTER - VII

LIMITATION AND SCOPE FOR FUTURE RESEARCH

7.1 Limitations

1. It is basically a micro-level study because it focuses on the Punjab state agriculture and the specific cropping systems and socio-economic environment that exist in the state. Therefore, the results of this result have limited applicability and may not validate in different Agro-climatic and socio-economic contexts.
2. The data was collected using structured questionnaire from different farm sizes and Agro-climatic zones at a particular time period in Punjab (2022- 23). However, a single-point data collection (cross-sectional data) is unable to capture the fluctuations that happen in input use, productivity, and profitability across different seasons or years. Therefore, to understand the long-run effects of government policies and technologies adopted, temporal studies are required. This limitation of the current study affects its capacity to fully understand and forecast agricultural dynamics in Punjab.
3. Data related to the cost of cultivation and input use are collected from the farmers directly, which may lead to biased data, as some of the respondents are illiterate or may not provide accurate data, or some hesitate in providing their monetary information.
4. No doubt, this study covered multiple socio-economic characteristics (Age, Education, Gender, Dependency status, ownership related to machinery equipment) along with economic variables like inputs use and cost per hectare. However, it has still gap related to farmer psychological factors, climatic variability, market fluctuations, and policy changes by the government that need to be addressed in future research.

7.2 Scope for Future Research

1. Globally, precision farming got recognized to promote efficient use of farm inputs like seeds and fertilizers, thereby lowering the cost of cultivation. Therefore, future research should be targeted at precision farming and climate change strategies adoption benefits in Punjab and their effects on per hectare productivity and profitability.
2. The incumbent government of India has been making efforts to formulate policies related to doubling farmers' incomes, investment in rural infrastructure, promotion of modern agricultural technologies, and credit facilities and financial support. Therefore, it is imperative to evaluate the ground-level impact of such policies through future research projects.
3. Empirical evidence suggests that the monocropping pattern prevalent in Punjab is the reason behind stagnant productivity and increased cost of cultivation that are adversely affecting the profitability of farmers. Thus, future research should focus on assessment of various crop diversification models and evaluate their impact on per-hectare productivity and profitability.
4. Our study talked about the absence of females and low participation of youth in the agriculture sector. The future study could investigate the impact of participation of females and Punjab youth in agriculture on productivity, profitability, and advancement in farming practices.
5. Future research should focus on panel or time-series data to evaluate the relationship between farm size, productivity, and profitability to present more dynamic and reliable results, as factors of production are variables that are influenced by market conditions.

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APPENDIX-A

Scopus Publication

1. Unlocking the Potential of Maize for Crop Diversification in India: Farm Size, Productivity, and Profit Analysis. Indian Journal of Economics and Development. (Indexing: Scopus, ESCI (Clarivate Analytics: Web of Science), and UGC -CARE List Group II. (Published).



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**Unlocking the Potential of Maize for Crop Diversification in India:
Farm Size, Productivity, and Profit Analysis**

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ABSTRACT
Today, farmers are searching for alternatives to wheat and paddy, which have reached saturation levels. This study investigated whether maize was a viable answer to crop diversification in India. The relationship between farm size, productivity, efficiency, and profitability of maize crops was analyzed across various landholding sizes to understand the feasibility of maize crop in replacing traditional crops. Spatial analysis was done to identify states having a comparative advantage in growing maize crop. The results showed a neutral relationship between farm size and productivity. Utilising the One-Way ANOVA and Tukey's Studentized Range tests as methodologies, no statistically significant differences were observed relative to land holding sizes in productivity and technical efficiency. The foremost factor which led to variations in profitability was the cost of cultivation. Maharashtra emerged topmost, and Telangana was second most in terms of profitability, whereas Rajasthan was indicated to be the least profitable.

Keywords
Cost of cultivation, efficiency, farm size, productivity, profitability.

JEL Codes
Q00, Q10, Q15, Q18.

INTRODUCTION
Globally, there is a call for crop diversification as a sustainable and ecological stability strategy. The need to move away from traditional crop monoculture is underscored by issues of climate change, food security challenges and market dynamics. In India, crop diversification is pertinent because agriculture contributes to economic stability and ecological integrity. Singh et al. (2013), Sen et al. (2017), Feliciano (2019), Neogi and Ghosh (2022) and Kumar et al. 2024 showed that crop diversification can increase farm income and protect our environment from the adverse effects of repeated plantation of traditional crops.
Theories of agricultural transformation and sustainability guide this study. These studies suggested that diversification can improve economic and environmental outcomes by optimizing resource use and enhancing resilience to market and climatic fluctuations. These frameworks will be instrumental in analyzing the comparative benefits of maize cultivation over traditional crops. The studies on farm size and productivity over the years have led to different interpretations of the relationship between these two variables.
Studies that relate to farm size and productivity have typically focused on traditional crops; alternative crop studies must be performed to evaluate their viability. The studies showed direct relationships between farm size and productivity and the inverse relationship between the two variables. Studies on the inverse relationship across the world, which are broadly classified under various groups, about their inverse relationships between farm size and productivity (Mazumdar, 1965; Rao, 1966; Bardhan, 1973); a few studies showed positive relationship (Saini, 1969; Rani, 1971; Chadha, 1978); then there are certain

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551

Conference Presentation

Paper Title: Insights Gained swapping to Digital Learning during the
Covid-19 Pandemic: A Ground Level Study



Paper Title : Exploring Farmers Variabilities in Socio-Economic Conditions Based Upon Land Holding Sizes in Pathankot and SAS Nagar(Mohali) Punjab: A Case Study



Paper Title : Factors Affecting Productivity and Profitability of Green Gram Crop : A case study of Ludhiana District



International Conferences



The UWA Institute of Agriculture

Professor Kadambot Siddique
AM CitWA FTSE FAIA FNAAS FISPP FAAS FPAS
BSc (Ag) Hons, MSc, PhD
Hackett Professor of Agriculture Chair and Director

7 June 2023

Shaveta Sharma
Research Scholar
Lovely Professional University
69 Preet Nagar, Sodal Road
Jalandhar, Punjab
Santoshi.kirpa@gmail.com

Dear Shaveta,

RE: Invitation to attend The University of Western Australia (UWA) Industry Forum

On behalf of The University of Western Australia (UWA), I invite you to attend the 17th Annual Industry Forum: Paving the way for the next generation of WA agriculture on 19 July 2023.

This offer is subject to you obtaining appropriate visas to visit Australia. You must comply with all visa conditions and Australian laws.

In the 2022 Academic Ranking of World Universities (ARWU), UWA occupies 99th place globally, with the discipline of Agricultural Sciences ranking 15th in the world, and number one in Australia.

I understand that you will cover all your personal costs, including accommodation, health insurance, living expenses and round-trip international air tickets. No financial assistance will be provided by UWA.

I look forward to welcoming you and your delegation to Perth in July.

Yours sincerely,

A handwritten signature in cursive script, likely belonging to Professor Kadambot Siddique.

Professor Kadambot Siddique
Hackett Professor of Agriculture Chair and Director

The University of Western Australia
M082, Perth WA 6009 Australia
T +61 8 6488 7012 M +61 411 155 396 E Kadambot.siddique@uwa.edu.au
CRICOS Provider Code 00126G

International Conferences



Date: 24/11/2025

Name and Address:

Shaveta Sharma

Lovely Professional University Phagwara,
Punjab.

House Address: 69 Preet Nagar Sodal

Road Jalandhar City Punjab. PIN Code:
144001

Registration ID #: 156994

Dear Shaveta Sharma

On behalf of the Allied Social Science Association (ASSA), I am pleased to invite you to attend the ASSA Annual Meeting to be held from January 3-5, 2026, in Philadelphia, PA, U.S.A.*

The ASSA is a professional organization composed of approximately 67 associations of related economic disciplines. The ASSA holds a three-day meeting each January to present papers on general economic subjects. Over 520 scholarly sessions are held during this three-day event.

Please note that the ASSA Annual Meeting registration fee covers admission to all sessions and open events of the conference. The fee does not cover any meals. Registrants to the conference are eligible for the discounted room rate at the ASSA block of hotels. Any and all travel expenses are the sole responsibility of the attendees.

This letter will serve as a formal invitation for you to attend and participate in the ASSA Annual Meeting.

We look forward to seeing you in Philadelphia.

Sincerely,

**Paityn
Younger**

Paityn Younger

AEA/ASSA Meeting Coordinator
assa@vanderbilt.edu

Digitally signed by Paityn
Younger
Date: 2025.11.24 13:24:31
-06'00'

**Please note that these are the actual meeting dates, and do not include any time that may be necessary to travel to the meeting.*

BOOK CHAPTERS

1. Deregulation of the Agricultural Sector: An expressway to India's Self-Reliance. (Book Titled —Atma Nirbhar Bharat||).
2. The road towards Liberalization, Globalization, and Privatization and their ramifications on the Indian Agriculture Sector.(Book Titled —Contemporary Issues in Indian Economy : A Roadmap Ahead||)

APPENDIX-B

Survey Instrument (Questionnaire)

1. Basic details

Questionnaire No		Date of Interview	
Name of Interviewer		District:	
Tehsil		Village Name	
Zone No.			

2. Basic information of respondent/head of household

Particulars	Ans.	Particulars	Ans.
Name of Respondent		Age	
Gender		Education	
Marital Status		Religion	
Present no. of HH members		Farm Size	

3. Household members basic information

S.N.	Name	Member Status	Sex (M/F)	Age (Year)	Education	Major Occupation	Minor Occupation

4. Information about Household Assets

S.NO	Facilities	Availability (Y/N)	Number	Value (Rs.)
1	Owned House			
2	Two -Wheelers			
3	Four Wheelers			
4	Animal Shed			
5	Silos			
6	Barn			
7	A chicken Coop			
8	Root Cellar			

5. Farm Machinery and implements Ownership details

S . N .	Farm Machiner y and impleme nts	Qu ant ity (N)	Capa city	Purc hase Year	Ag e	Rem. life	Own ershi p	Origin al Value(Rs)	Present Value(R s)	Salvage Value (Rs)
1 .	Tractor									
2 .	Trolley									
3 .	Harrow									
4 .	Plough									
5 .	Seedier Machine									
6 .	Disc plough									
7 .	Thresher s									
8 .	Happy seedier									
9 .	Laser leveller									
1 0 .	Electric motors									
1 1	Oil Engines									

1 2	Generator									
1 3	Tubewell									
1 4	Submersible pump set									
1 5 .	Winnowing Fork									
1 6	Drip irrigation									
1 7 .	Sprayer									
1 8 .	Sickle									
1 9	Spade									
2 0	Power chaff cutter									
2 1	Hoe									
2 2	Cultivator									
2 3	Drum									
2	Power operated									

4	cart									
25	Bullock cart									
26	Rake									
27	Harvester Combine									
28	Rotavator									
29	Mulcher									

6. Livestock Ownership Details and income from livestock

S. N.	Livestock Type	Number	Animal Category	Purpose	Ownership	Value (Rs.) of Livestock	Culling Value	Annual Income
1.	Cows							
2	Buffalos							
3	Goats/Sheep							
4	Pigs							
5	Other Birds (Chicken, Ducks, other all)							
6	Fish and other aquaculture species							
7	Honeybees and other Flaying species							

7. Household Income from different sources

S.N.	Source	Income (Rs. Annual)	S.N.	Source	Income (Rs. Annual)
1.	Crop		2.	Livestock	
3.	Agri-business		4.	Other business	
5.	Salary or Pension		6.	Foreign Remittances	
7.	Direct Benefit Transfers(DBT)		8.	Interest received	
9.	Land Rental		10.	Other Rental	
11.	Wages if any wage working		12.	MNREGA	
13.	Others		14.	Total From all sources (Sum 1 to 13)	

8. Land Use Information

S.N.	Particulars	Irrigation Status	Major source of irrigation	Parcel	Area	Area Under Border Path	Land Use	Rental value (Rs./ha)
1.	Own Land							
2.	Leased/ Shared-in							
3.	Leased/Shared-out							
4.	Total cultivated land (4=1+2-3)							

9. Loans & Advances for crop cultivation

S. N.	Nature of loan(*)	Source(#)	Rate of Interest	Amount outstanding including interest as on the date of survey
1.				
2.				
3.				
4.				

Note : *= Nature of loan: Hereditary Loan-1; loan contracted in Cash-2; loan contracted in kind-3; loan contracted partly in cash and partly in kind-4.

#=Sources: Governemt-1; Co-operative society-2; Bank-3; Employer/ Landlord-4; Agricultural/professional money lender-5; Shopkeeper/trader-6; relatives/ friends-7; others-8.

10. Technical

SN.	Question	Ans	SN.	Question	Ans
1	Do you go for Technical Advice?		7	Do you have taken crop insurance	
2	Sources		8	Sources	
3	Frequency		9	You contribute in insurance premium	
4	Do you adopt suggestions suggested		10	You have faced any crop failure	
5	Effects on Cost of Production		11	In case of crop failure, you have got insured value	
6	Effects on Productivity		12	How much amount received (Rs/ha)	

11. Cropping Pattern

Crop name	Purpose	Area under crop	Total Production	Yield	Sale quantity	Sale value
Kharif season						
Rabi season						
Other season						

Crop Codes:

Paddy:101; Jowar:102, Bajra :103, Maize :104, Ragi : 105, Wheat 106, Barley 107, Small millets 108, Other cereals 109, Gram : 110, Tur: 111, Urad : 112, Moong : 113, Masur :114, Horse gram : 114, Beans(pulses):115, Peas(pulses):116, other pulses :117, Sugarcane :118, Potato: 119, Tomato :120, Water Melon:121, Musk Melon :122, Cotton : 123, Onion :124, Carrot :125, Radish :126, Rapeseed & Mustard :127, Groundnut :128, Sunflower :129, Safflower: 130.

12.(1) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

(2) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

(3) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

(4) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

(5) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

(6) Cost of Cultivation of during season.....

Input use	Purchased		Owned		Total	
	Quantity used	Value use	Quantity used	Value use	Quantity used	Value use
Labour						
Machine						
Irrigation Machine						
Animal						
Seed						
Fertilizer						
FYM Manure						
Insecticides						
Irrigation Charges						
Land Revenue, tax and cess						
Miscellaneous						

Declaration:

I hereby declare to the best of my knowledge that the information disclosed above is collected by me for the partial fulfilment of my Ph. D Degree. The data is collected in four districts of Punjab as per my study objectives.

Shaveta Sharma

Date 26-07-2025

Research Scholar