A STUDY ON SUSTAINABLE AGRICULTURE PRACTICES IN RICE CULTIVATION AMONGST THE GROWERS OF PUNJAB

Thesis Submitted for the Award of the Degree of

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in

Management

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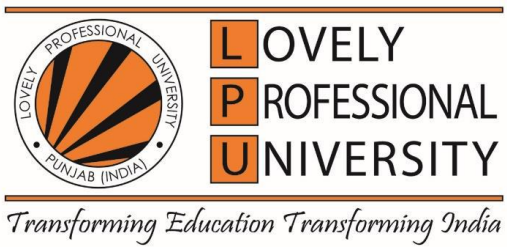

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled "A Study on Sustainable Agriculture Practices in Rice Cultivation amongst the Growers of Punjab" in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Lokesh Jasrai, working as Professor, in the Mittal School of Business, Management Department of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled "A Study on Sustainable Agriculture Practices in Rice Cultivation amongst the Growers of Punjab" submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Mittal School of Business, Management Department is a research work carried out by Bhiravi, 41900164, is bonafide record of 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.

Name of supervisor: Dr. Lokesh Jasrai

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ABSTRACT

"Sustainability is here to stay, or we may not be." – Niall FitzGerald

Sustainability has become the prime focus of concern at the global level. Adoption of Sustainable Development Goals have brought every aspect of life on earth under its ambit. The rising population demands food security not just for current times but also for the future generations. Therefore, the importance of sustainable agriculture cannot be overstated.

Punjab has been at the vanguard of agricultural productivity since the arrival of the Green Revolution; however, it is currently experiencing significant challenges due to the adverse effects of the Green Revolution. The "granary of India," a state that previously made the most significant contributions to the central grain pool, is currently grappling with a variety of challenges, including a decline in agricultural growth, stagnation in productivity, dwindling agricultural resources due to soil erosion and degradation, a declining groundwater table, excessive inputs, increased pest pressure, and a loss of profitability. The primary reason for this is the introduction of high-yielding wheat and rice varieties and the use of nitrogen fertilizers, which resulted in increased production. Farmers adopted both crops at the expense of the diversity of the agricultural system, as they provided significant socio-economic benefits at the time. The outcome is that Punjab has experienced an exponential increase in rice cultivation throughout the state, which is 99% irrigated, primarily through tubewells that drain the precious groundwater.

Rice is one of the most important crops, being staple diet of almost 3.5 billion people, accounting for nearly half of the global population. Rice is the most cost-effective food source for economically disadvantaged populations, especially in Asia and Africa. With projected global population expansion of 9.5 billion in 2050, rice plays a crucial role in ensuring food security. China holds a dominant position in the industry , representing 27% of the market share followed by India with significant 25% share in the commerce. Punjab, with 3 million hectares of rice cultivation, produces 11% of the national production, equivalent to 13 million tonnes. Rice cultivation has deep environmental impact as it belongs to grass family and thrives in wetlands. Challenges

in rice farming include increasing crop yield while conserving water resources, as rice cultivation uses approximately 80% of the total irrigated freshwater resources. Rice is a long duration crops ranging from 95 to 120 days, depending upon the cultivar used, grown in wet and humid weather prone to maximum pest pressure, requiring a whole range of inputs from herbicides to pesticides to combat different insects and fungal issues. In addition, rice production typically takes place in irrigated fields to maximize crop yield. The persistent water supply fosters anaerobic soil conditions, resulting in heightened CH4 emissions, globally it accounts for 10% of the greenhouse gas (GHG) emissions. Apart from these, there is another major challenge of residue management. Every year, the harvesting of rice in northern states, impacts the air quality to dangerous levels due to traditional practice of stubble burning. In-efficient mechanisation, over-irrigation leading to waterlogging and salinity issues, soil-erosion due to monocropping patterns are some other areas of concerns that plague the farming scenario in Punjab. Agricultural growth in Punjab was more than double the national average from 1971-72 to 1985-86, with a rate of 5.7%. It decreased to approximately 3%, which was consistent with the national average, between 1986-87 and 2005-06. In 2014-15, agricultural growth had reached a plateau of 1.61%, which is equivalent to half of the national average. The country's rice growers have consistently attained the highest yield per hectare, reaching 4341kg/hectare, despite the obstacles. The unsustainable practices in agriculture coupled with loss of profitability are leading to societal issues, in the form of transition away from farming, adding to unemployment and increased emigration. The solutions proposed by the policy makers have not been successful in addressing grassroots concerns. The predominant suggestion is to replace the water-intensive rice crop with alternative crops, including maize, cotton, and pulses. However, the agricultural community has shown limited interest due to the absence of a comparable market and assured purchasing options for these alternative commodities, in contrast to rice in the mandis. The data shows a consistent increase in the area allocated for rice farming. The producer's reluctance to cease rice cultivation is evident, and traditional farming methods are depleting natural resources at an alarming rate. It was in this context that the study was undertaken. The study examines whether Punjab can sustain rice agriculture without depleting resources while assuring economic viability. Growers could use sustainable agriculture practices to attain the goal. In the Agroecological

Ruralist approach, Organic Farming is the most popular sustainable agriculture technology. It is gathering worldwide momentum and provides price premium. Technology-focused initiatives like Climate Smart Agriculture with Precision and Variable Technology using Internet of Things in agriculture can boost profits by using resources efficiently. The study aimed to assess challenges in growing rice using sustainable methods. In addition to sensing the awareness level and frequency of use of sustainable practices, the study investigated the perception of rice growers towards the adoption of sustainable practices in rice cultivation. Furthermore, the moderating role of institutional support and market infrastructure was also studied.

The research method selection is contingent upon the nature of the research question, with quantitative methods typically employed in natural sciences for inquiries related to causality and generalizability, while qualitative methods are favoured in social sciences for exploring experiences, perceptions, and theoretical development. This study utilizes a mixed-methods research (MMR) approach, motivated by the need for exploration regarding Sustainable Agricultural Practices (SAP) in rice cultivation among Punjab's farming community, which predominantly relies on outdated conventional methods from the Green Revolution era. Despite awareness of the environmental impacts of these conventional practices, the adoption of SAP remains minimal. The literature indicates a gap in understanding the potential for sustainable rice cultivation in Punjab, necessitating data collection to identify the challenges faced in implementing SAP. The study is structured into two phases: Phase I employs qualitative methods, specifically in-depth semi-structured interviews, to explore the RQ1 about challenges associated with SAP usage in rice cultivation. The findings from this phase inform the development of final hypothesis model and research instrument. Phase II transitions to a quantitative approach, utilizing survey methods to address three additional research questions, RQ2 examines awareness and usage frequency of SAP, RQ3 assesses perceptions towards SAP adoption, and RQ4 investigates the moderating effects of institutional support and market infrastructure on behavioural intentions. This phase aims to achieve generalizability of findings across a broader population, employing statistical analysis to validate and expand upon the qualitative insights gathered in Phase I. Thematic analysis using MAXQDA 22 revealed key factors

influencing farmers' attitudes towards sustainability, particularly in rice cultivation. Farmers expressed concerns about the complexity and resource demands of SAP, noting that conventional methods are more familiar and easier to implement. The need for skilled labour and new machinery for practices like Direct Seeding of Rice (DSR) was highlighted, alongside the challenges of pest and weed management without agrochemicals. In contrast, farmers practicing sustainable methods shared transformative experiences that led them to abandon chemicals, citing health impacts and environmental degradation. They embraced traditional practices, such as 'Kudarati-Kheti' (natural farming), and emphasized a collective responsibility towards ecological preservation. These findings were validated when compared with the results of quantitative analysis. The findings indicate that profitability, complexity, environmental commitment, and resource availability significantly influence farmers' intentions to adopt sustainable practices. The lack of a dedicated market for sustainable produce and mistrust of corporate entities further complicates the situation. Farmers believe that with adequate institutional support and market infrastructure, their commitment to sustainable agriculture could significantly increase. Findings indicate a moderate level of awareness and usage but also significant variability among farmers. The analysis of sustainability performance indicates a general positive attitude towards adopting SAP, with a strong intention to engage in sustainable practices. However, there is a need for targeted educational initiatives to enhance awareness and usability of SAP among farmers. The findings underscore the importance of social norms and community engagement in promoting sustainable agricultural practices, as well as the necessity for improved policy support structures and market infrastructure to facilitate farmer participation in sustainable initiatives. Finally, while there is a foundational engagement with sustainability concepts, significant opportunities for improvement exist in enhancing knowledge, usability, and support systems to foster greater adoption of sustainable practices in rice farming in Punjab. The implication of this study extends beyond the corridors of academia. Understanding the narrative of challenges and farmers perceptions towards behavioural intention to adopt SAP in rice cultivation is the first step towards achieving success in implementation of SDG of Zero Hunger.

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List of Abbreviations

Abbreviation	Definition
AAOD	Absorption of Optical depth of Aerosol
ACZ	Agroclimatic Zone
AI	Artificial Intelligence
AMF	Arbuscular Mycorrhizal Fungi
AOD	Optical depth of Aerosol
AP	Acidification Potential
APEDA	Agricultural & Processed Food Products Export Development Authority
APH	Analytical Hierarchy Process
AT	Attitude
ATP	Aquatic Toxicity Potential
AVE	Average Variance Extracted
AWD	Alternate Wet and Dry
BF	Bio-dynamic Farming
BI	Behavioural Intention
CA	Conservation Agriculture
CF	Continuous Flooding
CFA	Confirmatory Factor Analysis
CH_4	Methane
CO2	Carbon Dioxide
CT	Conventional Tillage
DAIPW	Days After Infiltration of Ponded Water
DTPB	Decomposed Theory of Planned Behaviour
DSR	Direct Seeding of Rice
EFA	Exploratory Factor Analysis
EP	Eutrophication Potential
ES	Extension Services
ESR	Efficiency, Substitution and Redesign
EUT	Expected Utility Theory

FAO	Food and Agricultural Organisation
FSN	Food Security and Nutrition
GFT	Green Farm Technologies
GHG	Greenhouse Gas
GI	Geographical Indication
GJ	Giga Joules
GR	Green Revolution
GSI	Groundwater Sustainability Index
GSI	Graded Stability Index
GWP	Global Warming Potential
HTMT	Hetero-trait Mono-trait
HTP	Human Toxicity Potential
HYVs	High-yielding Varieties
ICAR	Indian Council of Agricultural Research
ICRIER	Indian Council for Research on International Economic Relations
IFOAM	The International Federation of Organic Agriculture Movement
IFS	Integrated Farming Systems
IGP	Indo-Gangetic Plains
INM	Integrated Nutrient Management
IoT	Internet of Things
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
IS	Institutional Support
LCA	Life Cycle Assessment
LLL	Laser-controlled Land Levelling
LO	Land Occupation
LR	Literature Review
MD	Midseason Drainage
MI	Market Infrastructure
ML	Machine Learning
MMR	Mixed-method Research

MODIS	Moderate Resolution Imaging Spectroradiometer
N	Nitrogen
N_2O	Nitrogen dioxide
NEP	New Ecological Paradigm
NED & WD	Non-renewable Energy and Water Depletion
NF	Natural Farming
NGO	Non-Government Organisation
NM	Nutrient Management
NNI	Nitrogen Nutrition Index
OF	Organic Farming
PA	Precision Agriculture
PBC	Perceived Behaviour Control
PC	Perceived Compatibility
PEOU	Perceived Ease of Use
PGPR	Plant Growth Promoting Rhizobacteria
PGS	Participatory Guarantee Systems
PIP	Plant Incorporated Pesticides
PR	Perceived Resources
PTR	Puddled Transplanted Rice
PU	Perceived Usefulness
RMMF	Rigorous Mix Method Framework
RQ	Research Question
RW	Rice-Wheat
SAP	Sustainable Agricultural Practices
SDGs	Sustainable Development Goals
SE	Self-Efficacy
SEM	Structural Equation Model
SFSs	Agroecology is Sustainable Food Systems
SI	Social Influence
SN	Subjective Norms
SRC	Sustainable Rice Cultivation
SRI	System of Rice Intensification

SRP	Sustainable Rice Platform
STP	Soil Toxicity Potential
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TT	Technical Training
UN	United Nations
UNEP	United Nations Environment Programme
VIF	Variance Inflation Factor
VR	Variable Rate
WPI+R	Total Water Productivity
ZT	Zero Till

1. Chapter 1 - Introduction

"If agriculture goes wrong, nothing else will have a chance to go right."

– M. S. Swaminathan

1.1 Overview

This chapter provides an overview of the study on Sustainable Agricultural Practices in rice cultivation amongst the growers of Punjab. Having been a pioneer in agricultural growth since the sixties, Punjab at present is faced with dire struggle in agricultural scenario. Once a leader in the country is at the helm of plethora of issue due to the methods of agricultural production. Water guzzling paddy, culture of monocropping, excessive inputs, stagnating economic avenues and associated social issue are all eating away the peace and prosperity of Punjab. This study aims to view the sustainability aspect of rice cultivation in addition to farmers perspective on adoption of the same. The chapter begins with a background and introduction to the study bringing forth the most vital aspect of the study, the connection between the Agri-Resources of Punjab and the practices being used in rice cultivation by conventional farmers and its impact thereof. The research makes an attempt to understand the notion of sustainability in rice cultivation from farmer's perspective to bring forth suggestions to mitigate the adverse effects.

The first section of the chapter brings forth a historical context of Agri-Resources of Punjab and presents the launch and success of Green Revolution with rice cultivation making its roots in Punjab. The section two presents the data supporting the otherwise impact of rice cultivation in Punjab. In the third section, importance of rice as a crop and the sustainability issue related to its cultivation are discussed. The next section presents the global focus on sustainable agriculture and Sustainable Development Goals. It also discusses briefly the approaches to sustainability in agriculture. The concluding section of the chapter brings about the Need and Scope of the study followed by organisation of the chapters in the thesis.

1.2 Background and Introduction to the Study

Punjab, distinguished for its pivotal role in agricultural production and renowned as the "granary of the country," is today facing a pressing situation regarding agricultural sustainability. Although it covers a mere 1.5% of the entire geographical area of the country, this region contributes around 10% to the country's rice production (Economics and Statistic Division, 2023). Nevertheless, this significant level of productivity has a substantial impact on its ecosystem. Before the Green Revolution, the main crops grown in Punjab were sugarcane,

maize, and wheat, whereas rice was not the dominating native crop. In response to the nation's need for food grain self-sufficiency, farmers of Punjab adopted rice cultivation. The adoption of rice agriculture has undergone significant expansion over time. Punjab has had a substantial expansion in its rice cultivation area, expanding from 2.27 lakh hectares in 1960-61 to around 32 lakh hectares in 2022-23. During this time frame, the production of rice has experienced a huge surge, going from 2.29 lakh tonnes to a remarkable 137.5 lakh tonnes, setting a record. In addition, the yield has averaged from 1009kg/hectare to 4341kg/hectare which is almost 1.5 times the national average of 2809kg/hectare (Directorate of Statistics, Department of Planning, Govt of Punjab, 2023) However, this production has come with a substantial influence on natural resources, leading to the exhaustion of the groundwater table across the entire state, deterioration of soil quality, excessive utilisation of inputs, chemical leaching in the soil, excessive mechanisation, and a gradual decrease in agricultural growth (Punjab State Council for Science and Technology, Chandigarh, 2024). This gives rise to questions over the long-term viability of the existing agricultural system.

At the time of occupation by British in mid-nineteen century the agriculture in Punjab was completely dependent on wells and rainfall, the land mass had 20% area as sand dunes, alluvial plains and arid dry western region (Bhalla, 1995). Production in Punjab's agriculture domain, in true sense started when an extensive investment was done by British for irrigation by creating canal system. An estimate indicates that for irrigation purpose, the British allocated almost 40% of their total capital in Punjab, in contrast to the rest of India, mostly due to the land's fertility and the industrious disposition of the Punjabi populace. Consequently, the proportion of irrigated land in Punjab constituted 50 percent of the total agricultural acreage (Shigemochi, 1978). In Punjab, agriculture has seen a rapid technical transition in seed systems, methods of irrigation, and fertilizers due to the Green Revolution (Sidhu, 2005).

After independence and the tragic episode of partition, Punjab endured significant hardships that adversely affected its agricultural resources. In the 1960s, Punjab was selected as the first state for the experimentation of Green Revolution in India, despite its arid conditions, due to its developed canal system and comparatively affluent farmers (Sebby, 2010). The introduction of High Yield Variety seeds and fertilizer technology in Punjab during the mid-1960s resulted in significant changes that spurred remarkable increases in agricultural productivity, especially for wheat and rice (Bhalla & others, 1990). It enhanced the conditions of the farmers, both economically and thus socially and led to elevating the region to the

designation of the "grain bowl of India." Subsequently, agriculture in Punjab transformed into a highly mechanized and costly occupation. Simultaneously, irrigation coverage attained 95% of the net agricultural area, accompanied by a 98% increase in high-yielding types. Punjab exhibited the highest cropping concentration in the nation; however, the substantial grain output and guaranteed procurement by governmental agencies led to a persistent monocropping culture of wheat and rice. This practice has become the principal cause of soil degradation, increased pest pressure, and groundwater depletion. The Green Revolution sparked a strong interest in growing rice among the farming population in Punjab. The farmers in this region have achieved an expertise in rice cultivation which is evident from a comparison of area, production and yield of the state and comparing it with national average. It is also worth noting that farmers of Punjab achieve this feat with only one cropping season per year, which contrasts with many states like West Bengal and Uttar Pradesh which have a rather larger area under rice and enjoy multiple cropping seasons of rice. The credit is attributed not just to the diligent and enterprising rice farmers of Punjab, but also to the comprehensive infrastructure that was made available during the Green Revolution era.

Despite India's overall food self-sufficiency, its food production during the period from 1947 to 1960 was significantly poor and posed a potential risk of famine. Hence, the Green Revolution was launched throughout the 1960s with the aim of augmenting agricultural output, mitigating dire poverty and malnutrition, and providing sustenance to millions. The Green Revolution incorporated numerous high-yielding varieties (HYVs) with the aim of enhancing agricultural production. The International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines created these genetically enhanced strains of wheat and rice, respectively. The High-Yielding Varieties (HYVs) exhibited a 20% increase in grain yield compared to their previous cultivars and demonstrated greater sensitivity to nitrogen fertilisers. The utilisation of fertilisers, insecticides, and groundwater resources were an integral part of the Green Revolution experiment. The yield potential increased twofold because of integrating many features and specialised genes for reduced height in high-yielding varieties (HYVs). The government's implemented policies resulted in a boost in the production of grains including wheat and rice and to an extent pulses too ultimately achieving food self-sufficiency in the country. However, it also eradicated the varied genetic reservoir that was accessible. Nevertheless, the land's soil degradation and the constant depletion of groundwater were a direct result of mismanagement, excessive use of chemical fertilisers and pesticides, and the absence of crop rotation. In the time before the

Green Revolution, the main crops grown were millets in addition to rice. Furthermore, there was an abundance of sorghum, maize and barley too with wheat. However, the cultivation of millets has substantially dropped and the staple diets of vast majority of households turned into animal fodder within couple of decades as an impact of Green Revolution (Eliazer Nelson et al., 2019). That along with significant increase in yield and production per hectare as well as overall, have been huge economic incentive albeit at the cost of ecological concerns. Several problems, including monocropping, groundwater depletion, and excessive inputs, high farm mechanisation, deterioration of soil quality are the issues that the state confronts now.

1.3 Impact of Rice Cultivation in Punjab

While the impressive success in Rice farming has brought significant socio-economic benefits and a strong sense of pride to the state, it has also had a detrimental impact on the overall agricultural ecosystem of Punjab. The transition from a diverse cropping pattern to a very intensive monoculture cropping pattern of Wheat-Rice rotation has had significant and wide-ranging effects on the content and quality of sustainable assets.

1.3.1 Receding Water Table

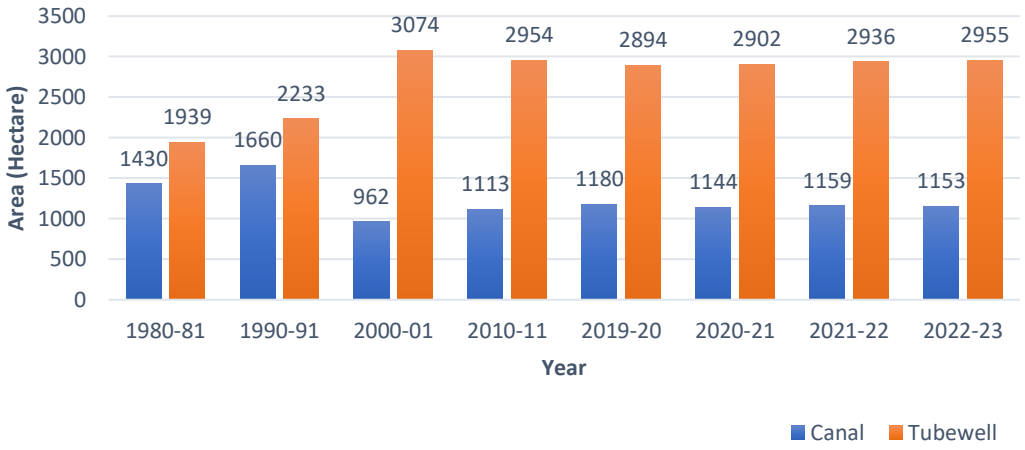
Punjab is proud to have a 99.9% irrigation coverage in its cultivated lands, thanks to its comprehensive surface and groundwater irrigation infrastructure. Approximately 70% of the region's land is being irrigated via tube-wells (Fig 1.1), resulting in excessive exploitation of the state's groundwater resources. Out of the 140 blocks classified based on their subsurface water resource, 109 are excessively exploited and fall into dark zone, while 2 are considered critical and 5 are semi-critical.

1.3.2 Excessive Input Application of Chemical Fertilisers and Pesticides

The contemporary High Yielding Varieties (HYV) of rice, although promising higher yields, were not as resilient to weather and pests as the traditional ones. In addition, these varieties show a tremendous responsiveness to nitrogen. Thus began the era of chemical fertilizers and pesticides. Intensive farming and monoculture practices contribute to an increase in weeds species. The use of synthetic inputs is currently leading to a significant buildup of residues in crops, which then enters the food chain. Additionally, this practice is contributing to the development of pest strains that are resistant to these inputs and causing unintended harm to non-target plants in the surrounding area. The utilisation of fertilisers in Punjab exceeds the national norm by over 1.7 times with national consumption being 139.81kg/hectare while Punjab's figure is 247.61kg/hectare (RajyaSabha, 2024) (See Fig 1.2, 1.3). With meagre 1.5%

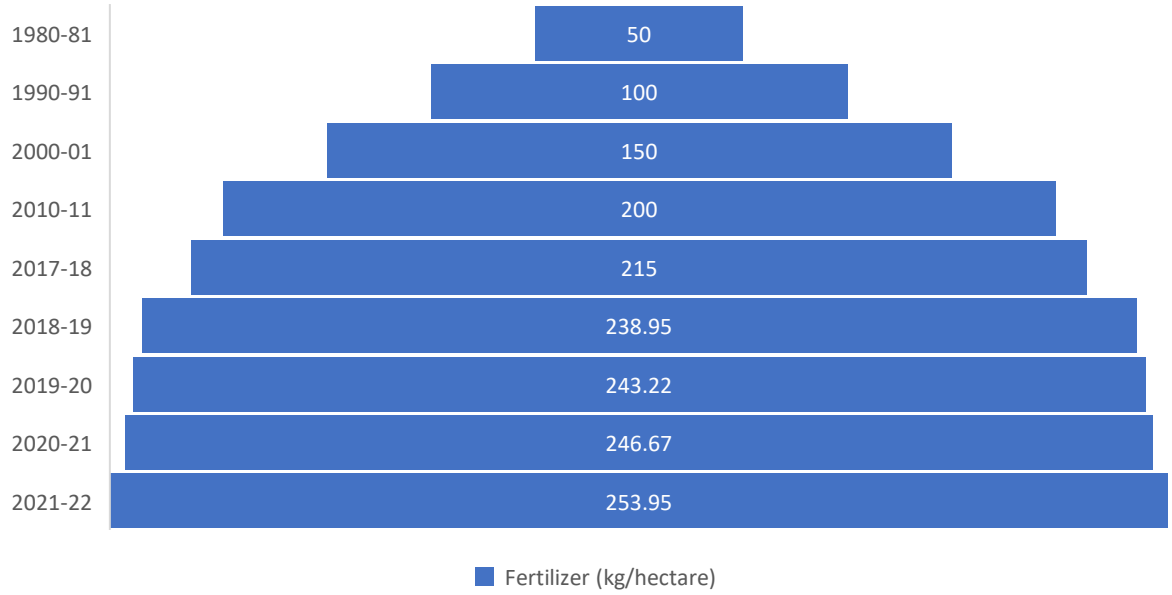
of the geographical area to its account, this kind of fertilizer and pesticide consumption is 9% of the total consumption of the nation, which indeed is an alarming scenario.

Figure 1.1 *Net Irrigated Area by source in Punjab 000 Hectares*



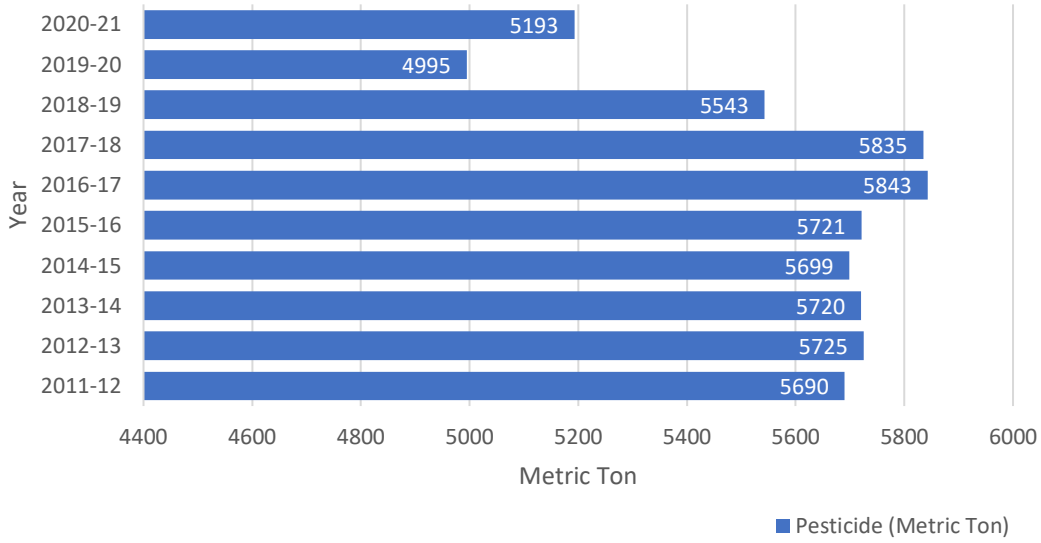
Note. Source: (Directorate of Statistics, Department of Planning, Govt of Punjab, 2023; Punjab State Council for Science and Technology, Chandigarh, 2024)

Figure 1.2 *Trend of Fertilizer usage in Punjab*



Note. ***Source:*** (LokSabha, 2022; Punjab State Council for Science and Technology, Chandigarh, 2020)

Figure 1.3 *Trend of Pesticide usage in Punjab*



Note. Source: (LokSabha, 2022; Punjab State Council for Science and Technology, Chandigarh, 2020)

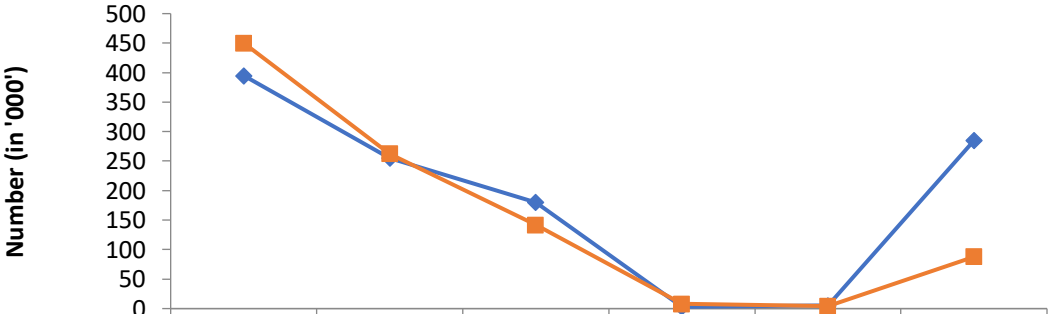
1.3.3 Degradation of Soil

In Punjab, the major cause of land degradation is over-irrigation which leads to waterlogging and thus become a major source of alkalinity and salinity of the soil. The issues present include soil erosion, leaching of pesticide residue in soil, decline in organic matter, ongoing decrease in micronutrient levels, salinity, and water logging in specific areas (Punjab State Council for Science and Technology, Chandigarh, June 20). As per the harmonised database of ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), the degree to which soil erosion has occurred in arable part of India is 92.4mha. The soil erosion is measured when there is more than 10 tonnes of erosion every year per hectare. Punjab, with 220000 hectare of cultivable land, ~5% of the total, is one of the major states that have been chosen for pilot program for Reclamation of Problem Soils scheme since 2016-17 (Rajya Sabha, 2021).

1.3.4 Intensive Agricultural Mechanisation

The substantial investment in mechanisation has negatively impacted economic viability. Punjab has double the number of tractors compared to the rest of the country, but it utilises them for just half the amount of time as the rest of the country (Fig 1.4). This lack of efficiency is contributing to the expenses and eroding the profitability.

Figure 1.4 *Agricultural Machinery & Implements in Punjab*



	Tractors	Disc-Harrow	Seed cum Fertilizer Drills	Combine Harvester (Self-Propelled)	Combine Harvester (Tractor driven)	Threshers
2000-01	395	255	180	2.9	5.1	285
2018-19	450.2	262.5	141.5	7.98	4.2	88

Note. *Source:(Punjab State Council for Science and Technology, Chandigarh, 2020)*

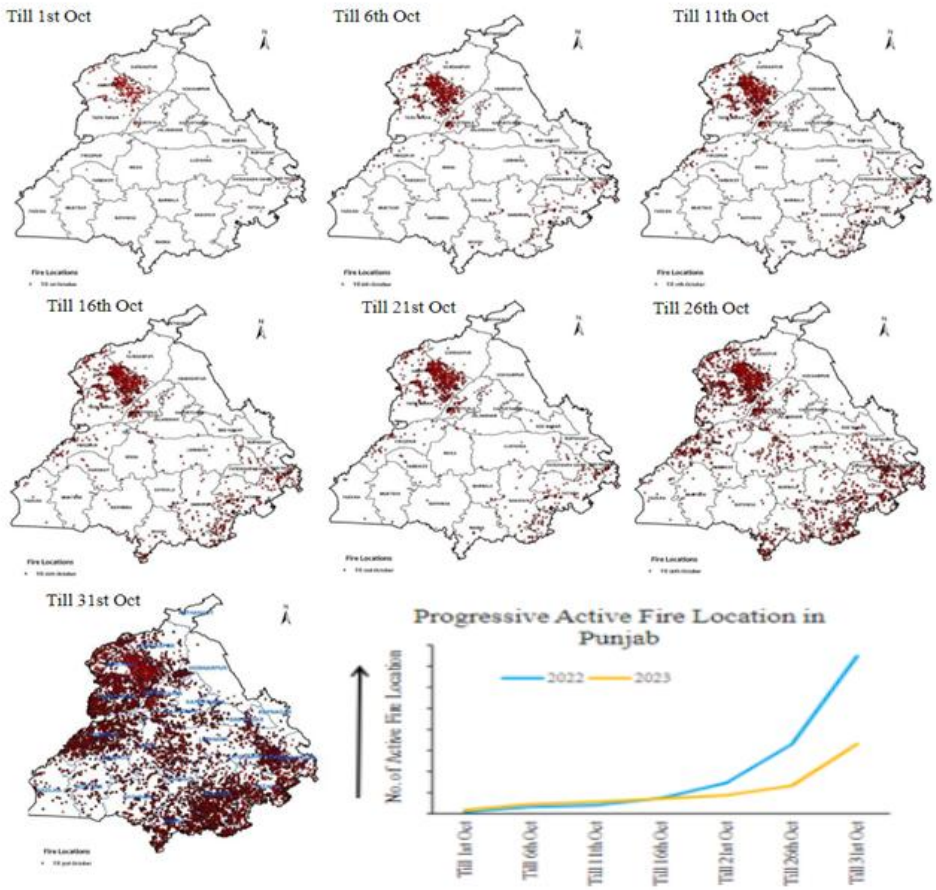
1.3.5 Paddy Residue Management

Traditional methods of straw management in Punjab include burning, which is the most common practice due to its convenience and speed (Fig 1.5). However, this method leads to negative consequences such as air pollution and soil degradation. It leads to the release of harmful pollutants into the air, contributing to poor air quality and negative impacts on public health. This practice also exacerbates climate change by releasing greenhouse gases into the atmosphere. Burning paddy residue can result in increased costs for farmers due to the need for additional fertilizers to compensate for nutrient loss.

Shaik et al. (2019) examined the alterations in biomass burning and its impacts on regional aerosol optical characteristics in Northern India. The researchers analysed active fire points using data from multiple satellites, covering the period from January 2003 to December 2017. MODIS active fire count statistics indicate an increase in the occurrences of fire episodes in India, averaging 1477 fires per year over a 15-year period from 2003 to 2017. The main fire seasons include the pre-monsoon period from March to May, contributing approximately 45% of the yearly fire counts, instances that occur after the monsoon period, lead to almost 24% of the net annual fire counts. The region of Punjab and Haryana, identified as a hotspot for crop residue burning, contributes to 26% of the total fires in India. Through the paddy period, an average of 15,456 fire incidents were reported, representing 77.08% of the overall total. Conversely, 3,296 fire counts were recounted during the wheat cultivation period, accounting for 16.44% of the total. The incineration of crop residue in Punjab significantly affects the aerosol optical properties of both local and downwind areas during the post-monsoon season.

The incidence of crop residue fires rose by 4% (170 fires annually), leading to an 8% increase in the optical depth of aerosol and (AOD), a 9% increase in absorption of optical depth of aerosol (AAOD), and thus raising the aerosol index (AI) by almost 11%. Each year, the combustion of wheat and paddy straw in the Indo-Gangetic Plains (IGP) releases drastic amounts of reactive nitrogen and other pollutants into the atmosphere. Bray et al. (2019) conducted a study on the emissions of reactive nitrogen species, specifically oxides of Nitrogen, NH_3, N_2O, during the wheat and rice harvest periods of 2016 and 2017. This estimation was based on satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor aboard NASA's Aqua and Terra satellites. The emissions from agricultural burns were analysed in relation to the fine particulate matter (PM2.5) in New Delhi to evaluate the influence of these burns on PM2.5 levels. Extended exposure to high levels of PM2.5 is associated with numerous health and environmental impacts.

Figure 1.5 *Number of Farm Fire Incidents in Punjab till 31st October 2023*



Note. Source. (National Remote Sensing Centre, 2023)

1.4 Significance of Rice and Concerns with its cultivation

Rice is the predominant crop worldwide, with around 3.5 billion people, accounting for nearly half of the global population, consuming it as their primary food source on a daily basis. Rice is responsible for providing around 20% of the total dietary energy consumed worldwide. Rice is the most readily available and cost-effective food source for the economically disadvantaged populations, especially in Asia and Africa. Given the projected global population expansion of 8.7 billion in 2030 and 9.5 billion in 2050, with much of this growth expected to occur in Asia and Africa, it is crucial to recognise the significant role that rice plays in ensuring food security. Internationally, there exists a combined area of 163 million hectares that is specifically allocated for the purpose of growing rice. The outcome is a total production of 509 million tonnes of rice, with an average yield of 4602 kilogrammes per hectare. China, India, Indonesia, Bangladesh, Vietnam, Myanmar, Philippines and Thailand collectively contribute about 82% of the world's rice production and approximately 78% of the consumption too (Maraseni et al., 2018). China, as the primary producer, holds a dominant position in the industry, representing 27% of the market share. Following closely is India, with a 23% share of the worldwide market. Out of the entire worldwide production, only 45 million tonnes of rice are accessible for international trade. India has a significant share of 25% in the world commerce, which is valued at ₹54 thousand crores. This amount accounts for over 20% of India's total agricultural exports. The data for Punjab is also quite intriguing. Punjab, with 3 million hectares of rice cultivation, accounting for 7% of the country's total, produces 11% of the national production, equivalent to ~13 million tonnes. This output represents 2.5% of the global production. Punjab boasts the largest paddy output in the country, producing 6167kg per hectare, which is 160% more than the national average. Additionally, Punjab achieves a rice yield of 4341kg per hectare, which is 155% higher than the national average. Another crucial factor is the specific Geographical Indication (GI) tagging of the Basmati variety, which accounts for 45% of India's rice exports valued at ₹15 thousand crores.

Despite its utmost significance, rice has deep environmental impact when it comes to its cultivation. Rice belongs to grass family and thrives in wetlands. The most widely cultivated and consumed species is Oryza Sativa, which has thousands of different cultivars planted worldwide. The ecological varieties can be classified into three primary types that are widely cultivated: the long-grained indica variety, found in tropic and subtropic parts of Asia; the short-grained japonica rice, grown in temperate areas such as Japan and northern China; and the medium-grained japonica rice, cultivated in the Philippines and the mountainous regions of

Madagascar and Indonesia. Rice is cultivated in various water regimes and various kinds of soils be it saline or alkaline and even in the acid-sulphur soils. Irrigated lowland systems, can produce two to three harvests per year, accounting for approximately 75% of global rice production. Rain-fed rice is grown in fields surrounded by embankments and relies exclusively on rainwater for irrigation. This is practiced across South Asia, parts of Southeast Asia, and the entirety of Africa, and accounts for 20% of the worldwide rice supply. Upland rice farming, practiced in arid land conditions, accounts for only 4% of global rice production (Muthayya et al., 2014). Therefore, a major challenge in rice farming is to increase crop yield while simultaneously conserving water resources. Freshwater scarcity for agricultural use is increasing, especially in Asia, where rice cultivation utilizes approximately 80% of the total irrigated freshwater resources.

1.4.1 Environmental Impact of Agriculture

Agriculture contributes about 12% of the total yearly greenhouse gas (GHG) emissions worldwide, which is equivalent to 7.1 gigatonnes of carbon dioxide (CO2). The main sources of these emissions are methane (54%), nitrous oxide (28%), and carbon dioxide (18%). Therefore, agriculture plays a substantial role in both causing and being affected by climate change (Rosa & Gabrielli, 2023). The adoption of intensive practices in agriculture has led to an increase in crop yield. However, this has also resulted in higher energy inputs and a larger carbon footprint, which leads to global warming. Since Indian agriculture exhibits a wide range of crops and production systems; an assessment was conducted by Pratibha et al. (2024) to assess the energy and carbon balance of multiple crops. The choice of crops inclusion was based on various types of production systems. The rainfed crops chosen were pigeon pea, soybean, sorghum, and pearl millet. From the irrigated system, wheat and sugarcane were chosen. The crops which were grown both through rain-fed system as well as irrigation system were rice, castor, cotton, maize, groundnuts and chickpea. The research examined data specific to the field regarding different crop management strategies, alongside grain and biomass yields. Rainfed production methods exhibited reduced environmental impact and carbon footprint in comparison to irrigated systems. The main sources of energy input consist of non-renewable resources, including fertiliser (64%), irrigation (78%), diesel fuel (75%), and electricity (67%). Rainfed crops exhibited superior crop use efficiency relative to those cultivated under irrigated conditions. The mitigation strategies encompassed the implementation of technologies including micro irrigation for efficient water use, site-specific nutrient management or slow-release fertilisers to improve fertiliser efficiency, conservation agriculture to minimize tillage,

and System of Rice Intensification (SRI) or direct seeded rice cultivation methods for rice production.

1.4.2 Role of Rice Cultivation in Agricultural Environmental Impact

Rice production often occurs in irrigated fields to optimise crop productivity. However, the continuous water supply promotes the development of anaerobic soil conditions, leading to increased emissions of CH_4. Indeed, rice paddy fields are the main human-caused contributor to methane emissions, making up 11% of the total CH_4 emissions. Rice cultivation worldwide contributes to more than 10% of greenhouse gas (GHG) emissions from agriculture and around 1.3%–1.8% of total anthropogenic GHG emissions (Basavalingaiah et al., 2020; Maraseni et al., 2018; Ritchie & Roser, 2024). Since climate change is expected to impact rice productivity. Therefore, the primary problems in rice farming are achieving sustainable production by minimising land usage, water consumption, labour requirements, chemical inputs, and greenhouse gas emissions.

1.4.2.1 Excessive Input Usage

Habibi et al. (2019) conducted an evaluation of the environmental impacts associated with rice agroecosystems in the two regions of northern Iran through the application of life cycle assessment in Amol and Rasht. The intent was to identify, quantify, and evaluate the resources utilized and the emissions released into the environment. Two parameters related to resource consumption and emissions of pollutants were estimated. One hundred paddy fields were chosen based on input planting techniques being low, conventional, and high. The selected fields represent small, medium, and large farms to illustrate semi-mechanized and traditional practices. The research indicated that the categories of effects, environmental pollutants, and agricultural management practices exhibited similarities across both regions. The CO_2 emissions related to climate change in Amol and Rasht were 277.21 kg CO_2 equivalent and 275.79 kg CO_2 equivalent, respectively. In both regions, the high-input semi-mechanized system exhibited the highest carbon footprint, global warming potential, and cumulative energy demand. In addition, the results for water depletion, terrestrial acidification, metal and fossil depletion were also comparable in the similar fashion. All regions exhibited that high-input and traditional systems released greater quantities of heavy metals compared to low-input systems. Small farms exhibited the greatest airborne heavy metal emissions. High-input and conventional systems exhibited greater pollution levels compared to low-input systems, attributable to their extensive reliance on chemical inputs such as fossil fuels and fertilizers. Therefore, altering chemical input utilization and decreasing reliance on non-renewable energy

sources is essential for enhancing agro-ecosystem sustainability and mitigating pollution effects.

1.4.2.2 Excessive Irrigation Water Usage

G. He et al., (2020) performed a meta-analysis of the rice system in China. A total of 2753 paired observations were utilised for the same with the intention to evaluate the potential benefits of improved water management, specifically through two types of alternate wetting and drying irrigation techniques and one method of limited flooding irrigation method. The analysis aimed to reduce irrigation water usage and greenhouse gas emissions, while maintaining yield and increasing income. Optimized management resulted in a 40% decrease in the usage of irrigation water with an increase of 34% in production compared to the continuous flooding irrigation method utilized by farmers. Yield reductions were observed during periods of severe shortages of soil water, whereas an increase of 1-6% in yield was recorded under mild alternate wetting and drying irrigation in comparison to continuous flooding irrigation. Optimized irrigation techniques led to a 37% decrease in greenhouse gas emissions, primarily due to reduced methane emissions and diminished energy consumption associated with irrigation.

1.4.2.3 Green House Gas Emissions

Methane emissions are affected by various factors, such as the physiological traits of rice cultivars, the use of organic manure and inorganic fertilizers, methods of water management, physicochemical characteristics of soil, temperature range, and the composition and activity of soil microorganisms. Bakhshandeh et al. (2022) executed a study in northern Iran to evaluate greenhouse gas emissions and conduct a financial analysis of eight different rice production systems. The analysis evaluates expenses, gross returns, and various financial metrics. This study investigates three variables: the origin of irrigation water i.e. whether it is groundwater from wells or the surface water from rivers, the category of rice cultivars meaning if it is low-yielding or high-yielding, and the technique used in transplantation i.e. if the traditional methods are employed or mechanical ones are used. Groundwater systems demonstrated 117.6% of greenhouse gas emissions more than those of surface water systems. Mechanical systems demonstrated greenhouse gas emissions that were 12.4% higher than those of conventional systems. High-yielding rice cultivars demonstrated greenhouse gas emissions that were 20.8% higher than those of low-yielding cultivars. Groundwater systems demonstrated the greatest share of greenhouse gas (GHG) emissions, with electricity accounting for an average of 52.2%. In contrast, diesel fuel constituted 51.0% of greenhouse

gas emissions in surface water systems. The most effective strategy for attaining increased and more profitable rice yields among the analysed production scenarios was the utilization of surface water for irrigation, notwithstanding the necessity for a higher volume of water consumption. The ideal combination for maximizing production comprises surface water irrigation, mechanized cultivation, and the application of high-yielding cultivars.

1.5 Sustainable Agriculture – Global Perspective

The word "sustainable" has its etymological origins in Latin, specifically from the words "sustenere" (where "sub" means "under" and "tenere" means "to hold" or "to ensure"). Therefore, it signifies the ability to ensure anything for a long duration. Sustainable Agriculture refers to the practice of farming in a manner that enables us to meet the worldwide need for food and fibre without jeopardising the capacity of future generations to meet their own needs. The concept of Sustainable Agriculture emerged in the early 20th century with the introduction of Biodynamic Agriculture by Steiner. This approach to farming, rooted in a philosophy of conservation, emphasised the importance of "humus farming," which is akin to modern-day mulching practices. In the latter half of the century, attention turned towards the progress made in the fields of science and technology, leading to the initiation of the Green Revolution. This revolution involved the development of high-yielding crop varieties and the use of chemical inputs. It was a period characterised by the dominance of Industrial Agriculture. However, over time, the effects on safety, health, and the environment became apparent. The release of pesticides into the food chain, pollution of water bodies, harm to the entire ecological system, and the emergence of resistant-pest varieties have redirected focus from productivity to sustainability (Harwood, 2020). The sustainability model operates on the principle that civilisation must and can coexist with its ecological environment, ensuring the well-being and safety of the environment while simultaneously maintaining economic viability. The Food and Agricultural Organisation of the United Nations (FAO) has provided a definition for sustainable agricultural development. FAO's vision for sustainable food and agriculture is one in which "food is nutritious and accessible for everyone, and where natural resources are managed in a way that maintains ecosystem functions to support current, as well as future human needs" ((FAOUN, 2024). The key determinants of sustainability are financial feasibility, ecological integrity and social acceptance. FAO emphasises the importance of taking a comprehensive perspective, considering the increasing population and the several interconnected challenges it brings, such as poverty, inequalities, hunger, insufficient nutrition, scarcity and degradation of land and water, pollution, loss of biodiversity, and climate change. It presents a conceptual

framework that seeks to achieve a harmonious balance between human activities and the natural environment, taking into account the inherent dynamics across time. The Food and Agriculture Organisation (FAO) presents five fundamental principles of sustainability for the food and agriculture sector (Fig 1.6). These principles form the fundamental basis for the measures taken to achieve the Sustainable Development Goals that were endorsed by the United Nations in 2015. These principles are: i) Increase productivity, employment and value addition in food systems, ii) Protect and enhance natural resources, iii) Improve livelihood and foster inclusive economic growth, iv) Enhance the resilience of people, communities and ecosystems, and v) Adapt governance to new challenges

Figure 1.6 *Five Key Principles of Sustainability*

Note. *Source: (FAOUN, 2024)*

1.5.1 Sustainable Development Goals

In 2015, the United Nations introduced 17 Sustainable Development Goals (SDGs) that were unanimously accepted by all 193 member states (Fig 1.7).

Figure 1.7 *17 Sustainable Development Goals*

Note. ***Source:*****(United Nations, 2023)**

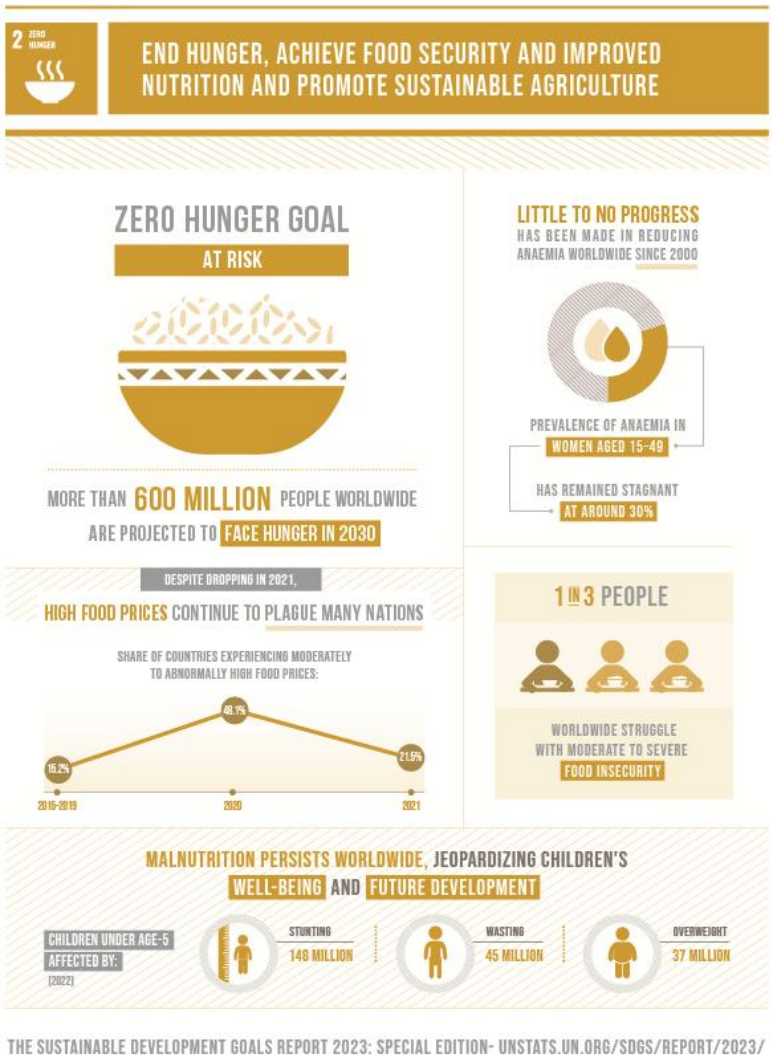
These goals were designed to collectively protect the planet and its inhabitants. The goals are integrated due to their intrinsic interconnectedness. The interdependence of many areas necessitates the achievement of a balanced approach to development that considers social, economic, and environmental sustainability. Curiously, the Sustainable Development Goals (SDGs) feature numerous targets that are represented by the number zero. The worldwide aim of "Zero Hunger" is closely linked to the first goal of "Zero Poverty". The objective of the "Zero Hunger" initiative is to eradicate hunger, ensure food security, enhance nutrition, and

foster sustainable agriculture (Fig 1.8 and 1.9). India is a signatory to this pledge as a significant member of the United Nations. This study is being done in the wake of Commitment to SDG, promotion of sustainable agriculture and creating necessary conditions for bringing down the negative impact of rice cultivation in Punjab.

Figure 1.8 *SDG Goal 2 - Zero Hunger*

Note. ***Source:*****(United Nations, 2023)**

Figure 1.9 *Infographic on Zero Hunger*



Note. Source: (United Nations, 2023)

1.5.2 Approaches to Sustainable Agriculture

According to Velten et al. (2015), in their comprehensive literature analysis, there are two main perspectives expressed by scientists about the approaches to achieving sustainable agriculture: Techno-economic and Agro-ecological Ruralist. These two techniques are not mutually exclusive and share common elements, but they also have distinct differences. The former perspective is grounded in economics and utilises current science and technology to impact the market. In contrast, the latter perspective prioritises ecology and is rooted in traditional knowledge, while maintaining a sceptical stance towards modernity and technology. The techno-economic approach promotes an entrepreneurial farming system that emphasises intensive agriculture with a heavy reliance on external inputs to achieve high production and system efficiency. On the other hand, the Agroecological attitude supports the idea of farmers acting as custodians of nature, practicing organic or low input usage, and engaging in diversified agricultural production on a small local scale. The main distinction between these two methods lies in their respective end objectives. Technoeconomic proponents advocate for a compromise with nature to address the needs of a growing population, whilst Agroecologists advocate for a shift in lifestyle and consumption habits. The debate revolves around global vs local scenarios, with one school of thinking promoting a competitive advantage in production and efficiency, while the other emphasises the importance of respecting the ecosystem's carrying capacity.

Contemporary technologies are designed to address the limitations of outdated agricultural methods used in the past. Multiple strategies are being implemented to achieve sustainable intensification of agricultural productivity in response to the increasing population and concerns over food security. In the light of the recent epidemic, the global community is acutely aware of the devastating consequences it brought. Consequently, there is a concerted focus on ensuring the preservation and optimisation of food crop production. Sustainable intensification, climate smart technology, precision agriculture, diversified farming system, low input sustainable agriculture, integrated pest management, green chemistry, biologicals (microbial-biopesticides, biochemical pesticides, PIP – plant incorporated pesticides), integrated nutrient management, biofertilizers, and phyto-nanotechnology are some of the prominent methods being implemented within the techno-economic production-oriented approach. The Agroecological approach to sustainable agriculture seeks to identify solutions that minimise or eliminate the need for external inputs from sources outside of agricultural ecosystems. They generally depend on natural or organic techniques for production. Several

global practices include Organic Farming, Conservation Agriculture, Integrated Farming System, Natural farming, and Regenerative Organic Agriculture. The main distinction is in the complete rejection of factory-produced materials on the farm.

1.5.3 Organic Agriculture

Organic agriculture, originally a niche market, is now becoming a profitable commercial opportunity due to growing consumer awareness and assistance from international organisations. The adoption of the Sustainable Development Goals (SDGs) at the United Nations (UN) level provided a significant boost to the movement. As per the 2021 annual report, Organic Agriculture has expanded its reach from 11 million hectares in 1999 to over 74.9 million hectares globally by 2020. The market value has surged from €15 billion to €120 billion in a span of two decades. A total of 190 countries worldwide have actively participated in Organic activity. India has the highest number of organic producers, with a total of 1,599,010 (IFOAM-Organics International, 2021). The International Federation of Organic Agriculture Movements (IFOAM Organics International) is a leading global organization that has been instrumental in formulating guidelines for formalising the standards and certification in organic agriculture at the national level. IFOAM presents four principles to Organic Agriculture:

- **"Principle of Health:** to sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible".
- **"Principle of Ecology:** need to have a system based on living ecological systems and cycles, work with them, emulate them and help sustain them".
- **"Principle of Fairness:** build relationships that ensure fairness with regard to common environment and life opportunities".
- **"Principle of Care:** management in precautionary and responsible manner to protect the health and well-being of current and future generations and environment" (IFOAM Organics International, 2024).

The current developments in India with regards to Organic Agriculture are promising, particularly with Sikkim and Meghalaya achieving the status of a completely organic state. Kerala, Uttarakhand, Mizoram, Goa, and Rajasthan have decided to adopt a similar approach in a gradual and systematic manner. Both Andhra Pradesh and Himachal Pradesh have implemented Natural Farming as a state-wide practice. India, with the highest number of organic producers globally, has the ability to expand its organic production with the right methodology. India implemented its Organic policy in 2001 under the National Programme for Organic Production. The national standards and policy have been established with a specific

certification structure, with the Agricultural & Processed Food Products Export Development Authority (APEDA) serving as the secretariat. A National Centre for Organic Fertiliser has been formed to guarantee the expansion of production and distribution, as well as provide extension support. The Paramparagat Krishi Vikas Yojana is a program aimed at promoting and establishing sustainable agriculture. However, there are concerns regarding its wider adoption in Punjab. The certification process for Organic farming is prohibitive due to its yearly renewal fee, periodic inspections, and high costs and is best suited for educated and resourceful farmers. The collaborative approach based Participatory Guarantee Scheme (PGS) is susceptible to exploitation by unscrupulous individuals seeking to manipulate the system for their own purposes. The absence of standards or guidelines and lack of an exclusively market for sustainable produce also makes the exercise futile.

1.6 Need and Scope of the Study

The agriculture sector in Punjab is currently plagued by numerous issues. The state farmers are facing a depletion of soil and water resources, which is causing economic losses due to increased capital asset and input costs. Despite this, the farmers are not showing any willingness to switch from cultivating water-intensive rice crops. The current net sown area has reached its maximum capacity, as has the yield productivity. Therefore, it is unclear where the growth factor will originate from. The deplorable status of agriculture gives rise to multiple socio-economic and environmental challenges. The state is currently experiencing severe water and land scarcity due to the excessive demands placed on its resources. This has resulted in depleted soil nutrients and a declining water table. From 1971-72 to 1985-86, agricultural growth was over double the national level, at a rate of 5.7%. Between 1986-87 and 2005-06, it decreased to about the same level as the national average, at 3%. By 2014-15, agricultural growth had stagnated at 1.61%, which is half of the national level. Despite the hurdles, rice growers in the country have consistently achieved the greatest yield per hectare, reaching 4341kg/hectare. The future is approaching with great significance and the farming community is facing intense pressure. The lack of sustainability in agriculture is causing societal problems, as the shift away from farming results in unemployment and frantic emigration. The policy makers have proposed suggestions, but they have been fragmented and ineffective in addressing the concerns at the grassroots level. The most frequently mentioned proposal is to substitute the water-intensive rice crop with alternative crops such as maize, cotton, and pulses. Nevertheless, the agricultural community has displayed little enthusiasm due to the lack of a comparable produce, market and guaranteed purchase for these alternative commodities, unlike

rice in the mandis. In contrast, the data indicates that the area dedicated to rice farming has consistently increased. It's evident that the producer does not want to stop growing rice for obvious reasons, and it is a fact that the traditional methods of farming are depleting natural resources at a concerning rate.

The study aims to assess the feasibility of sustaining rice agriculture in Punjab without causing resource depletion and ensuring economic viability. Growers could opt for sustainable agriculture approaches to achieve the intended objective. Among the different types of sustainable agriculture technologies, Organic Farming is the most renowned and widely embraced method within the Agroecological Ruralist approach. It is gaining significant momentum on a global scale and is also able to command a higher price. Furthermore, Climate Smart Agriculture with Precision and Variable Technology employing Internet of Things in agriculture is under the realm of technology-focused approaches and offers the potential for financial viability and success through the efficient use of resources. The study will focus on evaluating the extent of knowledge and usage and perception around the adoption feasibility of different sustainable agricultural practices in rice cultivation in Punjab. The assessment will be done from the perspective of farmers, considering factors such as practicality, viability, and the perception of wider commercial acceptance.

1.7 Significance and Contribution of the Study

There are several issues that the agriculture sector in Punjab must contend, including the depletion of soil and water, the rising costs of capital assets and inputs, and a loss in output productivity. Rice farmers produce the maximum amount of rice per hectare in the country, which is measured at 4341 kg per hectare, despite the limits that they face. Agricultural methods that are not sustainable are the fundamental explanation for societal problems such as migration and unemployment.

Even though a replacement of water guzzling rice crop has been considered and suggested by policymakers with maize, cotton and pulses as possible substitutes, the latter neither has a market that is equivalent to former nor a secure procurement. The study aims to estimate the possibility of cultivating rice sustainably in Punjab. This research investigates the challenges that are associated with cultivating rice in a sustainable manner, as well as the awareness and frequency of sustainable agricultural practices among growers in Punjab, their perspective on the adoption of these methods, and the ways in which institutional support and market infrastructure impact behavioural intention. The significance of the study lies in

analysing the practicability, viability, and perception of greater commercial acceptability of Sustainable Agriculture Practices from the point of view of the end-user audience.

With the use of Sustainable Agricultural Practices farmers can grow sustainable rice, which can fetch him premium price since Organic is a sector that is growing popular at an exponential rate. The global market for Organic Produce is ever rising and Punjab with its highest yield per hectare and 3rd highest production of the country has the potential to bring a boom in export sector. The study explores the issues of sustainable agriculture, environment, economic inclusion and welfare of farmers, export potential of quality rice from Punjab thereby meaning contribution to national economy and meeting the global demand of quality rice. Specifically, the research focused on the Punjabi growers. Both the improvement of the economic well-being of the state's agricultural sector and the acquisition of a better understanding of sustainable agriculture are the most significant contributions that this study makes possible

1.8 Organisation of the Chapters in Thesis

This thesis includes 7 chapters and brief description of each chapter is given below:

Chapter 1 briefly introduces the background of the research, including the problem statement and significance of the study. It also provides a brief on how the current study will contribute to existing knowledge of research.

Chapter 2 introduces review of literature on Sustainable Agriculture and various approaches towards its implementation. It further provides scholarly details on Sustainable Agricultural practices both from the techno-economic zone and agroecological zone. Thereon, chapter presents literature evidence on benefits of sustainability practices for rice. Finally, factors and barriers impacting the acceptance and adoption are discussed. In the final section, it provides the existing research gap, research questions, and conceptual framework with theoretical underpinnings.

Chapter 3 This chapter provides a comprehensive explanation of the research methodology, and the mixed methods research design employed in the study. This chapter elucidates the sequential exploratory mixed methodological research design employed for the study. It emphasises the utilisation of qualitative research design in phase I, quantitative design in phase II for research instrument creation, and quantitative research design in phase III.

Chapter 4 describes the phase I of the study which is characterised by a qualitative approach. The chapter provides comprehensive information on the sample plan, data collection process, grounded theory approach, and conclusions from the first phase of the study. It further provides a literature review of the new variables that have emerged as a part of analysis of phase one. It further delves into the initial proposed framework and the revised new conceptual framework highlighting the structural relationship between the variables. This chapter finally presents the hypothesis development based on the research gaps and research questions of the study given in chapter 2.

Chapter 5 describes the phase II of the study which is quantitative design phase. This chapter explains the process and steps taken to develop the research instrument. The chapter also describes the pilot study and discusses in detail the reliability and validity of the research instrument. This section explicates the sampling method, sample size and provides details of testing of techniques used for analysing the conceptual framework.

Chapter 6 presents the data analysis of the quantitative study. The chapter begins with demographic analysis, leading to descriptives. The next section draws details on exploratory factor analysis. Thereon, the structural model analysis is carried out, beginning with measurement model followed by structural analysis. This section explains the relationships based on direct paths followed by mediation analysis. The last section shares findings of moderation analysis.

Chapter 7 summarises the insights from the findings with its interpretation. IT begins with discussions based on respective research questions leading to conclusions and implications. Finally, the chapter ends by sharing the sharing the limitations of the study and possible future research directions

1.9 Chapter Summary

The chapter primarily provided information on the status of Punjab in the context of its declining renewable agricultural resources and the socio-economic impact thereof because of wide-spread rice cultivation. It further elucidates the importance and need of sustainability in the context of environmental impact of rice crop. The chapter also highlights the global attention on Sustainability with Sustainable Development Goals. The chapter further presents the need and significance of the research.

2. Chapter 2 - Review of Literature

"We cannot choose between growth and sustainability -we must have both."

- Paul Polman

2.1 Overview

This chapter presents the review of the existing literature on Sustainable Agriculture. The chapter begins with bringing forth the aspect of Sustainable Agriculture and nuances around its understanding amongst the academia. This section also highlights the debate on objectives and methods of sustainable agriculture. This second section presents with details of various approaches to Sustainable Agriculture. The third section shares details on various Agroecological Practices. In addition, LR support for the various SAP in rice cultivation are shared. The section also shares mitigation suggestions made in literature for Punjab. The next section reviews the literature for determinants and barriers of acceptance and adoption of sustainable agricultural practices. The last section of the chapter presents the Research Gaps and Research Questions, followed by a Conceptual Framework and theoretical underpinnings.

2.2 Defining Sustainable Agriculture

The conventional agricultural practices that flourished worldwide post-World War II under the name of Green Revolution in-fact lacked "the green aspect" as we understand it today. These practices were replete with use of latest technologies of the day, Agri-chemicals as fertilisers and pesticides, intense mechanisation, high energy input and monocropping culture with the sole objective of maximising production. This method was akin to industrialisation of agriculture and eventually became the main stay of agricultural practices to feed the ever-rising global population, an objective that it did fulfil and successfully. However, by 1970s, the negative impact on environment was beginning to show and the term 'Sustainability' caught the attention of the agriculturists and economist in the developed nations. It was being realised that human extraction is going beyond the carrying capacity of the planet. The effects of industrialisation in all the factors of production including agriculture needed to be arrested for a thriving planet. Growing resistance against the industrial method of agriculture is palpable now at all levels and in all sections of the society. A section of consumers has been vocal about their concern on usage of chemical laden food and quite ready to pay the premium to access wholesome food full of unadulterated nutrients. From 1980s onwards there has been a gradual evolution in the concept of Sustainable Agriculture. It's imperative since source of 80% of the food in the world is through agriculture and 10% is fishery.

The Brundtland Report, published by the United Nations World Commission in 1987, identifies three key components of sustainability: environmental, economic, and social dimensions (Keeble, 1988). The text is significant for its role in instigating a sequence of conversations, debates, ideas, policies, and, most importantly, tangible action. In addition to government authorities, the business world also started incorporating sustainability by adopting the 'triple bottom line approach'. This concept, introduced by John Elkington in 1994, emphasises three main goals for corporations: Profit, People, and Planet, which correspond to economic, social, and environmental objectives (Elkington, 1994).

Although the three-pronged approach has gained more widespread recognition, it has faced severe opposition from many researchers, especially in relation to growth and development. Redclift (2005) describes the term 'sustainable development' as an oxymoron, suggesting that there is an inherent conflict between the socio-economic and environmental goals. Kuhlman & Farrington (2010) extend the argument and challenge the fundamental concept of the triple bottom line. Their study argues that a government's public policy cannot be approached with the same mindset as a profit-driven business initiative. In addition, it is worth considering that the immediate and short-term economic needs, as well as the mid-term social needs of the current generation, may be prioritised above the long-term environmental needs. This might potentially undermine the overall purpose of ensuring the well-being of future generations. The subsequent claim pertains to the aim of sustainability, which is to enhance the well-being of individuals by integrating social and economic objectives. Mensah (2019) shares the same perspective, stating that sustainability encompasses intergenerational equity and has both short-term and long-term concerns. It is noteworthy that Elkington, the originator of the term "triple bottom line," has decided to retract the word due to its reduction to a simply accounting tool, rather than being seen as a comprehensive system approach (Elkington, 2018).

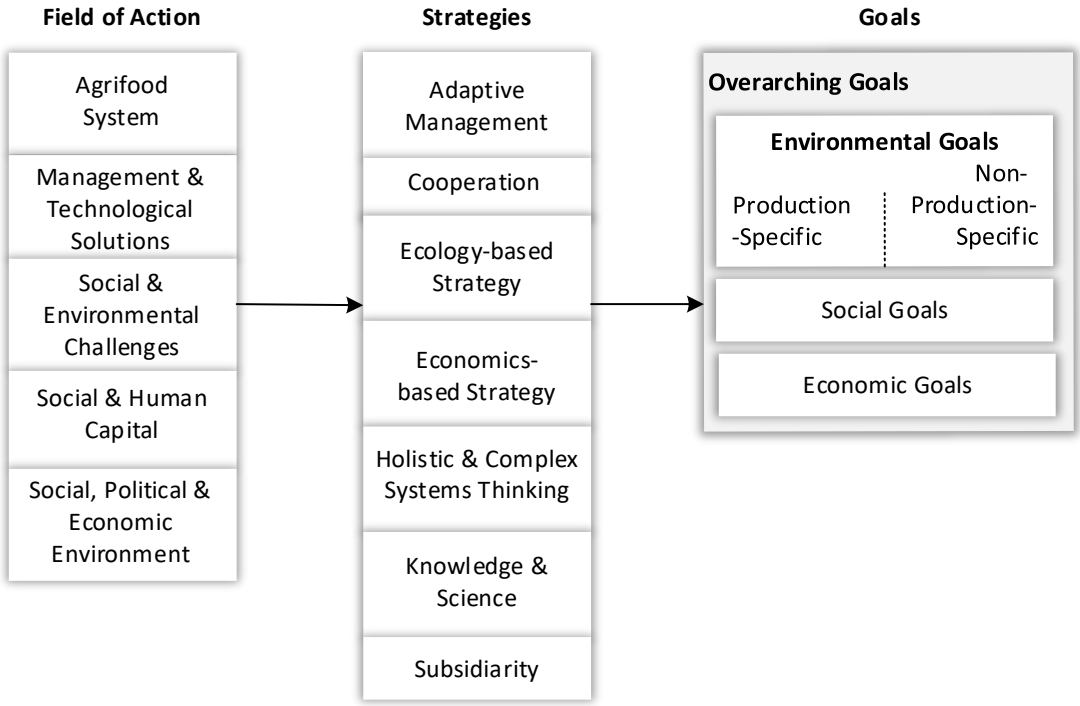
Bali Swain and Yang-Wallentin (2020) have proposed, using a Structural Equation Model (SEM) analysis, that in order to achieve sustainable development, developing nations should prioritise social and economic objectives, while developed nations could derive greater advantages from socio-environmental goals. The social dimension of sustainability is derived from cultural origins, and there have been advocates calling for the inclusion of a fourth pillar - culture - asserting its significant role in development (Cicerchia, 2021). The concept of sustainability is complex and has significant significance in all aspects of human life. Pretty (1994) has expressed disapproval of the positivist approach that seeks to provide an absolute

definition and prescribed course of action for sustainability. Instead, she argues that sustainable agriculture necessitates a system-oriented approach. According to Pretty (1995), the idea of sustainability is too intricate to be described by a single absolute definition. Pretty emphasises the importance of adopting a participative approach. Consequently, the presence of contradictory explanations of the concept of sustainability complicates its application to agriculture. The interpretation of the term 'Sustainable Agriculture' may vary and have significant consequences depending on the specific factors of the location. Hence, the authors have opted to adopt an interpretative methodology as a part of this research. Jules N Pretty insists that there should not be an absolute definition of Sustainable Agriculture as it's a contested term and is prone to different interpretations as to what would be acceptable in differing trade-off scenarios. There are complex issues and challenges a farmer faces on account of geography, climate, biodiversity, availability or lack of resources, hence there is need for a participatory approach in defining and adoption of Sustainable Agriculture (Pretty, 1995). Amidst these debates, the widely accepted definition of the term, however, is by Food and Agriculture Organisation of United Nations (FAO) as defined it as,

"The management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAOUN, 2014).

The fundamental question, however, is how to effectively engage the farmer, the most crucial key agent, in this endeavour. The existence of inconsistent interpretations of sustainability makes it challenging to determine what qualifies as sustainable agriculture. Resolving this issue requires the existence of a framework that can serve as a foundation for the present investigation. In their systematic literature review, Velten et al. (2015) have introduced a framework (See Fig 2.1 and Table 2.1) that is grounded on Goals, Strategies and Field of Action to attain economic, social, and environmental goals. The environmental objectives here are classified into two categories: production specific and non-production specific. The latter target the preservation of nature for its intrinsic value, rather than being driven by human interests. The provided framework is quite beneficial for comprehending the academic perspective on the subject. However, the main deficiency lies in the perception of the intricacies of sustainable agriculture by farmers at the grassroots level, within their own environment. Furthermore, what are the determinants contributing to this perception?

Figure 2.1 *Groups and Themes of the sustainable agriculture*



Note. *(Source: Velten et al., 2015)*

Table 2.1 *Themes and categories making up the goals of sustainable agriculture.*

Goals	**Theme**	
	General	*Specific*
Overarching Goals		• ethics • multifunctionality • safety • stability & resilience
Environment Goals; Production Specific	ecological soundness	• ecosystem function conservation • natural resource conservation • providing capacity
Environmental Goals; Non-Production Specific		• animal well-being • environment conservation & improvement • harmony with nature
Social Goals	social responsibility	• acceptability • cultural preservation • equity, justice, fairness • fulfilment of human needs • good working conditions

Goals	Theme	
	General	*Specific*
		• human health • nourishment • quality of life • strong communities
Economic Goals	economic viability	• development • livelihood • provision of products • thriving economy

Note. *Source:* (Velten et al., 2015)**.**

2.3 Implementing Sustainable Agriculture

Once the debate around the objectives of Sustainable Agriculture is settled, the next matter that comes forth is how to achieve these goals? There are two major ways to sustain agriculture, one is rooted in ecology and the other takes the support of modern technology. At the heart of Eco-centric approach is local production and consumption, this is no-growth or low growth system with an advocacy for a complete lifestyle change in how production and consumption patterns are carried out and need for prudent resource allocation and utilization. These methods are in complete contrast with the system of conventional agricultural. Technocentric approach insist on terming agriculture itself as a biotechnological process where plants and animals co-create and convert their form of energy. This perspective finds eco-centric approach as unrealistic and politically impractical. Horrigan et al.,(2002) in their review cite that Sustainable agricultural systems rely on relatively small, profitable farms that utilize fewer external inputs, integration of animal and plant production as suitable, preserve higher biological diversity, prioritize technologies commensurate with production scale, and transition to renewable energy sources. However, the authors subsequently contradict this by asserting that Sustainable Agriculture ought not to be confined to a specific set of methods. It necessitates a novel perspective that acknowledges agriculture's dependence on finite natural resources, recognizing that issues linked to management of farms cannot be addressed in isolation but require a whole ecosystem-based approach (Horrigan et al., 2002). The heart of the debate has been captured by Robinson (2009) that what constitutes Sustainable Agriculture. Technological advances can bring about sustainability through adoption via an industrial system of conservation-oriented farming. Further research in biotechnology can lead to innovations to

meet our sustainability goals. There have been advances in biotechnology since the times of Green Revolution. From creating HYV of seeds, technology has moved to genetic engineering and desirable traits can be created (Robinson, 2009).

2.4 Approaches to Sustainable Agriculture

As per Velten et al. (2015), In achieving goals of sustainable agriculture, the positions taken by scientists from various streams largely presents itself in two categories being Techno-Economic and Agroecological-Ruralist. The author states that it's a function of who proposes the strategies and field of action and with which goals in mind. It's the economist who have production centric approach considering the global scale of food security aspect and advocate the use of modern technology (See Table 2.2). Whereas the ecologists are rooted in safeguarding the natural environment for the sake of it and advocate changes in consumption patterns. But interesting aspect is that these two spheres are not mutually exclusive and there are many over-laps in them. The authors also highlight that the academic literature showcases larger concern with economic benefits and production needs whereas the grey literature reflects more need towards social aspect and protection of natural resources for its own sake.

Table 2.2 ***Technoeconomic Vs Agroecological Ruralist Approach***

Technoeconomic Position	Agroecological Ruralist Position
Anthropocentric	Eco-centric
Economics and market centred approach	Ecology centred approach
Based on Modern Science and Technology	Based on Traditional knowledge
Exclusive and ad hoc solutions	Integrated and interdisciplinary solutions
Competent production efficiency	Understanding the limitations of ecosystem, minimal growth
Global outlook	Local Outlook
Entrepreneurial individual actions	Collective action, participation
Intensive agriculture, High input, monoculture	Organic agriculture, Low input, diversified production
Focused on Consumption needs	Advocates curtailing excesses of consumption styles

Note. Adapted from (Velten et al., 2015)

2.4.1 Technoeconomic Methods

2.4.1.1 Agriculture 5.0

Fountas et al. (2024) provide a historical context of the different versions of agriculture which has undergone a huge transformation since the advent of Green revolution. The first enablers of a more productive agricultural system were plough and animals in comparison to

farming by hands. Agriculture changed drastically during the 1950s Green Revolution. Farm machinery like Tractors and other farm tools, along with developments in agrochemicals and crop and livestock rearing methods, increased agricultural production. These innovations transformed Agriculture 1.0 into Agriculture 2.0. Since Agriculture 2.0, technology has advanced greatly, benefiting agriculture. Agriculture 3.0, also known as precision agriculture, emerged from earth observation satellites and computer science. Agriculture 3.0 was seen as humanity's solution to crop input misuse's environmental and health impacts. It helped in reduction of inputs while maintaining or raising crop or animal production. Agriculture 4.0, often termed as digital agriculture or smart agriculture, introduced new technology and capabilities. AI, big data, IoT, VR/AR, 3-D printing, quantum computing, blockchain, and robotics improve agricultural sustainability. To address food security, climate change, environmental protection, and human health, these technologies must be quickly integrated into real-world conditions. Furthermore, the authors provide a distinct definition of Agriculture 5.0 and its explanation.

“Agriculture 5.0 is the environmentally, economically, and socially sustainable agricultural production system that uses advanced technologies everywhere, every time. “Everything” is Agriculture 5.0's connectedness. Every physical and/or digital object, sensor, robot, farm gear, and person may communicate, share insights, and efficiently regulate agricultural actuators. "Everywhere" is place Agriculture 5.0 is used. Agriculture 5.0 can be used indoors and outdoors in urban, rural, and coastal locations using 6G and non-terrestrial networks. “Every time” refers to Agriculture 5.0 usage. Agriculture 5.0 uses the right technology to enable daily connectivity and operation in all situations” (Fountas et al., 2024).

The age of Agriculture 5.0, comprising of use Artificial Intelligence (AI), Internet of Things (IoT), Artificial Intelligence (AI) and Machine Learning (ML) all falling under the gambit of “Precision Agriculture (PA) has arrived on the horizon, but the developing nations are yet to gear up for it.

2.4.1.2 Nanotechnology

Sachin et al. (2022) have detailed the various Innovations in nanotechnology in their review. Nanotechnology is of paramount importance in the agricultural industry, extensively employed in a range of applications including plant protection, plant growth monitoring, and disease detection. Numerous scientists are currently investigating novel applications of nanotechnology, which holds significant potential for transformative developments in the

agricultural industry in the foreseeable future. Nanotechnology is the study of systems composed of nanoparticles ranging from 1 to 100 nm in size. These nanoparticles include distinct characteristics including colour change, enhanced reactivity, transformation of ferromagnetism to Para magnetism, and reduced melting point viscosity. These characteristics render them applicable in the development of very sensitive sensors across several domains such as medical, electronics, agriculture, food technology, and environment. Nano sensors are instruments with the ability to detect alterations in both abiotic and biotic compositions within the surrounding environment, enabling the monitoring of soil pollution, moisture levels, and environmental conditions. Nano agro particles are particles of nanoscale dimensions employed to address agricultural challenges, including pollution and nutrient insufficiency. Nano fertilisers are biofertilizers that enhance the biological absorption of nutrients and promote plant growth with superior efficiency compared to conventional biofertilizers due to their exceptional efficacy. Nano pesticides are enclosed within nanocarrier materials, therefore diminishing the necessity for physical pesticide formulations. Nano fungicides are employed for the purpose of safeguarding crops against fungal pests, which have the potential to cause substantial reductions in crop productivity. Nano bactericides have shown significant efficacy against an extensive range of phytopathogenic bacteria. In general, nano sensors provide viable options for the promotion of sustainable agricultural and environmental sustainability.

The application of green nanotechnology is being recognised as a crucial instrument in attaining sustainability in the fields of agriculture, food industry, and animal feed. Within the field of green nanotechnology, nanomaterials are produced using biological techniques and have extensive utility in the sustainable agricultural industry and related areas. Various plant tissues, including leaf, stem, bark, seed, root, fruits, and flower, have been utilised to produce nanoparticles. A wide range of engineered nanomaterials exhibit distinct effects, processes, and behaviours on plants (Muktesh et al., 2022).

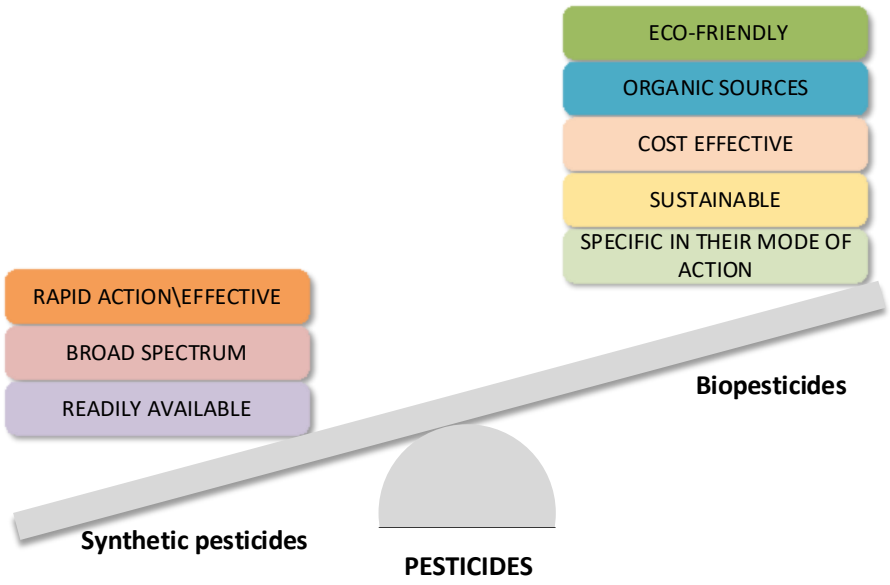
Microbial nanotechnology is a developing and advanced engineering technique that utilises microbes to produce distinctive nanostructures that are environmentally safe, non-toxic, and economically efficient. This groundbreaking technique sees vast uses in the agricultural industry, resulting in a wide range of products such as nano-antimicrobials, plant growth-promoting chemicals, and nano-biosensors, among others. This has significantly transformed the green chemistry methodologies as applied to the progress of the agriculture industry (Raj et al., 2021).

2.4.1.3 Biologicals

Biologicals refer to agricultural methods that utilise natural processes to safeguard and enhance the well-being of food crops. Biologicals provide farmers with novel approaches to control pests and diseases, mitigate abiotic stress, and improve nutrient utilisation efficiency and soil health. Furthermore, they can provide as a supplementary resource to conventional inputs. There exist three primary categories of biologicals, namely Bio-stimulants, Biofertilizers, and Bio-controls. Bio-stimulants augment and fortify crops. Agrochemicals are administered to plants, seeds, or the root environment to enhance the inherent physiological functions of plants, therefore improving nutrient utilisation efficiency, resistance to abiotic stress, and crop quality.

Biofertilizers are microbiological-based products utilised for nitrogen fixation, enhancement of nutrient availability and absorption, and stimulation of plant development. Bio-controls manage and regulate pests and diseases. These materials are naturally existing substances employed for the purpose of managing fungal and bacterial diseases, insect pests, nematodes, and weed. Under this category, there is a wider acceptance of Biopesticides. Biopesticides, being environmentally friendly chemical agents, have demonstrated the capacity to replace chemical pesticides while maintaining the same level of agricultural output. The implementation of bio-based insecticides through integrated pest management (IPM) has demonstrated its highly efficacy in influencing several aspects of sustainable agriculture. Therefore, biopesticide-driven Integrated Pest Management (IPM) if used with necessary education, skills, and research would enhance sustainable agriculture (Fenibo et al., 2022). Biopesticides are exogenous chemicals derived from animals, plants, and microorganisms including bacteria, cyanobacteria, and microalgae, employed for the management of agricultural pests and diseases. biopesticides, as defined by the US Environmental Protection Agency, are substances obtained from natural sources including animals, plants, microorganisms, and specific minerals. Products derived from these biocontrol agents, such as genes or metabolites, can be utilised to mitigate potential crop harm. In comparison to conventional chemical pesticides, the use of biopesticides offers significant advantages due to their eco-friendliness and host specificity (Fig 2.2). Utilising biopesticides can significantly enhance the use and deployment of agro-chemicals to safeguard crop plants from invading and infecting pests (Kumar et al., 2021).

Figure 2.2 *Advantages of Biopesticides over conventional pesticides*



Note. Source:(Ayilara et al., 2023)

2.4.2 Agroecological Ruralist Methods

Agroecology is a dynamic system and has gained a global traction in last decade across the scientific and agricultural forums. Agroecology is a bio-diverse ecosystem which is site-specific, based on indigenous traditional knowledge, capable of self-sustaining through Natural Resource Management which incorporates the ethnoecology aspect too. The concept is so vibrant and multidimensional that different institutions define it differently according to their set of priorities. It is sometimes seen as an interdisciplinary science characterized by the combination of research and education to bring about action and change that fosters sustainability throughout the entire food system. It can also be seen as a collection of approaches that optimize ecological processes and ecosystem services for the creation and execution of strategies. Agroecology, as a social movement, is perceived as a remedy for contemporary issues like climate change and malnutrition, in opposition to the "industrial" model. It aims to reformulate food systems to enhance local relevance, thereby bolstering the economic sustainability of rural regions through short marketing chains and equitable, safe food production. However, at the core the objective and intention of Agroecology is Sustainable Food Systems (SFSs) and Food Security and Nutrition (FSN) and with this context the whole concept could be defined as, "Agroecological approaches favour the use of natural processes, limit the use of purchased inputs, promote closed cycles with minimal negative externalities and stress the importance of local knowledge and participatory processes that develop knowledge and practice through experience, as well as more conventional scientific methods,

and address social inequalities. Agroecological approaches recognize that agrifood systems are coupled social–ecological systems from food production to consumption and involve science, practice and a social movement, as well as their holistic integration, to address FSN" (HLPE, 2019). Based on the seminal literature of Agroecology, there are 13 key principles of Agroecology. These principles have overarching dominant ideas of improving resource efficiency, to strengthen resilience and secure social equity and responsibility. These 13 principles are Recycling, Input reduction, Soil health, Animal health, Biodiversity, Synergy, Economic diversification, Co-creation of knowledge, Social values and diets, Fairness, Connectivity, Land and natural resource governance, and Participation with an aim to cover all aspects of sustainability that is social, ecological and economical, the three-pronged approach discussed earlier. Another beautiful aspect of these principles is that they count in the traditional knowledge which provide margins for local adaptability. The scholars in the field have defended the safeguarding of age-old traditional knowledge with inclusion of new practices which are not industrial in nature. (Curry & Kirwan, 2014) highlight the role of tacit knowledge which is passed on through mutual learning and sharing through personal connections. They emphasise that since the problems faced are endemic and there is possibility of multiple interpretations hence solutions are possible from local perspective. Wezel et al. (2014) has described the entire range of agroecological practices in terms how these can be applied at field level, cropping system level or landscape level thereby being able to enhance the efficiency of either a farm, crop, or entire food system. This reflects the resilience and adaptability of agroecological practices. These not only are scalable in a gradual manner but are cost effective and conservational too. These 13 principles have been guided individually if these can be scalable at Field Input level, Farm Agroecosystem level and Food Systems level. Employing these principles, there are many different systems of farming that are in vogue globally and gaining popularity despite the critical view on food security. Some of these are Organic Farming, Biodynamic Farming, Permaculture, Regenerative Agriculture.

2.4.2.1 Organic Farming

IFOAM-Organics International, based in Germany, is the global authority that sets the path and standards for Organic Farming. Based on the four principles of Health, Ecology, Fairness and Care, Organic Agriculture is defined as, "Organic Agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the

shared environment and promote fair relationships and good quality of life for all involved" (IFOAM-Organics International, 2008). Organic agriculture, originally a niche market, is now becoming a profitable commercial opportunity due to growing consumer awareness and assistance from international organisations. The adoption of the Sustainable Development Goals (SDGs) at the United Nations (UN) level provided a significant boost to the movement. As per the 2021 annual report, Organic Agriculture has expanded its reach from 11 million hectares in 1999 to over 74.9 million hectares globally by 2020. The market value has surged from €15 billion to €120 billion in a span of two decades. A total of 190 countries worldwide have actively participated in Organic activity. India has the highest number of organic producers, with a total of 1,599,010 (IFOAM-Organics International, 2021). The International Federation of Organic Agriculture Movement (IFOAM Organics International) is a prominent global organisation that has played a pioneering role in the development of guidelines for the establishment of standards and certification at the state level in the field of organic agriculture. IFOAM presents four principles to Organic Agriculture:

- **"Principle of Health:** to sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible".
- **"Principle of Ecology:** need to have a system based on living ecological systems and cycles, work with them, emulate them and help sustain them".
- **"Principle of Fairness:** build relationships that ensure fairness with regard to common environment and life opportunities".
- **"Principle of Care:** management in precautionary and responsible manner to protect the health and well-being of current and future generations and environment" (IFOAM Organics International, 2024).

Organic Farming is a type of farming that is centred around the natural environment. It's almost a closed-circuit system with no external intakes and the whole system runs from ingredients within the farm ecosystem. It's by far the most promising, successful and popular farming system providing consistent and rather nutritious yields, improved soil health and no air pollution. With the efforts of IFOAM and other associated organisation, it has found itself a good market worldwide. Farmers require proper Organic Farming Certification from authorised agencies that ensure the requisite standards are adhered to. These third-party certifications have substantial fee structure and an elaborate procedure of review and inspection to be followed with necessity to leave the farms fallow for certain duration to let the effects previously used chemical run dry from the soil. There is another collaborative approach-based

system, Participatory Guarantee Systems (PGS) that began in Brazil and now has adoption in more than 70 countries around the world. Participatory Guarantee Systems (PGS) are local-level quality assurance procedures that certify producers through the active involvement of stakeholders. These systems are built upon a foundation of trust, social networks, and knowledge exchange. PGS offers improved access to organic markets for non-certified and agroecological farmers, together with marginalized and socially vulnerable farming communities. It also involves increased education and awareness among consumers, incentives for short supply chains and local marketing campaigns, and the empowerment of farmers and consumers through ownership of the conformity assessment system. Improved market accessibility allows farmers to increase their earnings, hence enhancing their overall income. The method, based on lasting relationships among members where solidarity and trust are essential values, facilitates the creation of safety networks that mitigate food insecurity and may empower disadvantaged farmers.

2.4.2.2 Biodynamic Agriculture

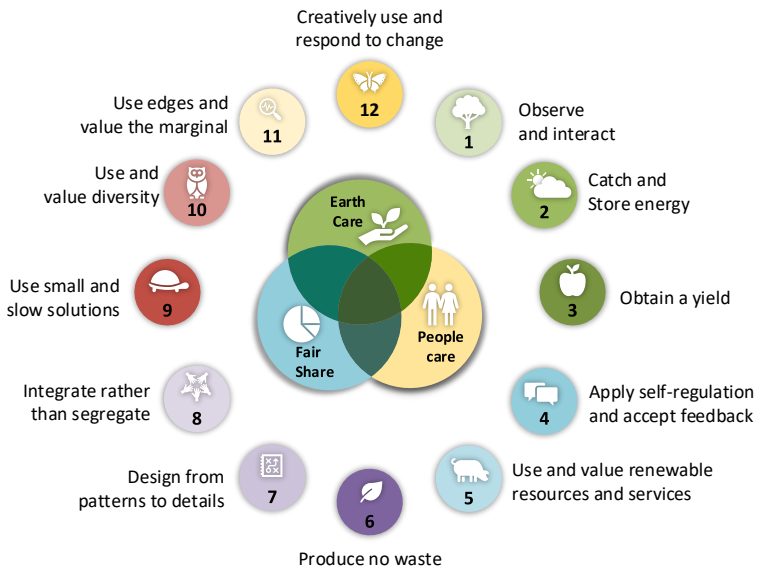
Biodynamic Agriculture can be termed as the forerunner of Organic Agriculture. Biodynamics originated from the contributions of philosopher and scientist Dr. Rudolf Steiner, who introduced a novel approach to uniting scientific knowledge with an acknowledgement of the spiritual aspects of nature in his 1924 lectures to farmers. Since the 1920s, biodynamics has undergone continuous development and evolution via the collaborative efforts of numerous farmers and academics. Biodynamic farming is an innovative agricultural approach that perceives the farm as a unified and self-sustaining natural entity. It integrates ecological, social, and economic sustainability into its methods, synchronising agriculture with the inherent cycles of the planet and universe. The concept of biodynamic farming was created by Rudolf Steiner, a versatile intellectual whose contributions encompass philosophy, education and agriculture. The fundamental tenet of biodynamic farming is understanding the farm as a self-sustaining living entity. Biological variety and animal integration are actively promoted in biodynamic agriculture. A diverse range of flora and fauna coexist in symbiotic relationships, giving rise to a robust and harmonious ecosystem. The concept of soil health in biodynamic gardening acknowledges the earth as a living organism. The incorporation of organic matter serves to augment the soil, therefore improving its structure and fertility. The most unique and distinct feature is utilisation of the Biodynamic Calendar that corresponds to the orbital and celestial cycles. Biodynamic farming is renowned for its distinctive formulations derived from herbs, minerals, and animal manures, employed to improve soil fertility and promote plant

biodiversity. The Biodynamic Demeter Alliance has 44,000 acres of farmland certified as Biodynamic®, 98 certified Biodynamic® enterprises (excluding farming), and an extended network of around 200,000 persons who have collaborative connections with over 30 regional organisations (Biodynamic Association, 2024; Sener, 2023).

2.4.2.3 Permaculture

Permaculture is the deliberate design of productive systems based on the fundamental guiding principles of natural structural and functional patterns. The concept of "permaculture" has been broadened to include two additional designations - permanent culture and permanent agriculture - in recognition of the essential role that social values play in food systems, and the inherent connection between all agricultural practices and cultural values. Permaculture includes design of the landscape, integrated management of water resources, sustainable construction, and the overall vision of creating regenerative environment that is self-maintained (Holmgren, 2002b). Originating from the observations of nature made by Bill Mollison, an ecologist from Australia teaching at the University of Tasmania, and his doctoral student David Holmgren in the 1970s, permaculture has now proliferated globally. Three fundamental tenets and twelve design principles underpin permaculture systems (Fig 2.3).

Figure 2.3 *Tenets and Principles of Permaculture*

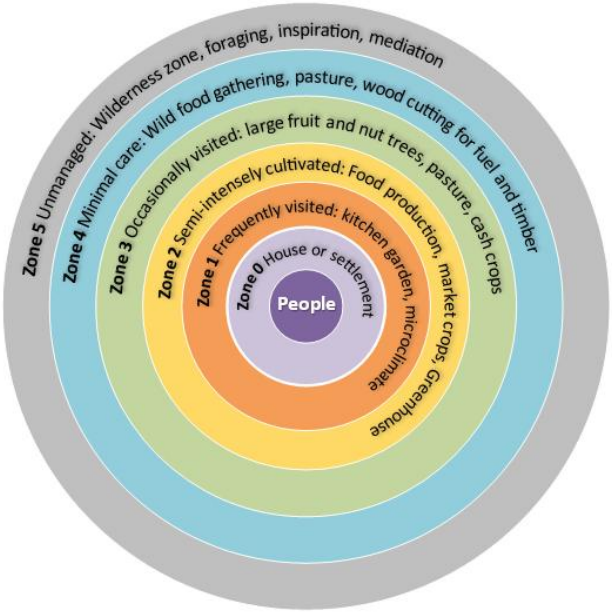


Note. Source: (Holmgren, 2002a)

Permaculture, like agroecological methods of the design and management of agroecosystems, is fundamentally rooted on the use of ecological principles for food production. A number of these principles pertain to the reduction in the usage of energy and

water, the integrating livestock with crop cultivation, the recycling of nutrients, avoiding chemical inputs, the maximisation of biodiversity, and the enhancement of soil health. The principles of permaculture clearly delineate the synergies among its integral components i.e. plants, animals, soil, climate, human labour, and knowledge with the objective of optimizing beneficial engagement and cooperation rather than competition. Fig 2.4 presents the zoning pattern of farm designs in Permaculture style of farming.

Figure 2.4 ***Cultivation Zoning pattern in permaculture***



Note. Source: (Holmgren, 2002a)

2.4.2.4 Regenerative Agriculture

Regenerative Agriculture as a term started getting in 1980s with Rodale Institute that worked on Organic Agriculture extended the scope of Organic Agriculture under this term. There is no specific definition however various organisation and foundations define it as per their needs and approaches. The foremost aspect to be noted is that it is an outcome-based approach of farming that works on the simple principles that foster soil health, mitigates climate change effects, improve the water cycle and nutrients management. As per Regeneration International, the definition is as follows,“ “Regenerative Agriculture” describes farming and grazing practices that, among other benefits, reverse climate change by rebuilding soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle”(Regeneration International, 2023). The central idea behind this approach is to discard all sorts of farming practices which are degenerative and make a shift towards regenerative practices. The suggested set of practices are Aquaculture, Agroecology,

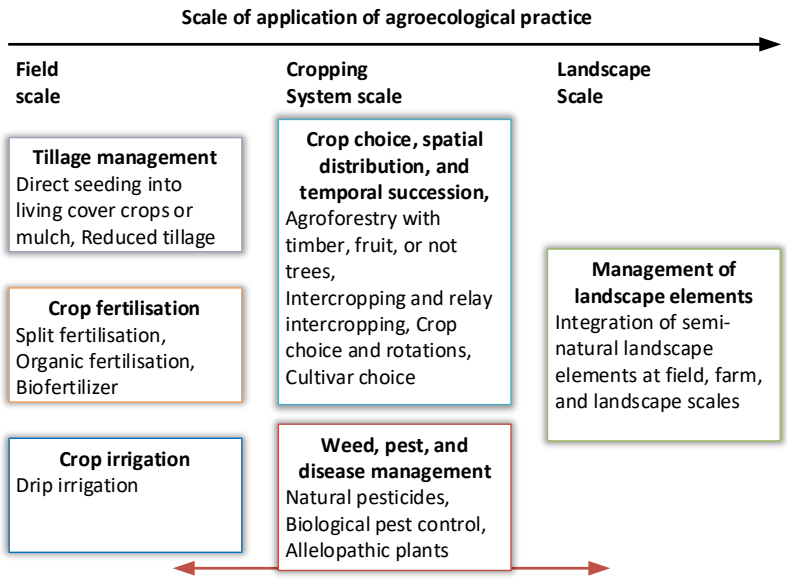
Agroforestry, Biochar, Compost, Holistic planned grazing, No till, Pasture Cropping, Perennial Crops, Silvopasture (Paco, 2023). Regenagri claims that if all the agricultural land on earth was converted to Regenerative System, then it could sequester 37.5Gt of Carbon per annum which is more than the current level of global emissions. The practices reflected by regenagri primarily include, limiting the soil disturbances, keeping soil covered, integrating livestock, keep living roots in the ground (regenagri, 2024). There are some other agencies that even promote the use of modern sciences like Precision Agriculture, that follow the lines of regeneration agriculture. However, for the scope of our study, we will keep the definition given by Regeneration International that follows agroecological approach.

2.5 Agroecological Practices

Agroecological practices enhance the sustainability of agroecosystems by leveraging diverse ecological processes and ecosystem services, including nutrient cycling, biological nitrogen fixation, natural pest regulation, soil and water conservation, biodiversity preservation, and carbon sequestration. Numerous strategies have been utilized to varying degrees throughout different regions globally for many years or even decades, although others were developed more recently and are still being implemented to a limited amount. While these practices can be categorised in many ways, for example, based on which part of the ecosystem these are particularly targeting but for the sake of this study which is aimed at adoption aspect of these practices, a framework of transition to sustainable farming given by Hill and MacRae (1996) is being chosen. They classified the ecological practices based on Efficiency, Substitution and Redesign (ESR). Efficiency Increase denotes strategies that diminish input consumption (e.g., water, pesticides, and fertilizers) while enhancing agricultural yield. Substitution practices pertain to the replacement of an input or method, such as employing natural insecticides in lieu of chemical pesticides. Redesign pertains to the alteration of the entire crop selection or agricultural system (Hill & MacRae, 1996).

Wezel et al. (2014) have further categorised these practices based on how these practices are based on either management at the crop level or at the landscape level. The list of these management practices follows below however there are distinctions based on at what scale (field or farm-system) level are these applied. Integration of diversification in the system is the foremost criteria be it in the form of variety of crops/cultivars, enhancing the biodiversity of soil, using natural methods of pest control e.g. biological control. Fig 2.5 reflects the scale of application of agroecological practices.

Figure 2.5 *Scale of application of agroecological practices.*



Note. Source (Wezel et al., 2014)

2.5.1 Efficiency Increase and Substitution practices

2.5.1.1 Crop choice, spatial distribution, and temporal succession

It refers to the choice of appropriate **crop and cultivar varieties**. Selecting a cultivar with better resistance to abiotic stress, pathogen and disease can yield better efficiency in the yield and with lesser input requirements. Another aspect is choosing the varieties which favour the development of beneficial organisms in the root system. Arbuscular Mycorrhizal Fungi (AMF) in the roots enhance the crop growth and agroecosystem sustainability. Plant Growth Promoting Rhizobacteria (PGPR) is another functional group that assists the plant growth by increasing the nutrients availability to the plant and by controlling the pathogen. In general, the selection of crops or cultivars tends to enhance the effectiveness of cropping systems, decrease the use of pesticides, and can be applied during a substitution phase. Resource use efficiency can be enhanced by planting or sowing a crop with lower demands after a nutrient or water demanding one. Enhanced water use efficiency in water-limited environments, especially with rainfed water, can be achieved by implementing appropriate crop rotations.

2.5.1.2 Crop Fertilization Management

Dividing nitrogen (N) fertilizer application, specifically administering it at the precise moment of plant demand, enhances N consumption efficiency while concurrently mitigating groundwater and surface water contamination from the fertilizer. Utilizing bio-fertilizers is an alternative approach to reduce fertilizer inputs and improve nutrient accessibility.

Microbiological substances are compounds containing living microorganisms that which colonize the rhizosphere or the inside of the plant when their application is done to seeds, plant surfaces, or soil. This colonization fosters growth by augmenting the supply or accessibility of vital nutrients to the organism. Biofertilizers are categorized into three primary groups of microorganisms: arbuscular mycorrhizal fungi (AMF), plant growth-promoting rhizobacteria (PGPR), and nitrogen-fixing rhizobia. The latter was created over a century ago and is frequently utilized with legumes. Organic fertilization is a technique for substituting inorganic fertilizers and improving the efficacy of fertilization processes by augmenting total soil fertility. Nonetheless, it may also lead to a fundamental restructuring or reconfiguration of the system. The application of organic fertilizer enhances soil biological activity and may result in increased soil mineralization.

2.5.1.3 Irrigation practices

Better **irrigation** methods that use less water but effective irrigation are utilised. In horticulture, it could be drip-irrigation that matches crop water demand time and space. For rice cultivation, it could be using Alternate Wet and Dry (AWD) system or Direct Seeding of Rice (DSR) where lesser number of irrigations are required as compared to continuous flooding of filed.

2.5.1.4 Weed, pest and disease management practices

For pest management, natural pesticides are used replacing the synthetic pesticides. These may include botanicals derived from plant-based sources such as seeds, essential oils, pyrethrum from flowers, or other tree components. There are **Biopesticides** which employ the use of bacteria or fungus to control the harmful organism in the plants. Their mode of action is antibiosis, competition, initiating inactivation of pathogens. **Biological Pest Control** is another method where natural enemies are introduced in the farm. It also could employ use of Pheromones to destroy the sexual activities of the target pests.

2.5.2 Redesign Agroecological Practices

2.5.2.1 Crop choice, spatial distribution, and temporal succession

Cover crops are an excellent method to reduce fertilisers use and the risk of water contamination with decreased leaching effect to the ground, in addition to prevention of soil and wind erosion. **Crop rotation** brings about diversification in the system and enhances overall production system in many ways. Leguminous crops are an excellent choice as it fixes the atmospheric nitrogen for the following crop, add nutritional efficiency and reduces use of

fertilisers and prevents leaching of nitrates to the ground. It helps in biodiversity of the farm, provides soil protection. Roots of the successive crops improve the carbon content and soil structure. **Intercropping** is another popular technique. Intercropping is the simultaneous cultivation of two or more crops in the same land without overlapping their cultivation. These species can be arranged in various spatial configurations, and the intensity and nature of their interactions gets varied depending on the chosen arrangement and the different species involved. Social interactions can manifest as either positive (facilitation) or negative (competition).

2.5.2.2 Allelopathic plants

Some plants produce certain chemical compounds that inhibit the growth of pests, weeds and disease, such plants are called as **Alleopathic** plant. For example, Onion work as an allelopathic plant when sown with carrots, as it naturally destroys the carrot fly. The allelopathic plants can be used either as cover crop or in rotation or as intercropping practice too.

2.5.2.3 Tillage Management

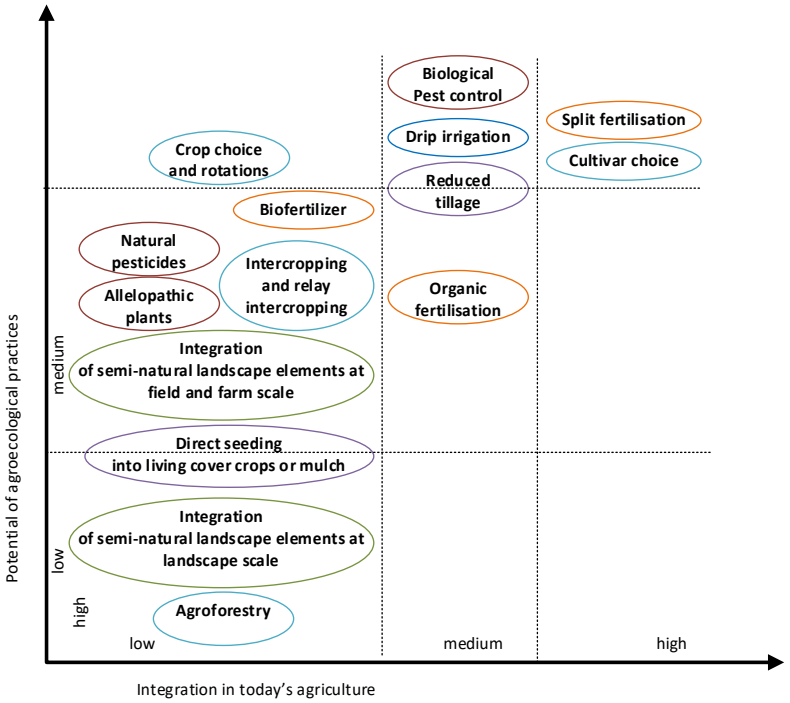
Transition to **no-tillage** (direct seeding) or **reduced tillage** brings about immense benefits to the farm by bringing reduction in energy consumption, soil and wind erosion, soil compaction and creating an enhancement in soil biodiversity and organic content leading to carbon sequestration. In the No-tillage practice, direct seeding is practiced without disturbing the soil in a living crop or in mulch. The reduced tillage refers to causing least soil disturbance, working the depth only up to 5 to 15 cm and doing no soil inversion. It helps in keeping the organic content of the soil intact and assist in enhancing it.

2.5.2.4 Management of Landscape elements

The integration of landscape features that are natural or semi-natural, includes hedges and vegetation strips, within or around fields or on a broader landscape scale, represents a modern agroecological trend. Landscape features can provide essential habitats and overwintering sites, along with resources like alternative prey for beneficial insects or pest predators, thereby reducing reliance on pesticide treatments. Their enhanced natural plant diversity and flowering can positively influence crop pollination by attracting pollinators and offering suitable habitats outside the crop flowering period. Additionally, the in-field and adjacent landscape characteristics offer protection against wind and soil erosion, along with

surface water contamination. Furthermore, they effectively maintain biodiversity in agricultural areas.

Figure 2.6 *Potential Vs Current Integration of agroecological practices*



Note. Source: (Wezel et al., 2014)

2.5.3 Critiquing Agroecology

It is widely accepted that enhancing agricultural production is crucial to satisfy the demands of a swiftly expanding global population, projected to reach 9.7 billion by 2050, unless significant modifications occur in global food systems. A projected doubling of agricultural production at the global level is anticipated from 2012 to 2050. There is ongoing debate regarding the necessity of a substantial enhancement in agricultural productivity, as previous assumptions are being rigorously evaluated. Some estimates suggest that the current food supply could adequately support 9 billion or even 9.75 billion individuals. The claim that agroecology can guarantee global food security may rest on a questionable foundation, evidenced by the ongoing issues of food insecurity and malnutrition in the nations like Brazil and South-Africa which are exporting food. Approximately 33% of food intended for human consumption is lost or wasted, and various forms of malnutrition are prevalent in many countries. Approximately 820 million individuals worldwide continue to experience hunger, while roughly 2 billion are classified as overweight or obese. Additionally, an estimated 2 billion people are affected by malnutrition due to deficiencies in essential micronutrients such

as iron, iodine, vitamin A, folate, and zinc. An analysis by the FAO indicated that a 50 percent increase in gross agricultural output would result in significant undernourishment by 2050 if drastic changes are not incorporated. A 40 percent increase in agricultural production, coupled with alternative scenarios focused on sustainability—defined by balanced diets, sustainable patterns of production and consumption, and just distribution of food and income—can significantly mitigate undernourishment and enhance nutritional security, in alignment with agroecological principles. Therefore, merely increasing output may not suffice to attain Food Security Network (FSN) across its four dimensions: availability, access, utilization, and stability. Recent evidence indicates that hunger and malnutrition are not solely the result of food production, but are significantly influenced by disparities in entitlements, which result in unequal access to food, natural resources, inputs, markets, and services. Agroecological interventions are proposed as effective strategies for achieving Food Security Network (FSN) objectives, as they extend beyond mere productivity to tackle social discriminations and power inequalities, particularly regarding gender and ethnic minorities (HLPE, 2019).

2.6 Sustainable Agricultural Practices for Rice Cultivation

2.6.1 The Sustainable Rice Platform (SRP)

SRP is an international consortium including more than 100 entities from the public, commercial, academic, civil sector, and financial domain. SRP, a non-profit member association, seeks to revolutionize the global rice industry by enhancing smallholder livelihoods, mitigating the social, environmental, and climatic impacts of rice cultivation, and providing sustainably produced rice in the international market. In 2011, IRRI, United Nations Environment Programme (UNEP), and collaborators from the scientific and corporate sectors established SRP. The objective is to advocate for sustainable and socially responsible rice cultivation methods that enhance productivity for both commercial and subsistence farmers. In 2015, SRP introduced the inaugural voluntary Standard and Performance Indicators for sustainable rice cultivation (SRC), targeting smallholders and grounded in scientifically validated best practices. The aim was to enable the measurement and unbiased assessment of the sustainability of any rice system. These instruments collectively define the process of sustainable rice cultivation. The Sustainable Rice Program (SRP) equips policymakers and the supply chain with an established array of instruments to facilitate the extensive adoption of sustainable best practices in the rice sector worldwide. The three documents, specifically the SRP Standard for Sustainable Rice Cultivation, the SRP Performance Indicators for Sustainable Rice Cultivation, and the SRP Assurance Scheme, are intricately linked.

2.6.1.1 SRP Standard

To substantiate claims about sustainability performance in rice supply chains, a normative framework for sustainable rice cultivation is provided by the SRP Standard. The significance of maintaining the Standard as a clear and comprehensive tool for practitioners to encourage the widespread adoption of climate-smart sustainable best practices among rice smallholders has been underlined by stakeholders throughout the creation and revision process. In January 2019, SRP published the SRP Standard (Version 2.0), which consists of 41 standards organised on eight main themes. The current 2.2 version revised in 2023 is reflected in Fig. 2.7.

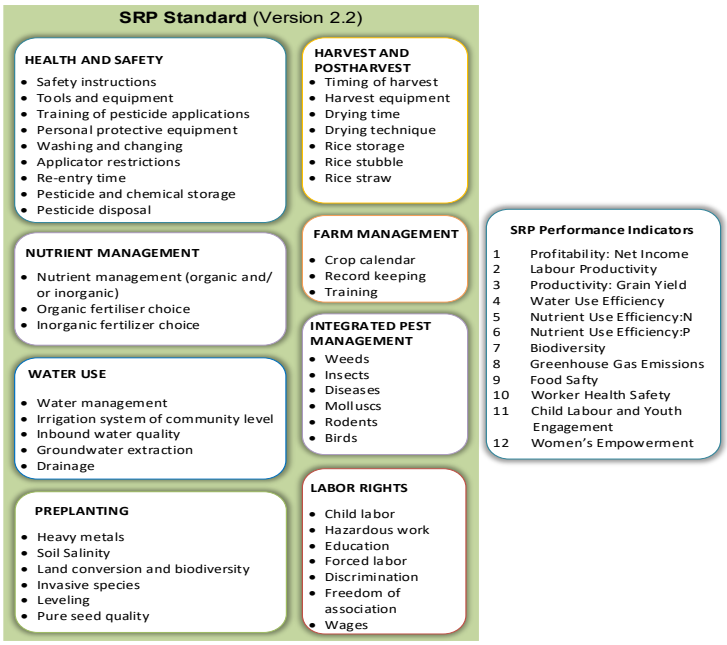
2.6.1.2 SRP Performance Indicators

The SRP Performance Indicators for cultivating rice sustainably enable the quantitative evaluation and quantification of the sustainability effects resulting from the implementation of suggested operations. The Performance Indicators facilitate the compilation of yardstick data and the communication of results from the filed in a uniform manner by implementation partners and academics, utilising a collection of 12 shared indicators. Version 1.0 of the SRP Performance Indicators was published in April 2015 and has since undergone various revision. The current version in place is 2.2 finalised in August 2023. Fig 2.7 presents the 12 shared indicators.

2.6.1.3 SRP Assurance Scheme

The SRP Assurance Scheme allows participants in the value chain to validate their compliance with the SRP Standard and evaluate their impact through the SRP Performance Indicators. The Scheme offers three assurance levels to support various production modes and includes farmer registration in a central SRP database, self-assessments, and verification of farmer groups via internal control programs. External verification and recognized certification provide supplementary alternatives. SRP has given gold standards in terms of sustainability of rice cultivation by choosing 8 major themes that include each aspect of rice cultivation. The themes range include from Farm management, Pre-planting, Water use, Nutrient Management (NM), Integrated Pest Management (IPM), Harvest and Post Harvest, Health and Safety, Labour rights. The scope of sustainable agricultural practices generally is restricted till harvest and probably not extended to logistics aspects beyond the post-harvest storage.

Figure 2.7 *SRP Standard Version 2.2 and List of Indicators*



Note. Source:(SRP, 2023)

2.6.2 Evidence of Efficacy of various SAP in Rice Cultivation

Researchers have examined various sustainable approaches in rice cultivation, yielding promising results regarding their effectiveness. Ravisankar et al. conducted an experimental comparative analysis of various sustainable production systems, including Organic Farming (OF), Conservation Agriculture (CA), Integrated Farming Systems (IFS), Natural Farming (NF), Integrated Nutrient Management (INM), and Bio-dynamic Farming (BF), all of which are categorized under sustainable agricultural approaches. The evidence indicates seasonal specificity in the performance of these production systems and highlights the necessity for an integrated approach in the upcoming Rabi season to achieve optimal yield. A long-term experiment indicates that substituting up to 50% is feasible and necessary for maintaining cereal-based yields. Additionally, it is essential to supplement organic manure at least once during a cropping cycle. Integrated Farming, when implemented with adequate knowledge, can effectively integrate various components and incorporate integrated crop management practices, including conservation and precision farming, as a viable alternative system (Ravisankar et al., 2020). Some of the useful approaches that have been experimented with and been found successful are Eco-efficiency with SAP, Use of Land Leveller, Conservation Agriculture, Short duration of rice cultivar, Alternate Irrigation Techniques, Precision Agriculture with VR Nitrogen Fertilization, and Organic Rice Cultivation.

2.6.2.1 Harnessing Eco-efficiency with SAP

Eco-efficiency, defined as the economic profitability per unit of environmental impact, exhibits considerable variation among farms producing the same crop. Understanding the key factors that lead to differences in eco-efficiency may help identify effective strategies for improving the environmental performance of products. Saber et al. (2021) analysed variations in eco-efficiency among 200 paddy fields in Iran. The study employed multiple linear regression modelling to assess the impacts of various farming systems (conventional, limited input, organic) and yield, while considering potential interactions, on eco-efficiency and human health. The findings indicate a positive correlation between the eco-efficiency of organic farming systems and yield. Moreover, this eco-efficiency consistently outperforms traditional and resource-limited agricultural systems. The findings indicate a positive correlation between the eco-efficiency of conventional and limited input systems and yield, particularly regarding their effects on terrestrial ecosystems. The results of our research demonstrate that organic paddy farms show greater economic profitability and lower environmental impacts per unit of rice produced when compared to the other two production systems (Saber et al., 2021).

2.6.2.2 Use of Land leveller

Land levelling during preparation to address variable slopes enhances water utilization and contributes to improved yields (Quirós-Vargas et al., 2020). Laser levelling has significantly improved rice cultivation by bringing about a reduction of 47-69 hours of irrigation time per hectare per season in addition to an increase in yield by approximately 7% compared to traditional field levelling methods (Aryal et al., 2015). Laser-controlled land levelling (LLL) improves the spatial and temporal management of rice production, leading to enhanced water and crop management. This study established sustainable performance metrics indicating that LLL is an effective technology for rice cultivation. The assessment was conducted in Cambodia, the Philippines, Thailand, Vietnam, and India. The benefits of LLL include the preservation of land, water, and agricultural resources, improved yield, and minimized postharvest losses, resulting in energy savings of 3 to 7 GJ per hectare and a reduction in emissions by 1151–1486 kg CO_2 equivalent per hectare. The LLL application can generate a net return of USD 52–84 per hectare each rice production season in the studied countries. The results demonstrate that LLL is an effective method that markedly improves sustainable rice production (Nguyen-Van-Hung et al., 2022).

2.6.2.3 Conservation Agriculture (CA)

CA denotes a system that employs no tilling, also known as Zero Till (ZT). In rice cultivation, it denotes a system similar to direct sowing of rice. Jat et al. (2019) demonstrated through experiments that the adoption of Conservation Agriculture (CA) methods in the Rice-Wheat (RW) cropping pattern can achieve sustainability while enhancing crop yield, water productivity, profitability, and soil quality. Management based in California utilizing zero till direct seeded rice-wheat-mungbean achieved a system yield that was 36% higher than that of the Conventional Tillage (CT) rice-wheat system. The California-based rice-wheat system and the rice-wheat-mungbean system demonstrated a reduction of approximately 35% in irrigation water usage compared to the conventional rice-wheat system. The total water productivity (WPI+R) increased by 67% with the conservation agriculture-based rice-wheat-mung bean system compared to the conventional system. The CA-based rice-wheat-mung-bean system demonstrated a 42% higher net return compared to the conventional system. The integration of mung beans in the basmati rice-wheat system accounted for a 29% share of the system's net returns across the treatments. The implementation of a CA-based management system resulted in approximately 40% and 150% improvements in soil chemical and biological properties, respectively (Jat et al., 2019).

2.6.2.4 Impact of Short Duration Rice Cultivar

The implementation of water-efficient irrigation methods and enhanced rice varieties is crucial for reducing greenhouse gas emissions and tackling water scarcity, all while sustaining high agricultural productivity. Kaur et al. (2024)performed a field experiment involving two rice cultivars (long-duration and short-duration) and three irrigation regimes: continuous flooding (CF), irrigation two days after infiltration of ponded water (2DAIPW), and irrigation three days after infiltration of ponded water (3DAIPW) during the years 2019 and 2020. The findings indicated that, irrespective of the irrigation regime, the short-duration cultivar conserved irrigation water (17%), decreased CH4 (12%), N2O (11%), and net GHG emissions (12%), while exhibiting a lower grain yield compared to the long-duration cultivar. Regardless of cultivars, the 2DAIPW regime resulted in a 21% reduction in irrigation water usage, a 24% decrease in CH4 emissions, and a 49% increase in N2O emissions compared to conventional farming (CF). The 3DAIPW regime resulted in a 31% reduction in irrigation water usage, a 39% decrease in CH4 emissions, and a 29% increase in N2O emissions compared to the CF regime. The findings indicate that cultivating short-duration rice cultivars alongside the

3DAIPW irrigation regime may effectively reduce GHG emissions and conserve irrigation water (Kaur et al., 2024).

Brar et al. (2021) conducted an experiment comparing the short-duration variety PR126 with the long-duration varieties PR115 and PR124, revealing that PR126 produced 23.3% more grain. PR 124, irrigated at 2 DAIPW in Puddled Transplanted Rice (PTR), utilized the highest volume of irrigation water, totalling 130.3 cm. In comparison, PR 126, when direct seeded and irrigated at 4 DAIPW, resulted in a savings of 42.8 cm of irrigation water and demonstrated increases of 43%, 30.2%, 6.6%, and 6.3% in apparent crop water productivity, total crop water productivity, energy use efficiency, and energy productivity, respectively, while maintaining statistically similar grain yield and benefit-to-cost ratio (BRAR et al., 2021).

Singla et al. (2022)developed a composite groundwater sustainability index (GSI) utilizing data from 1998 to 2019, employing the analytical hierarchy process (AHP) with a Saaty scale. The favourable criteria identified were precipitation, canal-irrigated land, and non-paddy regions. Rice and Basmati acreages, density of tubewells, and sugarcane area were regarded as adverse indicators. Multiple management strategies were employed to improve the Graded Stability Index (GSI). This encompassed the transformation of paddy fields into non-paddy crops, the substitution of long-duration paddy types with short-duration ones, and the augmentation of canal-irrigated areas (Singla et al., 2024).

2.6.2.5 Impact of Alternate Wetting and Drying Method of Irrigation

Due to the time and resource limitations of performing field tests across extensive areas, Tian et al., (2021) executed a computer modelling simulation at 24 representative locations in China to assess the regional impacts of various irrigation methods. The irrigation strategies assessed comprised Conventional Continuous Flooding (CF), Midseason Drainage (MD), and Alternate Wetting and Drying (AWD). Simulation results demonstrate that water-saving irrigation methods can significantly reduce CH4 emissions from paddy rice fields, while preserving or perhaps lowering expected rice yields in comparison to traditional agricultural practices. AWD significantly reduced irrigation water usage and CH4 emissions. In comparison to CF, CH4 emissions under AWD were 60% to 71% lower at locations in Northeast China and 34% to 65% lower at sites in South China. Irrigation water use in AWD was reduced by 23% to 34% at sites in northeast China and by 18% to 50% at sites in south China, relative to CF. The study's findings suggest that enacting regulations to enhance AWD in paddy rice

cultivation can yield advantageous trade-offs among food production, water usage, and greenhouse gas emissions (Tian et al., 2021).

Win et al., (2021) investigated the effects of manure application, rice varieties, and water management on greenhouse gas (GHG) emissions from paddy rice soil. This study aimed to assess the effects of different manure amendments and rice varieties on GHG emissions and to determine the optimal manure application rate that maximizes rice yield while minimizing GHG emissions in paddy cultivation by employing alternate wetting and drying irrigation. This study investigated the impacts of two different organic fertilizers (compost and cow dung) and a control group (no fertilizer), alongside two rice cultivars: Manawthukha (135 days) and IR-50 (115 days). The findings revealed that the total CH_4 emissions from Manawthukha with1.084 g CH_4 per of soil significantly exceeded those from IR-50 with 0.683 g CH_4 per kg of soil ($P<0.0046$), correlating with an increase in grain yield ($P<0.0164$) attributed to the prolonged growth duration of the former. In comparison, IR-50 exhibited greater cumulative nitrous oxide emissions (2.644 mg N_2O per kg of soil) than Manawthukha 2.585 mg N_2O per kg of soil. The influence of water management and organic fertilizers on greenhouse gas emissions was examined using second pot experiments in Madaya township encompassing both the dry and wet seasons. Two water management approaches, continuous flooding (CF) and alternate wetting and drying (AWD), were assessed alongside four rates of cow dung manure: 0, 2.5, 5 and 7 tonne per hectare respectively . No significant effect was noted on grain yield or greenhouse gas emissions in this experiment across the different rates of cow dung manure. The implementation of AWD irrigation in manure treatments led to a significant 70% and 66% drop in CH_4 emissions in the dry and wet season respectively (Win et al., 2021).

2.6.2.6 Precision Agriculture and Variable Rate(VR) Nitrogen Fertilization

Precision agriculture is widely acknowledged as an effective measure to mitigate the environmental impacts of agricultural activities. This is due to its ability to utilize multi-source information in decision support systems, hence improving the efficacy of farm management. Variable rate (VR) nitrogen fertilization is a significant agronomic practice and an efficient approach to provide quantitative, globally distributed assessments for VR. N fertilization entails integrating remote sensing data with a limited number of intelligent scouting-based ground assessments to generate nitrogen nutrition index (NNI) maps. A novel application, PocketNNI, was developed for field NNI estimations, including remote sensing data. The environmental impacts were evaluated utilizing the Life Cycle Assessment technique, focusing on a case study of rice agriculture in northern Italy, and a comparison was made with the

uniform application of nitrogen. The findings demonstrated that VR fertilization resulted in a reduction of environmental impact between 11.0% and 13.6% when compared to uniform nitrogen application. The effect on climate change has diminished from 937.3 to 832.7 kilograms of CO_2 equivalent per metric tonne of paddy rice. The primary environmental benefits, primarily derived from an improved ratio of grain yield to nitrogen fertilizers, were realized in energy conservation during fertilizer production and decreases in nitrogen compound emissions. While further verification is necessary, these first findings are promising and provide a quantifiable indicator of the environmental benefits achievable through the use of digital technologies in nitrogen fertilization (Bacenetti et al., 2020).

2.6.2.7 Organic Rice Cultivation

The organic rice farming method is a sustainable approach to cultivating rice that excludes the use of chemical inputs and has the capacity to mitigate environmental effects. Organic farming is seen as a highly promising approach to mitigate the environmental impact associated with agricultural activities. Agricultural production of rice has a significant ecological footprint, and transitioning from traditional to organic rice farming could therefore have a potentially substantial effect. However, it is a gradual process for organic agricultural systems to achieve a new state of equilibrium following their conversion to organic practices. Hence, it is crucial to analyse if the disparity between organic and conventional products will diminish or broaden as time progresses, as the environmental characteristics of the former will undergo changes.

A research in Subtropical China assessed the environmental impacts of organic rice cultivation at 5 (OR5), 10 (OR10), and 15 (OR15) years post-conversion, comparing them with conventional rice (CR). The environmental impact of rice production systems was assessed through the life cycle assessment (LCA) methodology, utilizing nine environmental impact categories namely Non-renewable Energy and Water Depletion, (NED & WD), Global Warming, Acidification, Eutrophication Potential (GWP, AP, EP), Aquatic, Human and Soil Toxicity Potential (ATP, HTP and STP) and Land Occupation (LO). The findings reveal that the commercial production of rice exhibited the highest complete environmental effect index (9.65), exceeding that of organic systems by more than tenfold. The data revealed a decrease in the environmental impact indices of organic rice systems over time, decreasing from 0.80 to 0.72 to 0.68 respectively for OR5, OR10 and OR15. Hence increasing the disparity with conventional rice systems over time. Conventional rice exhibited greater impacts from NED, WD, AP, EP, ATP, and HTP, while organic rice demonstrated elevated levels of LO, GWP, and

STP variables. The principal environmental indicator for conventional rice was ATP, but for organic rice it was WD. This study's findings indicate that organic rice systems are promising as viable sustainable farming methods compared to conventional practices (X. He et al., 2018).

In summary, we can confidently conclude that numerous sustainable practices can be included into rice growing methods to mitigate environmental impact while preserving economic and social considerations. All the practices outlined below are within the scope of technoeconomic and agroecological approaches. The spectrum of technoeconomic methods is extensive, although Punjab has not adequately implemented them. Despite the intriguing potential, concerns arise over its expense, technical complexity, and dependence on technocrats functioning as private entities. Concerning agroecological activities, these methods are relatively simpler and more accessible to implement. Numerous of these approaches necessitate minimal training or financial expenditure. Therefore, agroecological techniques provide broader potential.

2.7 Sustainable Agricultural Practices in Punjab

2.7.1 Suggestions

The environmental issue in Punjab is looming large for quite some time now. There is plethora of solutions which have been suggested since the turn of the century. Here are some of these listed below. Dr Hira has worked exclusively on water scarcity in Punjab and connects this to food security. The large-scale cultivation of rice and early transplantation in June, coupled with a consistent supply of electric power for irrigation, has been identified as a contributing factor to the declining groundwater levels in Punjab. He proposed that postponing the transplantation of rice from June 10 to June 30 could mitigate the declining trend in water levels. He further proposed to shift the input subsidy to output subsidy in the form increased procurement price (Hira, 2009).

Rice is not the immediate output from agricultural fields. The process involves a series of sequential steps beginning with harvesting. Paddy must undergo storage, aging, husking, packing, and branding prior to being marketable. Therefore, it is essential to focus on this aspect to ensure the viability of sustainable rice farming. Farmers in India frequently lack accessible storage and processing facilities. The current rice supply chain structure in India operates within a traditional framework that includes numerous intermediaries in both supply and distribution processes. The existing supply chain structure of rice in India requires significant improvement in efficiency and necessitates reforms. Sharma and Rai have noted that the

conventional supply chain structure encounters challenges in inventory management, characterized by either overstocking, which leads to obsolescence and heightened supply chain costs, or stockouts of demanded varieties, resulting in lost sales. The rice supply chain in India is encountering issues pertaining to procurement, distribution, collaboration among intermediaries, and the logistics system, necessitating a redesign. An effective framework is essential for establishing mechanisms for inventory tracking and visibility, procurement and sourcing of paddy, operations of rice processing companies, distribution systems, retail strategies, and logistics systems, thereby enhancing the efficiency and global competitiveness of the Indian supply chain. India, as the second largest producer and a major consumer of rice, possesses a significant presence in the global agri-food market; however, it does not contribute to the global food business to the extent warranted (V. Sharma et al., 2013). No specific provisions exist for farmers employing sustainable cultivation methods. They primarily operate independently, selling within their immediate network of family, friends, and small groups of NGO networks or retailers. A proper system is urgently needed to effectively incentivize sustainable cultivation practices.

N Sharma & Singh (2013) reviewed the Punjab Contract Farming Act 2013, which aimed primarily at promoting diversification in agriculture. It has been proposed that the government should enhance infrastructure, marketing, and pricing structures while identifying region-specific crops for diversification (N. Sharma & Singh, 2013).

Abbott et al., (2015) hold intensive agriculture responsible and an indiscriminate use of tube-wells and submersible pumps for irrigation in the state for declining ground water and insist on judicious planning for farming and usage of water. The team also suggests a recourse in sustainable agriculture with a farm management approach in place of crop management (Abbott et al., 2015)

Indian Council for Research on International Economic Relations (ICRIER) did research in 2017 on ways to get agriculture in Punjab back on high growth path. Their findings summarise as need for diversification from monocropping cycle, Shift from rice to maize and other suitable crops, promoting processing industry and most importantly promotion of sustainable agriculture by shifting to Direct bank Transfer scheme of subsidy instead of free water and power and increasing the usage of micro-irrigation techniques and solar power pumps (Gulati et al., 2017).

Despite the proposed solutions, farmers have demonstrated a persistent commitment to rice cultivation. The current data indicates a sustained expansion in rice cultivation alongside a reduction in the area dedicated to cotton and pulses. Taneja et al. conducted a study on the sustainability of resource use in Punjab, developing a composite index for land, water, and air from 1970 to 2015, which illustrates the extent of damage incurred over four decades. The initial two decades exhibited a low status, while the subsequent two decades are characterized by a phase of over-exploitation. There is significant variability among districts. Forty percent of all districts are identified as highly impacted and require immediate attention. The recommendations advocate for the development and implementation of sustainable agricultural technologies that facilitate resource conservation (Taneja et al., 2018)

2.7.2 The Factors of SAP adoption

2.7.2.1 The Determinants

It would be prudent to begin with analysing the factors of adoption of Green Revolution (GR). GR is a major case study in terms of its success with a huge adoption across the states wherever it was launched. John and Babu (2021) state that there existed a profound scarcity of both food crops and commercial crops. Around time, Norman Borlaug, an agronomist, made a substantial contribution to the green revolution, which had far-reaching consequences worldwide. He introduced novel seeds for field cultivation, characterised by their robustness, resistance to diseases, rapid growth rate, and excellent sensitivity to fertilisers. Dr. M. S. Swaminathan, a geneticist, spearheaded the implementation of Green Revolution in India. Green Revolution substantially boosted the food production in the country. To alleviate poverty and malnutrition, the primary aim of Green Revolution was to develop high-yielding varieties (HYVs) of grains. Undoubtedly, the green revolution had the capacity to alleviate hunger and malnutrition in the immediate period as well. The green revolution resulted in exceptional crop productivity by implementing various adapted techniques, that included, expanding the agricultural area, practicing double-cropping by planting two crops each year, using high-yielding variety (HYV) seeds, drastically raising the usage of inorganic fertilisers and pesticides, augmenting irrigation facilities, and improving farm implements, methods of crop protection, and modifications in farming tools (John & Babu, 2021).

Pingali (2012) asserts that a significant factor contributing to the success was the convergence of substantial investments in crop research, infrastructure, and market growth, together with suitable governmental support implemented during the initial Green Revolution (GR). The initial GR period is defined as 1966–1985, whereas the post-GR period encompasses

the subsequent two decades. Significant government funding in crop genetic enhancement followed the scientific progress achieved in industrialised nations for the primary staple crops, rice, maize, and wheat and modified such advancements to suit the circumstances of emerging countries. The strategy deployed during Green Revolution for crop productivity development was specifically founded on the assumption that, with suitable institutional structures, it would be possible to capture technology spillovers across political and agroclimatic boundaries. The environmental impacts were not inherent to the GR technique itself, but rather stemmed from the policy context that encouraged imprudent and excessive use of resources and extension of agriculture into regions unable to support high levels of intensification. The implementation of output price protection and input subsidies, particularly for fertiliser, insecticide, and irrigation water, created imbalanced motivations at the farm level to adopt methods that would improve the efficiency of input use and hence, help to maintain the agricultural resource capacity. This can be true for Punjab in India which never had rice as native crop. A lack of attention towards canal water for irrigation and over support on tubewells led to depletion of ground water table. The author further insists that upon the correction of legislative incentives, farmers promptly adapted their behaviour and embraced more sustainable techniques. One notable consequence of eliminating pesticide subsidies in Indonesia during the early 1990s was a significant decrease in the application of insecticides. An example can be given in Punjab to the same effect. It's about delayed transplantation of rice through an act Punjab Preservation of Subsoil Water Act 2009. The rice transplantation which used to take place late May or early June has been shifted to 15 June and then onwards in phased manner in various districts of Punjab.

The same view is corroborated by Eliazer Nelson et al (2019). The agricultural productivity achieved during the Green Revolution in India can be credited to several key actors, including the Indian government, international agricultural research institutions such as IRRI and CIMMYT, multilateral and bilateral donor agencies like Ford Foundation, Rockefeller Foundation, and USAID. The Ministry of Food and Agriculture and the Indian Council of Agricultural Research (ICAR) carefully and methodically carried out the efficient transfer and dissemination of innovative technology (Eliazer Nelson et al., 2019).

It is essential to recognize that at the time of GR, the entire implementing machinery and adopters resembled a blank slate. No concerns were present; only potential gains were evident, promising increased production and profitability, alongside the benefit of a food security pool. Both local and international bodies were experiencing the effects of newfound scientific knowledge and its practical benefits. GR appeared to be a comprehensive solution

for all issues related to agriculture. However, the current scenario has changed. The aftermath of GR has resulted in a regional divide that requires prompt, focused, and careful attention.

The research studies have tried to explain the factors that determine the adoption of Sustainable Agricultural Practices in the regional settings. In a systematic study aimed at evaluating the framework of perceived awareness regarding sustainable farming practices among the paddy farmers across the state of Malaysia, Adnan, Nordin et al.(2017) did a structural equation analysis of responses from 132 farmers. The study revealed that technology-assisted communication is defined as a moderator of the connections between attitude, subjective norm, perceived behavioural action control, and intention. Furthermore, the results of this study connected noneconomic benefits to profitability with the characteristic of relative advantage And stresses the need to account for farmers perspective to bring about the necessary change (Adnan, Nordin, et al., 2017). The same authors further delved into examination of decision-making process of Malaysian paddy farmers in adopting Green Farm technologies (GFT) by incorporating a conceptual framework based on the extension of three famous behaviour theories namely Theory of Planned Behaviour (TPB), Theory of Reasoned Action (TRA), and Expected Utility Theory (EUT). This chosen framework confirms the adoption decisions through a self-motivated process, that accommodates a combination of multiple variable present in the chosen theories. It postulates that external factors like Socio-economic, Agroecological, Institutional and Informational contribute to creating the belief factors of Theory of Planned Behaviour which affirm the perception and attitude of the farmer towards adoption (Adnan, Md Nordin, et al., 2017).

Dung et al. (2018) insists that the use of sustainable agricultural technology by farmers enhances their revenue, supplies high-quality agricultural products to society, and maintains the ecological limitations of agriculture. This study utilizes the binary logit model to investigate the factors affecting the adoption of sustainable agricultural technologies by rice farmers in the Mekong Delta, Vietnam. The results demonstrate that adoption Behaviour is affected by various factors, specifically: i) human capital; ii) farm size; iii) social capital; iv) extension opportunities; and v) market accessibility. Furthermore, the study suggests that governments should make policies that consider these elements as basics for promotion of adoption.

Mishra et al. (2018) examined the influence of various farm or farmer characteristics on the extent of adoption of sustainable farming practices amongst the farmers in Kentucky, USA. The study revealed significant disparities in the adoption of sustainable farming practices

across Kentucky's agricultural areas. Farmers involved in row crop cultivation, equipped with irrigation systems, and advocating for crop diversification were significantly more predisposed than their peers to adopt more sustainable agricultural practices. The presence of a college degree and participation in the Tobacco Buyout Program significantly influenced the adoption. A deficiency in adequate understanding of sustainable farming and a lack of familiarity with technology are positively and significantly correlated with reduced implementation of sustainable agricultural practices.

Syan et al., (2019)conducted an empirical study to assess farmers' intentions to embrace sustainable agricultural practices from various regions of Punjab state, India. The research examined six dimensions identified in the literature: perceived usefulness, self-efficacy, extension services, social capital, conducive conditions, and compatibility. The study findings further confirmed that perceived usefulness, self-efficacy, and extension services significantly impact the decision to adopt sustainable agricultural techniques. Nevertheless, social capital, favourable environment, and compatibility do not substantially influence these judgments.

In another study Adnan et al.(2020) revealed that the perception of sustainable farming among Malaysian paddy farmers is influenced by several factors, including communication channels, environmental conditions, socio-psychological aspects, socioeconomic aspects, innovation attributes, education level, age, participation in farming events, and productive use of knowledge. These factors collectively contribute to the adoption (Adnan et al., 2020).

Pineiro et al.(2020) did an assessment to understand how the incentives offered to farmers promote the SAP adoption and, ultimately, the degree to which they provide measurable outcomes. This scoping analysis examines data from around 18,000 publications. The results demonstrate that, irrespective of the incentive type, programs linked to immediate economic advantages had a higher acceptance rate relative to those aimed at providing only ecological services. Ultimately, a primary motivation for farmers to adopt sustainable practices is the anticipated benefits for their farms, the environment, or both. This scoping research highlights the importance of technical support and extension services in promoting sustainable practices. The efficacy of policy instruments is improved with the incorporation of characteristics concerning the target population. (Piñeiro et al., 2020).

Jha & Gupta (2021) sought to present the human dimension of farmers' adaptation choices in rural parts of India. The study analysed farmers' perspectives on climate change and the socio-economic aspects affecting farm household decisions and adaption strategies. The

researched covered a comprehensive assessment of 700 farmers and agricultural households throughout seven districts in the northern region of Bihar, India. The survey indicates that 80 percent of the surveyed farmers possessed the capability to perceive and predict climate changes, and deliberately opted to adapt to them. Several socio-economic characteristics, such as age, gender, household size, education level, off-farm income, and farm size, significantly impact the adaptation decisions of farmers. This study emphasised the need to identify essential household features for incorporation into future policy development and implementation to enhance planning and adaptation (Jha & Gupta, 2021) .

Foguesatto et al.(2020) examined 63 papers as part of their systematic literature review on factors of adoption. The taxonomy created by them included six categories "farmer and farm household characteristics," "farm general characteristics," "farm financial/management characteristics," "exogenous factors," "attributes of SAP," and "psychological factors", reflected in table 2.3. Th study particularly stresses that most of the evaluated publications neglected to integrate psychological factors into their models of farmers' adoption decisions. Moreover, the ones that included psychological dimensions, the constructs, specifically farmers' perception, were insufficiently evaluated. The study recommends the need to focus on developing a comprehensive methodology that considers the socioeconomic characteristics and psychological factors of farmers to enhance understanding of SAP adoption (Foguesatto et al., 2020).

Table 2.3 ***Factors for adoption of SAP***

Category	Variables
Farmer and farm household characteristics	Age, education level, caste, ethnicity, experience, family size, gender, health, household's member economically inactive, lack of skills.
Farm general characteristics	Distance to agricultural extension office, Distance to district centre, Distance to main market, Distance to the farm plot from residence, Land slope, Land slope x Distance, Rented plot x Soil quality, Position of plot in watershed, Soil colour, Soil depth, Soil erosion severity, Soil fertility, Soil type, Soil quality x Distance
Farm financial/management characteristic	Access to credit, crop cultivated, district, do not pay for irrigation water, farm income, farm size, food sufficiency, hired labour, household has agricultural implements, household has agricultural machinery, household member has salaried employment, irrigation, land use, mixed livestock-crop system, number of cash crops, number of livestock owned, number of traders that farmer knows,

Category	Variables
	off-farm income, pay for irrigation water, practice organic farming, pests and diseases, plot size, remittance, staff training, subsidies, subsistence farming, tenure, timely availability of fertilizer, total asset value of farm equipment and household furniture.
Exogenous factors	Annual precipitation, collective action, climate change, crop price, drought stress, extension service, evapotranspiration, frost, hail rain, household has relative in leadership position, information (training/knowledge), mass media exposure, neighbouring plots have soil land management measures, number of relative that farmer has inside the village, number of village development committees in the community, participation in farmers' group association/cooperative, peer compliance, rainfall index, rely on government, temperature variation.
Attributes of SAP	Compatibility, complexity, relative advantage.
Psychological factors	Agro-products quality concerns, general farmer concerns, habit, satisfaction on farming labour, recreational values, risk aversion.

Note. Source: (Foguesatto et al., 2020)

2.7.2.2 The Theoretical Underpinning and barriers

Anibaldi et al.,(2021) conducted a literature review on use of theory in research pertaining to adoption of SAP. The authors have specifically included papers that used practical application of theory and presented list of barriers that prevented adoption. A closer examination of barriers listed corroborates to the determinants discussed in the previous section and presses upon the need to incorporate site-specific variation. Table 2.5 reflects the list of barriers that were identified. Use of theory helps in interpreting the result in uniform manner which can have global results. The role and importance of theory in research cannot be underestimated as it assists in bringing about a uniformity toward understanding a phenomenon. The authors have rightly pointed out that if the target of sustainable food security targets of 2050 is to be met, the pace of adoption needs to be enhanced across the globe for relevant crops (Anibaldi et al., 2021).

2.8 Research Gaps and Research Questions

Extensive research in this area underscores the current vulnerability of Punjab's agricultural sector and its deteriorating agroecology, which adversely impacts the environment, particularly concerning rice cultivation. This, coupled with anticipated financial losses, leads to proposals for a shift away from rice cultivation. There is a paucity of studies that establish an economic and profitable rationale for rice growers in Punjab to adopt sustainable agricultural

practices, despite evidence supporting this potential. This overlooks the industrious and innovative characteristics of Punjabi farmers who have significantly contributed to India's transition from poverty to a prosperous agricultural society. It is noteworthy that Punjab achieves the highest output despite its comparatively limited territory. Undermining the expertise that farmers have developed in rice farming would be detrimental to Punjab. Section 2.6 indicates that sufficient data exists to demonstrate that the adoption of Sustainable Agricultural Practices (SAP) in rice cultivation can significantly mitigate adverse impacts. Organic Agriculture represents the most widespread and favoured approach to Sustainable Agriculture. The traditional farming system of Punjab was characterized by organic agriculture, extensive crop diversification, and crop rotation, benefiting from some of the most fertile soils. However, this trend shifted with the introduction of GR. The current state of organic farming requires significant attention from policymakers, particularly with respect to rice cultivation. Identifying the challenges associated with organic rice cultivation and evaluating its market, as well as assessing export potential, is essential. The farming community in Punjab has consistently embraced technology, investing significantly in contemporary advancements such as mechanization, renewable energy sources like solar power, and modern agro-tech methods. This characteristic can be utilized to advance Precision Agriculture. Insufficient sources were identified to evaluate the scope or intentions of farmers regarding the use of Precision Agriculture; however, the adoption of laser-assisted land levellers is increasing in the state. This study primarily aims to determine whether farmers are aware of alternative farming methods and practices that can effectively address issues related to rice cultivation. It is essential to evaluate the interest and readiness of conventional farmers to transition to Sustainable Agriculture by examining their concerns regarding potential yield reductions and their perceptions of the acceptance of this new technology. Commercial production is conducted using conventional methods, while a portion of the farm is designated for self-consumption and managed organically. It is noteworthy that this organic cultivation focuses on wheat and various kitchen vegetables rather than rice. The reason is that rice is not included in the regular daily diet of Punjab. A limited number of progressive farmers are exploring the scope and potential of commercial organic farming; however, they express reservations regarding the selection of rice as a commercial crop for this purpose. The predominant recommendation given for enhancing Agricultural Sustainability in Punjab is to transition away from rice cultivation. Additionally, significant factors include the delayed transplantation of the Pusa variety, which shows potential for positively impacting the excessive decline in the groundwater table. Promoting the cultivation of Basmati is another significant

recommendation. Basmati is an aromatic long-grain rice primarily exported, with Punjab accounting for 45% of the share due to its Geographical Indication (GI) tagging. Basmati is a short-duration variety that is sown later than the regular Pusa variety of rice. Late sowing of Basmati during the first and second weeks of July facilitates irrigation through monsoon rains, thereby conserving groundwater resources. However, organic farming remains limited and is characterized by vulnerability. The market rates exhibit significant volatility, influenced by business entities, and there is an absence of a Minimum Support Price and guaranteed procurement, as seen with the Pusa variety. Consequently, the farmer lacks the motivation to adopt Basmati and persists with the long-duration Pusa variety. The market structure for rice and wheat in Punjab is significantly bolstered by a well-established government procurement system that fails to accommodate sustainable production practices. There is a clear absence of a dedicated marketing structure for sustainable farmers.

The data presented in Chapter 1 illustrates the excessive use of inputs and its effects on resources. Although farmers recognize the decline, the pertinent question is whether they are acquainted with alternative Sustainable Agricultural Practices that could mitigate the adverse effects. Establishing a defined set of practices for investigation is crucial to comprehend the level of awareness and usage in a specific context. This prompts our research questions regarding the absence of these practices in Punjab to date and the challenges that may hinder their implementation moving forward.

RQ 1. To examine the challenges faced in growing rice using Sustainable Agricultural Practices?

RQ 2. To examine the level of awareness and frequency of use of Sustainable Agricultural Practices?

Sustainability is defined as the integration of long-term environmental stewardship with the management of present social and economic needs, ensuring consideration for future generations. Nevertheless, the practical considerations of social and economic demands often oppose the acceptance of environmental standards. Section 2.2 illustrates that the concept of Sustainable Agriculture is multidimensional, with academia exhibiting diverse interpretations and employing various perspectives to reach a consensus. In this scenario, it is entirely understandable that farmers would also face challenges in interpreting and adopting the meaning. Furthermore, an examination of the factors and barriers to adoption reveals that psychographic aspects have not received adequate attention. Foguesatto et al. (2020) and

Anibaldi et al. (2021) conducted a comprehensive systematic literature review, emphasizing the necessity of understanding farmers' perceptions regarding the adoption of sustainable agricultural practices (SAP). The comprehensive literature review on the sustainability aspects of Punjab revealed a lack of studies involving direct interactions or surveys with farmers to evaluate their perspectives. This leads to the subsequent research questions.

RQ3. To evaluate the perception of Punjab rice growers regarding the adoption of Sustainable Agricultural Practices.

Section 2.7 provides literature that attributes the success of GR to government initiatives and a highly robust support system facilitated by market infrastructure. At that time, the scenario differed. The significant concern regarding food security, coupled with the potential for Malthusian famines, has prompted coordinated efforts from international organizations to national leaders, which contributed to the success of the Green Revolution. The current situation differs significantly. The context has shifted. A sense of complacency appears to have emerged as ecological resources are being excessively utilized. The study investigates whether the provision of a support system analogous to GR will enhance farmers' performance. This leads to the formulation of our final research question for the study.

RQ4. To investigate the moderating influence of institutional support and market infrastructure on behavioural intention.

To summarise, the study seeks to identify opportunities for the implementation of SAP in rice cultivation in Punjab. The process starts with assessing the farmer's current knowledge and utilization of SAP, if applicable. The research aims to investigate farmers' perspectives on the challenges associated with the adoption of SAP in rice farming. The study aims to assess farmers' perceptions regarding their behavioural intentions toward adoption. The final aspect to be examined is the impact of institutional support and market infrastructure.

2.9 Conceptual Framework and Theoretical Support

As the LR on determinants reflects, there are some common factors which appear regularly as factors responsible for adoption as per table 2.4 Attitude, Subjective Norms, Perceived Behavioural Control, Perceived Compatibility, Relative Advantage, Extension Services, Perceived Usefulness, Perceived Ease of Use. Table 2.5 presents list of barriers which highlights complexity of the system, low perception of sustainability, lack of knowledge and resources, need for market infrastructure, lack of policy and incentives for adoption. The barriers further the cause of factors already discussed. For the sake of this project, we have

taken maximum number of these factors and collated them for our theoretical ground and conceptual framework. The decomposed theory of planned behaviour proposed by Taylor and Todd (1985) encapsulates majority of these factors hence has been chosen as the theoretical background for this study.

Table 2.4 ***Common Determinant of Adoption***

Common Determinants	References
Age, Education, Farm Size, Gender, Experience, Attitude, Subjective Norms, Perceived Behavioural Control, Relative Advantage, Compatibility, Complexity, Social Capital, Extension Services, Perceived Usefulness, Ease of use,	Mishra et al., 2018; Adnan et al., 2020; Dung et al., 2018; Pineiro et al., 2020; Adnan, Md Nordin, et al., 2017; Jha & Gupta, 2021; Syan et al., 2019; Foguesatto et al., 2020

Note. Collated by author

Table 2.5 ***Common Barriers to Adoption***

Common Barriers	References
Perceived Complexity, Perceived irrelevance, Lack of knowledge, Lack of market infrastructure, Perceived resources, Lack of Extension Services, Perceived Compatibility, Perceived Low Ease of Use, Negative Influence of Extension Services, Normative Beliefs, Perception of Irrelevance	(Blesh & Wolf, 2014; Blythe et al., 2017; Borremans et al., 2018; Brown et al., 2018; Goldberger et al., 2015; Márquez-García et al., 2019; Martin et al., 2015; Ndah et al., 2015; Tajeri Moghadam et al., 2020; Tapuswan et al., 2014; Vidogbéna et al., 2016; Zeweld et al., 2017)

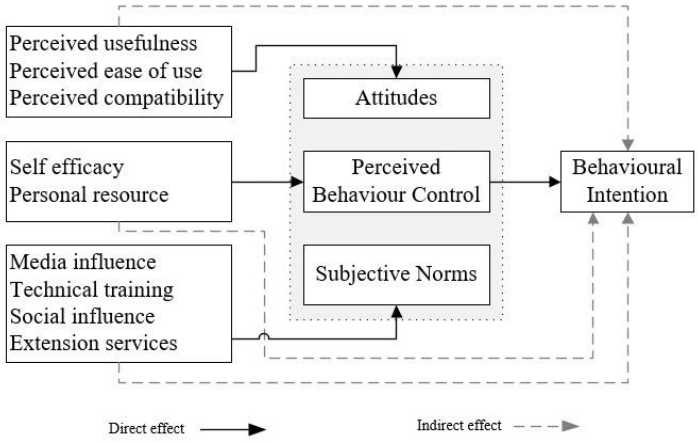
Note. Collated by author

2.10 Rationale of using Decomposed Theory of Planned Behaviour

A theoretical framework establishes a foundational basis for the research study. The Theory of Planned Behaviour (TPB), an extension of the Theory of Reasoned Action (TRA), is a widely utilised framework for behavioural exploration. TRA posits that behavioural intention is determined by attitude and subjective norms. The Theory of Planned Behaviour was extended by incorporating Perceived Behaviour Control (PBC) as an additional factor. The PBC gradually refined itself and established access to the resources and opportunities necessary for executing the behaviour. The components include facilitating conditions, such as time, financial resources, and specialised resources, as well as self-efficacy, which refers to an individual's belief in their ability to perform the specified behaviour. The Theory of Planned Behaviour posits that the belief structure underlying the component factors is unidimensional. Taylor and Todd (1995) propose an extension at this stage, indicating that the introduction of multidimensionality in the system aids the process by decomposing its components. The study integrates elements of the Theory of Innovation Diffusion (Rogers, 1995), emphasising

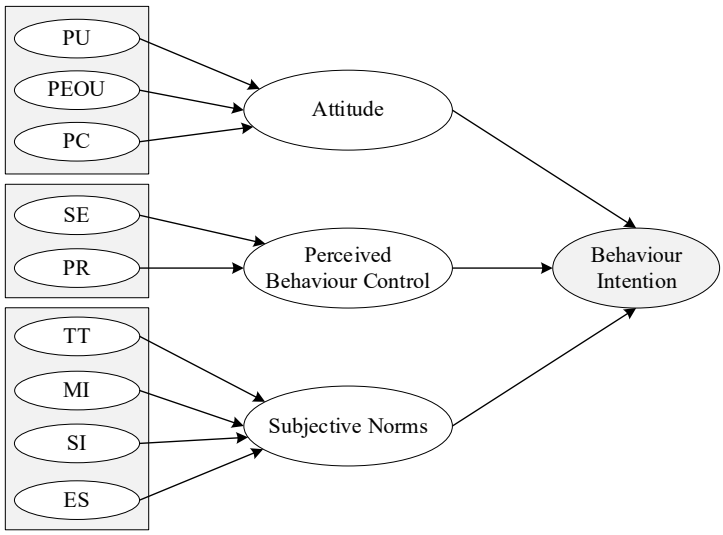
perceived characteristics, relative advantage, complexity, and compatibility of the innovation in relation to attitudinal beliefs. Control beliefs are influenced by self-efficacy and the perceived availability or constraints of resources, while normative beliefs are context-specific, contingent upon whether the normative group shares similar views or presents divergent perspectives.

Figure 2.8 ***Decomposed Theory of Planned Behaviour***



Note. Source: (Taylor & Todd, 1995)

Figure 2.9 ***Proposed Conceptual Model for the Study***



Note. PU -Perceived Usefulness, PEOU-Perceived Ease of Use, PC-Perceived Compatibility, NEP-New Ecological Paradigm, SE-Self Efficacy, PR-Perceived Resources, TT- Technical Training, MI- Media Influence, SI-Social Influence, ES-Extension Services, AT-Attitude, PBC-Perceived Behaviour Control, SN-Subjective Norms, BI-Behavioural Intention. Adapted from (Zeweld et. al, 2017)

The theory additionally examines the crossover effects among components, alongside the direct relationships outlined by the Theory of Planned Behaviour (TPB) (Taylor & Todd, 1995). The current study identifies a comprehensive list of factors influencing SAP adoption, all of which are encompassed within the DTPB framework. Thus, it is appropriate to select DTPB as the theoretical framework for this research. Additionally, Zeweld et al. (2017) selected this theory to examine behavioural intentions regarding SAP in Ethiopia, specifically in the context of minimum tillage and row planting. Therefore, DTPB serves as the foundation for the present research study. Fig 2.8 is the model reflection of decomposed theory of planned behaviour taken from the seminal work of Taylor and Todd (Taylor & Todd, 1995). Fig 2.9 reflects the proposed conceptual framework for the study.

2.11 Chapter Summary

The chapter begins with presenting the route of evolution of Sustainable Agriculture with Brundtland Report, its historical context and global attention. It further highlights the difference in opinion in various quarters of academia regarding the process and objectives of Sustainable Agriculture. The chapter provides insights on two divergent methodologies to Sustainable Agriculture, namely technoeconomic and agroecological. Furthermore, the global standards of Sustainable Rice Platform are presented and literature support on the effectiveness of SAP for rice cultivation along with the determinants and barriers is discussed. Finally, the chapter builds a case for evaluated research gaps and objectives and provides rationale for the chosen conceptual framework.

3. Chapter 3 - Research Methodology

"Truth has nothing to do with the conclusion, and everything to do with the methodology."

- Stefan Molyneux

3.1 Overview

This chapter elaborates the research methodology used for the purpose of this study. Considering the nature of the study, a mix method research design was adopted. The first section of the chapter entails the research paradigms. The second section of the chapter describes the basic mix method designs. Then it explains the exploratory sequential mix method employed in the study and how the research was conducted in three phases. The third section presents the details of research methodology used in the three phases of the study. The phase III was quantitative in nature and was utilised for testing the hypothesis formulated based on the outcomes of Phase I of the study which was qualitative in nature. The concluding section shares details of sampling plan and approaches deployed for the purpose. The chapter closes with a summary and overview of research methodology used in the study.

3.2 Research Paradigm

A researcher's paradigm is founded on their views of reality and interpretation. The research world is divided into four paradigms: Positivist, Interpretivist or Constructivist, Critical Theory, and Pragmatic. Table 3.1 shows each paradigm's fundamentals and differences. The current study uses Pragmatic Paradigm and a mix method research design.

Table 3.1 ***Basic Tenets of Research Paradigms***

Aspect	Positivist	Interpretivist/ Constructivist	Critical Theory/ Transformative	Pragmatic
Prime Position	Focused on scientific outlook, objective and aimed at cause-and-effect relationship, experimental, based on deductive logic, formulation and testing of hypothesis,	To understand the subjective aspect of reality, rooted in social human behaviour. There are multiple realities which are socially constructed. The theory follows the data.	There is a socially reality, but it's shaped by historical realism. Based in social justice, this kind of research aims to change the situation political, social, or economic hence also	A practical approach that allows for use of both quantitative and qualitative methods suitable to ascertain the reality for the research topic/subject. Focused on finding the actual behaviour of

Aspect	Positivist	Interpretivist/ Constructivist	Critical Theory/ Transformative	Pragmatic
	extrapolation, wide generalisability. The data follows the theory.		called transformative.	subjects and the beliefs and reasons behind that behaviour.
Ontology	Naïve realism (Singular Reality)	Relativist (Multiple realities that can be found through interactions between researcher and the subjects.	Historical Realism (concerns with oppression)	Non-singular Reality (No single reality, rather each one has a unique interpretation of reality)
Epistemology	Objectivist	Subjectivist (The researcher makes meaning of data through her own thinking and cognitive process.	Transactional (The researcher interacts with the participants)	Relational (The researcher determines the relations in the research)
Methodology	Experimental, Quantitative	Naturalist, Qualitative, Interviews, discourses, interactions between and active participants.	Dialogic	Mix Method (A combination of quantitative and qualitative methods)
Axiology	Beneficence	Balanced	Cultural norms	Value laden (research that benefits all)

Note. Adapted from (Kivunja & Kuyini, 2017)

3.2.1 Mix Method Research Design: Purpose

Mix Method research is a category in which the researcher combines quantitative and qualitative techniques, approaches, methods, and concepts in a single study. Johnson and Onwuegbuzie(2004) have hailed Mix method research (MMR) as the third wave in research movement in philosophical context that goes beyond the paradigm conflict by providing a logical and practical alternative. The authors further state that, “the logic of inquiry in this method follows induction (discovery of patterns) then deduction (testing of theories and hypothesis) and abduction (relying on the best of a set of explanations for understanding one’s results)”. The research method is chosen based on the research question and not the other way

round. Since MMR allows for the use of both quantitative and qualitative approaches, this method is inclusive and pluralistic and for the same reason brings depth to the final analysis by mitigating the weakness of one method with the strength of other methods.

3.2.2 Rationale of Adopting Mix Method Research Design

MMR is best defined as research in which subjective experiences (qualitative data) and objective statistics (quantitative data) are combined to better explain the research phenomenon.

Onwuegbuzie et al (2010) have provided with four rationales for using mix method research design

i) Participant enrichment (to optimize the sample size)
ii) Instrument fidelity (to maximize the appropriateness of the instrument)
iii) Treatment integrity (to mix the research method techniques to ensure fidelity of interventions)
iv) Significance enhancement (to maximise researchers' interpretation of data)

Doyle et. al., (2016) further simplifies that the use of MMR is necessitated by the following factors, Triangulation (using qualitative and quantitative methods to confirm the findings) Expansion (to further expand the finding), Exploration (to develop an instrument or identify variables to test a theory), Completeness (to arrive at a comprehensive phenomenon), Offset weaknesses (to compensate for the weakness of a research method), Different research questions (the study has qualitative, quantitative and mix method research questions), Illustrations (qualitative mode is used to present the quantitative data).

3.2.3 Mix Method Research Design: Its Rigour and Application

Harrison et al., (2020) assert that in the process of MMR, the rigour of each mono methodological approach should remain intact. The authors have provided a framework to assess the quality of a mix method research design called as Rigorous Mix Method Framework (RMMF). They present the same in two categories, primary and advanced elements. The former has four components while the latter has two. The primary category begins with rigorous data collection of both the strands, the qualitative as well as quantitative, followed by rigorous data analysis of each strand. The third element corresponds to integration of the data, where the actual mixing appears, and the last element concerns itself on the type of mix method design used for the study. The advance elements deal with presenting the aims and purpose of using MMR and making use of language and terminology to promote the use of MMR. Table 3.2 represents the indicators of high levels of RMMF.

Table 3.2 *Rigorous Mix Method Framework (RMMF)*

RMMF Elements	High Levels of Rigor
Aims and Purpose	Includes a rationale for using mixed methods, mixed methods research question, and discussion of the value of mixed methods.
Data Collection	Includes the reporting of specific data collection procedures for both qualitative and quantitative data strands (e.g., sampling procedures, types of data to be collected, and instruments used in data collection).
Data Analysis	Includes the reporting of analysis procedures for both qualitative and quantitative data strands that range from basic to more sophisticated approaches; from descriptive to inferential quantitative analysis, to coding and thematic development qualitative analysis.
Data Integration	Includes the linking of both data strands. Depending on the design type, both data strands are either merged or one data strand is used to explain, or build from, the other. Joint displays and/or data comparisons are utilized.
Mix Method Design Type	Includes a mixed methods design type (e.g., sequential explanatory). Uses a diagram to show the design type.
Elements of Writing	Includes references to mixed methods literature. Identifies the study as mixed methods in the title, abstract, and/or paper.

Note. *Source: (Harrison et al., 2020)*

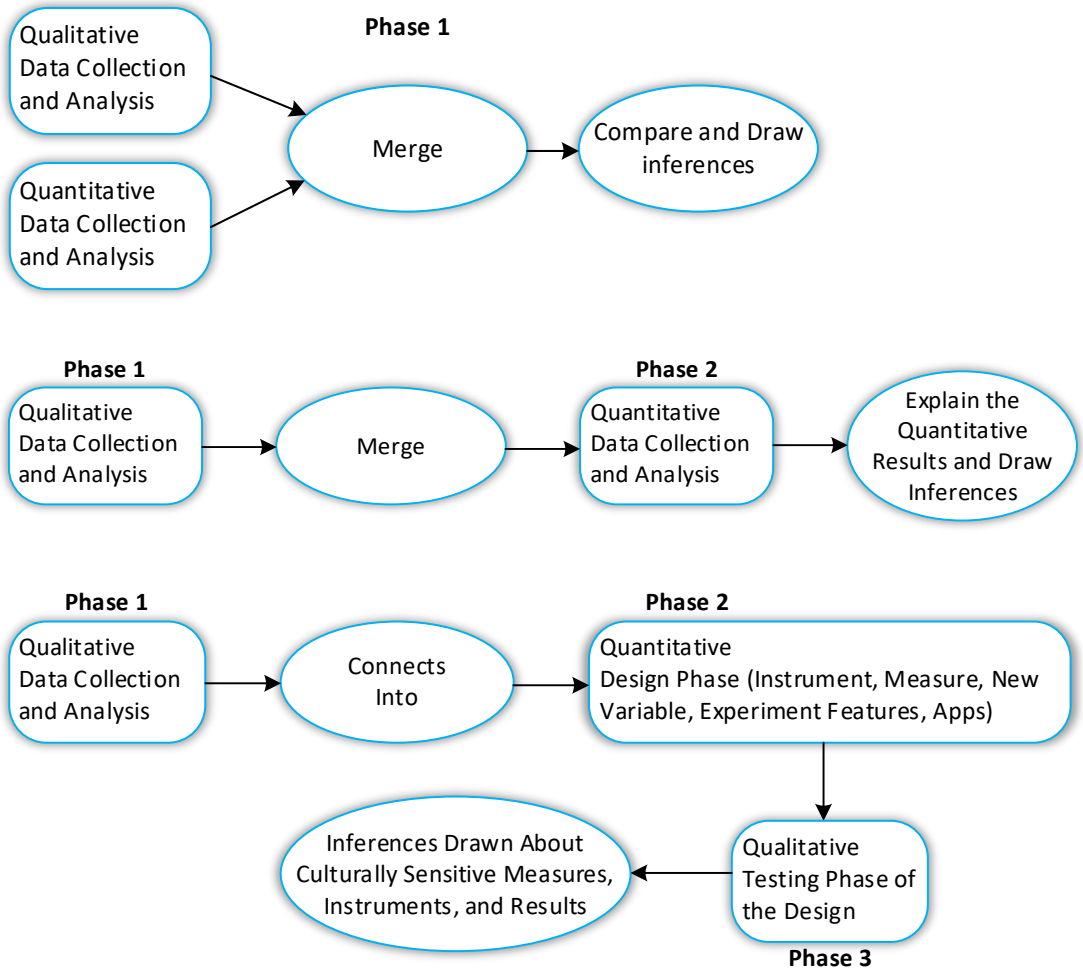
3.3 Integration in Mix Method Research Designs

The integration of two distinct research methods is the most critical element in a mixed methods research design. Fetters et al. (2013) indicate that integration of the two can occur at various levels within a study. At the Study Design level, three distinct designs emerge: Convergent, Explanatory Sequential, and Exploratory Sequential. Additionally, this is accomplished through four advanced frameworks: Multistage, Intervention, Case Study, and Participatory and Transformative. At the Method level, there are four approaches: connecting (one database links to another through sampling), building (one database advises the data collection approach of the other), merging (the two databases are combined for analysis), and embedding (data collection and analysis are linked at multiple points). At the Interpretation and Reporting level, options include Narrative Style Reporting (which may be weaving, contiguous, or staged), Data Transformation, or a Joint Display (Fetters et al., 2013).

Creswell(2021) highlights two most important aspects with respect to integration of two approaches. The first is ‘the intent’ of the integration. The same can be understood as why the integration is being done in this study. And then he further goes to highlight the second part ‘the process’ of integration that how the same is being done. Both these aspects impact the

rigor, process, and presentation of the study. As per him, it's the intent which provides for the design of the research study which in turn leads to the process of integration in terms of approach used to bring the two databases together. The intent aspect leads to one of the three basic designs of the study. In a convergent design, the intent is to compare the results of quantitative and qualitative databases, and the process of integration is through 'merging'. In explanatory sequential design, the intent is to explain quantitative results with the help of qualitative data and the approach used is 'connecting'. The intent of exploratory sequential design is characterised by the requirement to develop an instrument that is sensitive to needs of a specific cultural sample. The process of integration happens by linking the findings of first qualitative phase with the second quantitative phase. This is a three-stage process, Stage 1 is qualitative exploration, the stage 2 is a design phase where measure and instrument are adapted, and stage 3 is testing phase to administer the adapted instrument. Figure 3.1 shows the scheme of three basic mix method research designs.

Figure 3.1 ***The process of Integration in Three Mix Method Research Designs***



Note. Source: (Creswell, 2021)

3.3.1 Exploratory Sequential Mix Method: Purpose

The choice of research method depends on the research question. The inquiries pertaining to natural sciences, causality and generalizability make use of quantitative methods. However, the research that deal with social sciences exploring experiences or perceptions of subjects or figuring out the 'why' of a phenomenon or developing a theory need to use qualitative methods. In a Mix Method study, strength of both the methods gets combined to find a novel approach to address an inquiry (Fetters et al., 2013).

The rationale for using MMR in the current study is "need for exploration". The research at hand with title "A study on SAP in rice cultivation amongst the growers of Punjab" is aimed at exploring the various aspects related to the usage and wider adoption of Sustainable Agricultural Practices (SAP) in the rice cultivating farming community of Punjab. The major proportion of this community relies on conventional methods which are dated and are a legacy of Green Revolution (GR) era. The farming population of Punjab is fully aware of the environmental cost of these conventional methods yet the set of population that employs SAP in rice cultivation is rather miniscule in Punjab. The literature is replete with studies that show the otherwise impact of rice cultivation in Punjab, however there is need to explore if the rice cultivation in Punjab can be made sustainable? As explained in the previous chapter 2 (Review of Literature), the data needs to be gathered to understand if there is usage of SAP in growing rice. An understanding of the factors which are posing challenge in usage of SAP in rice farms can help formulate strategies and action plans for wider adoption. The rationale for using MMR in the current study is "need for exploration". In brief, the study utilised mix method research design to investigate the research questions which emerged after the literature review. Of the four research questions, the first one employed qualitative approach and the rest three were quantitative in nature. Thus, the study was carried out in two phases.

In phase I, a qualitative study was conducted through interview schedules and performing thematic analysis with grounded theory approach to explore the

Research Question (RQ)1 To examine the challenges faced in growing rice using Sustainable Agricultural Practices?

The nature of the RQ is exploratory aims (2021)to find out the real issues and concerns in usage of SAP. Hence a qualitative research methodology is adopted where in-depth semi structured interviews are used to gather qualitative data from rice cultivating farmers. The outcome of this phase requires further corroboration by developing a conceptual framework

and formulation of hypothesis. For this purpose, Phase II of the study employed quantitative approach through administering survey method to understand the following:

RQ2. To examine the level of awareness and frequency of use of Sustainable Agricultural Practices?

RQ3. To assess the perception towards adoption of Sustainable Agricultural Practices in rice cultivation amongst the growers of Punjab?

RQ4. To examine the moderating effect of institutional support and market infrastructure with respect to behavioural intention?

The RQ2, RQ3 and RQ4 are aimed at generalisability of the research findings for a larger population. It requires quantitative rigour. The research instrument developed in the preceding phase is utilised to gather quantitative data from farmers through a survey methodology. The statistical analysis obtained allows us to comprehend the perception of a broader population and aids in the generalisation of the findings from the initial phase.

3.3.2 Using Exploratory Sequential Mix Method Design

In Exploratory Sequential design, the qualitative study precedes the quantitative study. Creswell (2021) posits that when there is requirement to develop a research instrument that addresses specificity of a certain cultural section of a population, the stated design works well. The intent in this design is to explore qualitative data to enhance the cultural specificity of the quantitative assessment. The Process of integration is to build the quantitative assessment by incorporating the insights/findings/themes from the qualitative phase. The whole process takes shape in a sequential manner in three distinct phases.

Phase 1 - Qualitative Data Collection and Analysis – Qualitative Results – Developing themes.

Phase 2 – Quantitative Design Phase – Developing Quantitative Instrument building on the strength of qualitative insights.

Phase 3 – Quantitative Testing Phase – Quantitative Data Collection and Analysis

Table 3.3 *Steps in Exploratory Sequential Mix Method Design used*

Qualitative Phase 1				Quantitative Design Phase II	Quantitative Phase III			Discussion
Qualitative Data Collection	Qualitative Data Analysis	Qualitative Results (Capture themes/insights)		Develop quantitative instruments building on the strength of qualitative findings	Quantitative Data Collection	Quantitative Data Analysis	Quantitative Result	Inferences from Qual and Quant - present combined strengthened
'Intent' of Integration				'Process' of Integration	Hypothesis Testing Phase			Value of MMRD

Note. Adapted from (Creswell, 2021)

3.4 Three Stages of the study

The study focuses on a specific section of farmers who are primarily engaged in rice cultivation and have a scope for adopting SAP in their rice crops. The study works in three phases, (See Fig 3.2) Phase 1 is qualitative. The first phase helps in discovering the hidden theme which are then used as a base in Phase II to develop a quantitative research instrument. The phase III of the study is the testing phase where the research instrument is administered to a larger sample group.

3.4.1 Qualitative Study to Research Model and Hypothesis Formulation

The stage I of the study was qualitative in nature and was aimed at discovering answer to RQ 1 i.e. the challenges faced in growing rice using SAP. The sampling frame was rice cultivating farmers of Punjab. Since the inquiry dealt with perception and cultural aspects of the stakeholders', purposive sampling technique was used. The sample size determination was a function of two approaches, data saturation and information power. The former states that data must be collected until no new information is acquired. The latter approach presented by by Malterurd et al. (2016) shows another intriguing way to measure sample size based on 'Information power'. It believes that sample size depends on information power. A lower sample size may work if specialists are present, while a higher sample size may be needed without them. The data collection was carried out through a semi structured interview schedule. The interviews were conducted in an informal manner and local language to facilitate the research participants. The intent was to understand the experiences, interpretations and perceptions of rice growing farmers with respect to usage of SAP. The data collected revealed the latent contexts through thematic analysis using grounded theory approach. The emergent themes were utilised as variables to develop a conceptual framework in congruence with the

established theory. In this phase, qualitative data analysis software MAXQDA was used. This phase covers the 'intention' of integration of two research methods. Findings of the Qualitative study helped in finalising the research model of the study by revising the conceptual framework that was proposed initially.

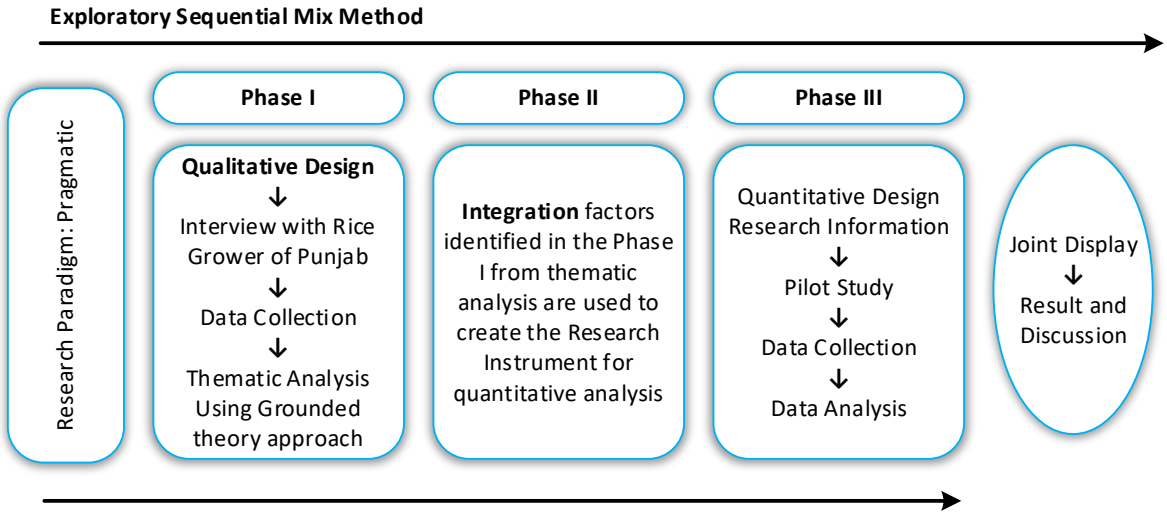
3.4.2 Quantitative Design : Research Instrument, Validity & Reliability

The Quantitative Design stage of the study deals with the process of integration of the study. The findings of the qualitative study, the themes which emerged were utilised to develop the Research Instrument meant for final Stage of Quantitative Study. Research Instrument is the most crucial aspect as the findings of qualitative research build the framework for final phase of the analysis. The steps involved in this phase involved creating and administering the instrument to a select group for pilot study to assess the validity and reliability of the Instrument.

3.4.3 Quantitative Study: Sampling Plan, Data Collection and Analysis

The final phase of the study dealt with administration of validated research instrument to a larger sample size through survey method. The sampling frame consisted of rice growing farmers who were using conventional method of rice cultivation and multistage sampling technique was used. The sample size calculation is based on the Yamen's formula. The farming population of Punjab is mentioned as 19,35,000 as per Punjab Statistical Abstract (Directorate of Statistics, Department of Planning, Govt of Punjab, 2023). The Yamen formula calculation with 95% confidence level sets the sample size at 400. The survey was self-administered by the researcher. The data analysis was done through descriptive statistical analysis and deployed PLS SEM software. PLS-SEM allows researchers to estimate intricate models with several constructs, indicator variables, and structural paths without making assumptions about the distribution of the data. PLS-SEM is a statistical modelling strategy that focuses on prediction and causal explanations. It estimates models that are aimed to provide causal explanations and emphasise prediction.

Figure 3.2 *Overview of Research Design Framework of the study*



Note. Author's representation

3.5 Overview of Framework of Research Design

Table 3.4 *An overview of Framework of Research Design in the study*

Objective	Research Approach	Sampling Procedure Sample Frame - Rice Growers of Punjab			Research Software
		Sample Size	Sample Design	Category of the sample type	
1. To examine the challenges faced in growing rice using sustainable agricultural practices.	Qualitative	12	Purposive Sampling	Sustainable + Conventional Rice Growers	MAXQDA22
2. To examine the level of awareness and frequency of use of Sustainable Agricultural Practices?	Quantitative	400	Stratified Sampling	Conventional Rice Growers	SPSS 27
3. To assess the perception towards adoption of Sustainable Agricultural Practices in rice cultivation amongst the growers of Punjab?	Quantitative	400	Stratified Sampling	Conventional Rice Growers	SmartPLS 4
4. To examine the moderating effect of institutional support and market infrastructure with respect to behavioural intention?	Quantitative	400	Stratified Sampling	Conventional Rice Growers	SmartPLS 4

Note. Author's representation

3.6 Ethical Considerations

The study has adhered to research ethics to prevent any violation of ethical standards. The questionnaire contained questions that expressly stated that the responses were being gathered for academic research purposes, and respondents willingly agreed to provide their responses. During the investigation, the goal of the research was explicitly communicated to all the interviews. Certain respondents objected to the disclosure of their names, while others consented to having their names recorded. They were well informed that confidentiality of the data shall be maintained and that there was no risk involved in participating in this survey. Furthermore, it was shared that they could choose to withdraw from the study if they wish so.

3.7 Chapter Summary

The chapter explains the parts and steps taken in the Research Methodology adopted for the study. The chapter begins with explaining the basic tenets of Research Paradigms and presents types of Mix Methods Designs. It further provides rationale for the chosen Mix Method Design. Phase 1 of the research design was exploratory in nature and used qualitative research design. Phase II was quantitative design phase which was based on the findings of phase I to develop a research instrument to be used in the Phase III. Finally, it concludes with an overview of the chosen Research Methodology.

4. Chapter 4 - Qualitative Research Approach – Thematic Analysis

"All research ultimately has a qualitative grounding." - Donald T Campbell

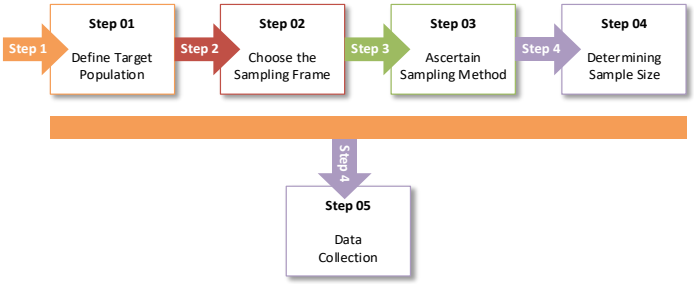
4.1 Overview

The research methodology employed for the study is Exploratory Sequential Mix Method, which uses two different kinds of research methods in a sequential manner. The stated methodology follows three phase process. This chapter deals with phase I of the study which is qualitative and exploratory in nature. The first section of the chapter presents the sampling procedure utilised for the qualitative phase of the study. This is followed by an explanation of the approaches used for qualitative data collection and analysis. The third section of the chapter enlists the process followed for data collection and analysis. The fourth section reveals the results of the qualitative data analysis. The final section elucidates the findings from the qualitative data and its incorporation in the research process with the revision of proposed conceptual model and presents the hypothesis formulation.

4.2 Sampling Plan

A sampling plan is a detailed strategy to select a true representative subgroup from a larger target population for the desired data collection. The strength of a research fully relies on accuracy and thoroughness of the sampling plan. The process requires various steps, from defining the target population, choosing sampling frame, finalising sampling technique and appropriate sample size before the actual data collection (Fig 4.1).

Figure 4.1 ***Sampling Plan***



Note: *Source:*(Taherdoost, 2016)

4.2.1 Sample Frame

A sampling frame is true representative of the target population. The target population for the study is rice growing farmers of Punjab. The qualitative RQ is aimed at finding out the challenges associated with usage of SAP in the process of cultivation of rice. The objective is two pronged, it tries to figure the problems faced by those set of farmers who have adopted

some or other form of SAP in rice cultivation and in addition, it also intends to find out the concerns of those set of farmers are who are not using any kind of SAP. Therefore, the sampling frame involves both the set of farmers who are using SAP in rice cultivation and those who have chosen to continue with conventional practices of growing rice. The true representativeness of a sample is a function of sampling method, sample size and the response rate (Acharya et al., 2013). These aspects are further discussed below.

4.2.2 Sampling Method

There are primarily two broad categories of sampling method, Probability Sampling and Non-probability Sampling. Probability Sampling allows for far greater generalizability with each unit in the population having an equal chance of being selected and in addition is suitable for statistical inferences. Non-Probability Sampling on the other hand is a preferred method in case of qualitative research as it covers real life, subjective experiences of the sample unit chosen, and the statistical aspect is secondary. Besides, Glaser and Strauss (1967) opined that in qualitative research, the sampling is done for theory construction rather than population representation. For the current study, Purposive Sampling method has been adopted. Purposive sampling allows for selection of suitable sampling unit that can provide relevant data or information for the chosen study in a purposive manner, based on the judgement of the researcher. In addition, the strength of this strategy is that it is low cost, convenient and is ideal for exploratory research (Taherdoost, 2016). Purposive sampling allows the researcher to make a selection based on theoretical, logical or analytical grounds, but can also be cause of researcher's bias if the judgement criteria are not properly documented (Berndt, 2020). A proper inclusion criterion is defined below to prevent selection bias.

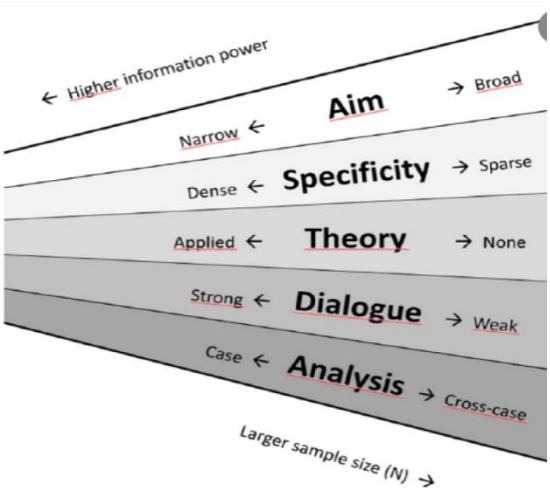
The inclusion criteria -

The study utilised purposive sampling method. The farmers were chosen from across Punjab. The inclusion criteria used ensured that farmers chosen had an operational land holding from a minimum of 1 acre to 10 acres and been engaged in rice farming for at-least 4 to 5 years. The farmer could be practicing conventional form or using some form of SAP in rice cultivation. The farmers who demonstrated receptive and inclusive attitude for thorough discussions were favoured. In addition to farmers, an organic farming expert and an organic retail store owner were also part of the sample for a comprehensive view.

4.2.3 Sample Size

In qualitative research, the concept of data saturation is often used to finalise the sample size, i.e. the data needs to be collected till no new information is being gathered. While, this is a much accepted method, Boddy (2016) is of the opinion that even a sample size of 1can be valid considering the context of the research and respondent. Another interesting method to assess the sample size on the basis of 'Information power' is given by Malterurd et al., (2016) as shown in figure 4.2. The authors postulate that sample size is a function of information power that can be gathered. If the sample has experts onboard, a smaller number could suffice whereas their absence may call for a larger number in sample size.

Figure 4.2 *Information Power and Sample Size*



Note: Source: (Malterurd et al., 2016)

For the current study, a mix of both these approaches have been adopted. It helped that the purposive sampling method is used. The sample size of 12 for the current study, showed elements of data overlapping and saturation, besides presence of experts and knowledgeable farmers who had extensive experience and authority in the field so that a valid view could be gathered on all aspect concerning the study. Table 4.1 provides information on the profile of the chosen respondents in the sample.

Table 4.1 *Sample size and respondent profile*

Distt	Village	Code	Category	Land Owned (Acres)	Respondent's Profile
Ludhiana	Dheri	R01	Sustainable Farmer	40	A Successful Organic Farmer, President, PAU Organic Club,

Distt	Village	Code	Category	Land Owned (Acres)	Respondent's Profile
					Ludhiana Member Of Natural Farmers Association Of Punjab
Sangrur	Punjgrahiyan	R02	Sustainable Farmer	30	Farming Since 1980 But Turned Sustainable For Last 5 Years By Adopting Chemical Free Farming.
Firozepur	Mallanwala-Khas	R03	Sustainable Farmer	1	Veternary Doctor And Also Does Natural Farming On His 1 Acre Farm Grows Rice, Wheat And Fruits And Vegetables
Barnala	Kotdunna	R04	Sustainable Farmer	3	Does Farming On 18 Acres On Leased Land14 Acres Are Pesticide Free President, Organic Farming Club Barnala
Firozepur	Fazilka	R05	Sustainable Farmer	17	Owns A Successful Natural Farm. Primarily Grows Basmati Variety Of 1121 and Parmal too. Carrying forward the legacy of green farming of his father-in law who had been engaged in natural farming since 1960.
Muktsar	Sohngarh	R06	Sustainable Farmer	20	Lawyer By Profession But Quit Practice To Start Sustainbale Farming. Very Passionate and successful.
Sangrur	Sunam	R07	Sustainable Farmer	100	In Organic Farming For Last 9 Years does 15 Acres Of Organic Basmati Also Has Guava Orchard, Gaushala And Educational Institutes
Moga	Dhalle Ke	R08	Sustainable Farmer	6	An Ex Army Officer, does Basmati On 4 To 5 Kanaal, largely Does Organic Wheat And Sugarcane
Moga	Khosa Randhir	R09	Conventional Farmer	16	Largely Grows Pusa Variety. Grows Basmati Only In 1 Or 2 Acres Where Water Or Irrigation Is An Issue

Distt	Village	Code	Category	Land Owned (Acres)	Respondent's Profile
Hoshiarpur	Bassi Ghulam Hussain	R10	Sustainable Farmer	3	Is A Passionate Organic Farmer, Though Is Handicapped And Wheelchair Bound But Still Out Of His Interest And Passion Takes Care Of Each And Every Part Of His Fieldsgrows All Seasonal Vegetables And Wheatdue To Paucity Of Land, Does not Grow Rice
Ludhiana	Ludhiana	R11	Sustainable Produce Retailer		Owns Kudrat Hut, an organic retail store. Gol Market, Ludhiana, Deals In Organic Fresh Fruits, Vegetables And Groceries, Buys Directly From Farmer And Sell At A Mark Up Of 10%, Provide Platform To Organic Farmers To Display Their Fresh Produce/Products In Their Shop,
Faridkot	Dabdikhana	R12	Sustainable Farming Expert		Organic Farming Expert and Consultant

Note: Author's representation

4.3 Qualitative Data Collection and Analysis

4.3.1 Data Collection Approach - Semi-Structured Interview Schedule

The major data collection approaches for qualitative data collection consist of Interviews, Focus Group Discussions, Observations, Open-ended survey, Audio-Video Recordings, Case study method. For the current study, semi-structured Interview schedule mode was chosen. The research instrument, Appendix A, was based on the review of literature and the proposed conceptual model. Some questions were set as fixed however the conversation was held in a manner that more themes and ideas could be explored. In addition to the basic demographic questions, the questions that were asked in the semi structured interview schedule were as below:

1. Could you please share something about your profile, landholding and how long have you been farming?
2. Is farming your full-time occupation? If no, what is other employment?

3. Do you use sustainable agricultural practices for rice cultivation? If so, what were your reasons to do that?
4. What was the ground water level when you started farming and what is its status?
5. Which variety do you use for rice-cultivation and what are the kind of sustainable methods/practices do you use?
6. What is your opinion regarding major challenges in adoption of sustainable rice cultivation in Punjab?
7. What kind of support do you think is needed for sustainable rice cultivation?
8. What can be done for mass adoption of sustainable rice cultivation?

4.3.2 Analysis Approach - Thematic Analysis using Grounded Theory

The qualitative data analysis approach used in the study is Thematic Analysis using Grounded Theory approach. The grounded theory approach deploys use of systematic steps for inductively create a theory in the very process of data collection and analysis through continuous interactions. As explained earlier in Chapter 2, an extensive review of literature was carried out to understand the phenomenon of adoption of SAP in rice cultivation, that presented the determinants and theoretical underpinnings. The proposed conceptual framework provided the base for interview questions. However, while interviewing, an open-minded approach was used so that new features or concepts could be captured. Corbin & Strauss (1990) highlight that in the ground theory approach, the data analysis part begins as soon as first chunk of qualitative data appears. The idea is to capture more in-depth information from the next respondent. The result with grounded theory approach is a framework which assists in understanding the phenomenon at hand.

4.4 Qualitative Data Collection and Analysis using software MAXQDA

4.4.1 Preparation of Interview Sessions and Data Collection

Corbin & Strauss (1990) recommend that researcher should have an initial set of research questions, hence the qualitative research instrument with some basic questions and demographic information were fixed (Appendix A). The proposed framework rooted in Decomposed Theory of Planned Behaviour ensured that the core themes that were asked revolved around. The aspects being explored were the opinions of respondents on the determinant, barriers, facilitating factors and behavioural intention. The respondents were informed well in advance of the interview timing schedule. All the interviews were conducted telephonically. The reason for telephonic sessions was restrictions imposed due to Pandemic. The interactions were carried out in an informal manner in local language to ensure a smooth

and comfortable engagement with the participants. The interview sessions began with the researcher introducing herself and that was reciprocated by the respondent. Then the researcher explained the purpose of the interview and the objectives of the research study. Some respondents had counter questions related to the current study and how their responses would be utilised. Once these questions were addressed fully, the interview sessions began. The average time of interview was 35 minutes with shortest session being 30 minutes and the longest one being 85 minutes. During the interview, the notes were recorded in written format. These interviews were conducted from August 2020 to October 2020.

4.4.2 Data Analysis Process

Glaser and Strauss (1967) in their book 'The Discovery of Grounded Theory', supported qualitative research and advocated that the theories should be developed from a research process which is grounded in data. These authors preferred it to having hypothesis testing from existing theories. They go on to provide strategic steps in the research process for the same. The foremost part is that the data collection and analysis should happen in a simultaneous manner. In addition, analytical codes and categories should be created from the data with continuous comparison and this should lead to theory construction. The review of literature is carried out as the final step in the process. Charmaz (2006) explains the process of coding in her book 'Constructing Grounded Theory'. She asserts that coding is the pivotal link between the data collected and the emergent theory. The first step is line by line Coding that allows for deeper understanding of the data and then a more focussed approach is used to convert the codes into categories based on frequency, repeated reference, critical aspect of the research phenomenon at hand. At this stage, Axial coding is introduced in the process. Axial coding connects the categories to sub-categories thus presenting a structure of relationships as an axis of the category (Glaser & Strauss, 1967). Another way to describe purpose of axial coding is that it helps to sort, synthesise, and organize a large amount of data of codes in a new way (Creswell, 2021).

The current study made use of qualitative data analysis software MAXQDA 22. The software provides an array of tools to analyse and understand qualitative data. It assists in coding and finding identical patterns and visual representation of data. The transcripts were translated and uploaded to MAXQDA software. The initial step was coding of each section of the verbal scripts to gather the issues spoken by farmers. The coded segments were again reassessed in the light of farmer's context and inherent similarity in multiple scripts. Keeping in view the literature review, the coded sections were further classified in various categories.

These categories were further integrated to arrive at the underlying themes. A deeper scrutiny of these themes led to collation of emergent variables that were utilised to generate theory that was validated through literature review. Table 4.2 summarises the steps taken and results thereof.

Table 4.2 ***Summary of Qualitative Data Analysis Steps***

Step	Action	Description	Result
1	Line by line coding	Coding of each section of transcript	295 coded segments
2	Focussed approach coding	Reassessment of the codes with farmers contexts	123 unique codes
3	Axial Coding	The codes were classified into unique categories	65 unique categories
4	Thematic Analysis	Based on intrinsic properties, the categories led to themes	26 unique themes
5	Integration of Themes	Comparison of themes	Properties of themes intensely organised
6	Emergent variable	Assimilation of similar themes	11 emergent variables
7	Generation of theory	Validation through LR	Conclusion - Revised Conceptual Framework for the study

Note: Author's representation

4.5 Results of Qualitative Data Analysis

The verbal transcripts were translated and uploaded to qualitative data analysis software MAXQDA 22. The scripts were read multiple times to create familiarity with the text. The verbal transcripts were uploaded as a project in the software and a word cloud of all the documents was created to understand the inherent themes (Fig 4.3). Each section of the interviews was coded keeping in mind the context of the grower. A total 295 segments codes were created. A reassessment of the codes was carried out keeping in mind the context of the farmers. The entire section of 295 coded segments was retrieved in an excel for deeper analysis. The codes were reassessed with contextual depth and redefined, post which these were consolidated into 123 unique codes. These coded were classified with different colours for better identification of themes. Fig 4.4 and 4.5 shows the Code Cloud and Code Matrix retrieved from MAXQDA. Based on our literature review and conceptual framework, a deductive approach was used to create a code system that led to creation of 65 unique categories. Next steps involved classifying the 65 Unique categories which evolved to 26 unique themes. Assimilation and integration of the emergent themes, lead to 11 emergent

variables (Table 4.3). The process led to generation of theory as the conceptual framework got revised post the qualitative research and data analysis.

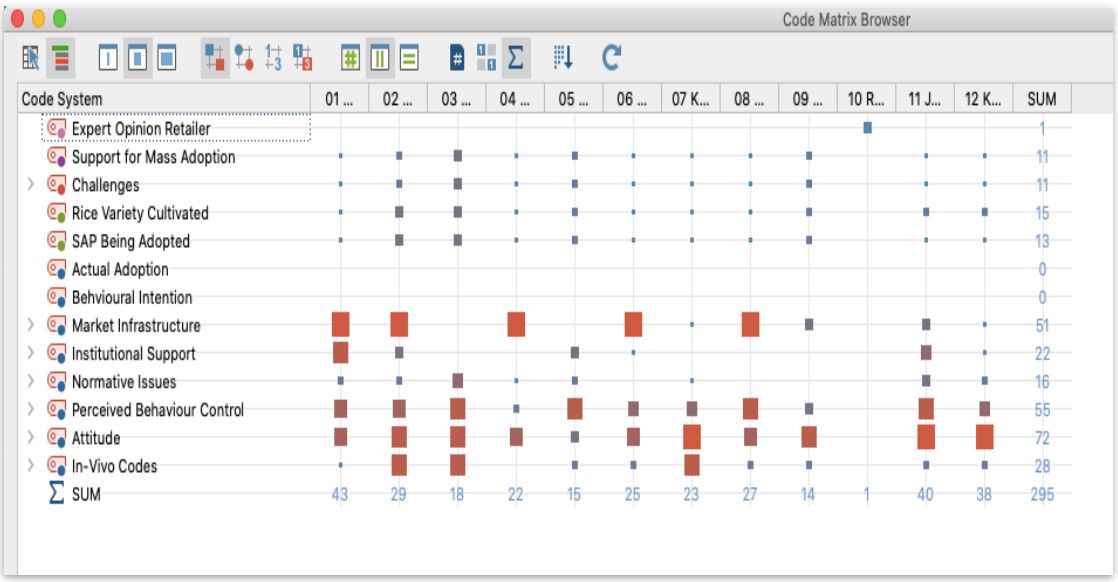
Figure 4.3 ***Word Cloud from Transcript***

Note: *Image captured from Software MAXQDA 22 based on Qualitative Study*

Figure 4.4 *Code Cloud*

Note: *Image captured from Software MAXQDA 22 based on Qualitative Study*

Figure 4.5 *Code Matrix*



Note: *Image captured from Software MAXQDA 22 based on Qualitative Study*

Table 4.3 ***Thematic Analysis leading to Emergent Variable***

Categories	Emergent Themes	Redefining the Themes	Emergent Variables
Farmer's attitude, quality aspect conscious,	Attitude	Attitude	Attitude
extension services, SAP Support Network	Extension Services	Extension Services	Extension Services
Exploitation by corporate, exploitation by traders, trust deficit,	Exploitation	Institutional Support	Institutional Support
Compensation during transition period, Institutional Support, Govt assured procurement, Lack of organic resources, Support Expectation, need for comprehensive policy, regulatory framework,	Institutional Support		
	Need for Comprehensive Policy		
Consumer Apathy,	Consumer Awareness	Market Infrastructure	Market Infrastructure
lack of Industry Infrastructure,	Lack of Industry Infrastructure		
Market Infrastructure, lack of local market, Lack of quality in Basmati in Punjab,	Market Infrastructure		

Categories	Emergent Themes	Redefining the Themes	Emergent Variables
Commitment to farming, Pro-environment, Environmentally Conscious, Incident triggered Transformation, Pro Envt value System, Conscious and aware, Progressive, Pesticide Concern,	Pro Environmental Value System	Pro-Environmental Values	New Ecological Paradigm
Basmati Bio Pesticide Ecological Pest Management, Green Farming Natural farming Organic Farming SAP Bundle for CAP,	Basmati Bio Pesticide Ecological Pest Management Green farming Natural Farming Organic Farming SAP Bundle	Sustainability	
Certification Concerns - complex and expensive,	Compatibility	Perceived Compatibility	Perceived compatibility
Conversion cost,	Conversion Cost		
Complexity of SAP, Comparison with EOU of Conventional Agricultural Practices	Perceived Ease of Use	Perceived Ease of Use	Perceived Ease of Use
Comparison with PU of Conventional Agricultural Practices, Productivity, Profitability, Food security,	Perceived Usefulness	Perceived Usefulness	Perceived Usefulness
Incentive to adopt,	Need for Incentive to adopt		
Experience of CAP, Farming Full time,	Self-Efficacy	Self-Efficacy	Self-Efficacy
Cyclical debt, High Land lease rate, Membership with SAP Network, other employment,	Perceived Resources	Perceived Resources	Perceived Resources
Social Apathy for environmental degradation, Lack of collective Initiative,	Social Apathy for Environmental degradation	Subjective Norms	Subjective Norms
Social Capital,	Social Capital		
Subjective Norms, support network,	Subjective Norms		

***Note**: Author's representation based on findings of Qualitative Analysis through MAXQDA 22*

4.6 Findings

4.6.1 Emergent Themes from Qualitative Study

Table 4.3 represents the emergent themes from the qualitative data analysis. These themes are incorporated into the study by revising the conceptual model with the following 11 variables as listed below.

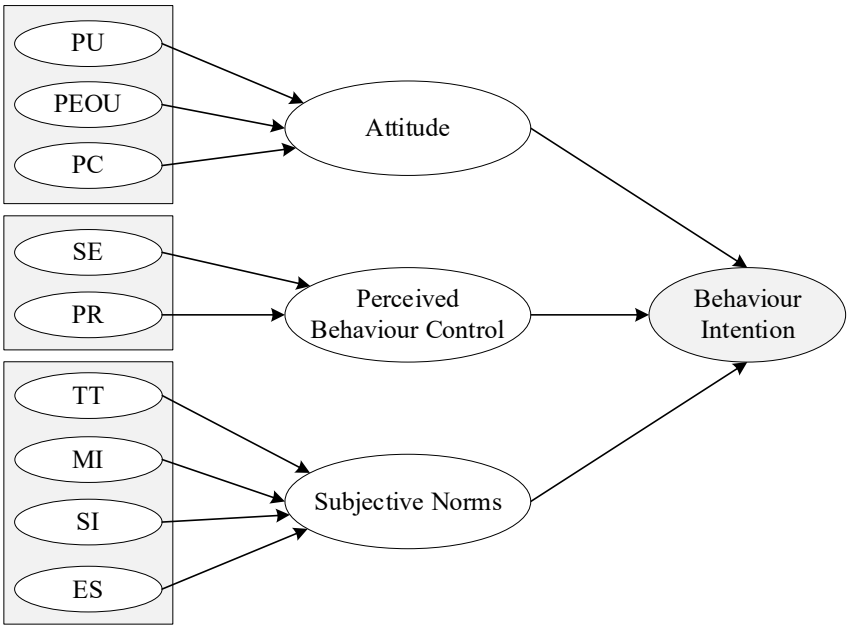
1. Attitude
2. Perceived Compatibility
3. Perceived Ease of Use
4. Perceived Usefulness
5. Self-Efficacy
6. Perceived Resources
7. Subjective Norms
8. Extension Services
9. Institutional Support
10. Market Infrastructure
11. New Ecological Paradigm

The initial 8 variables, namely Attitude, Perceived Compatibility, Perceived Ease of Use, Perceived Usefulness, Personal Efficacy, Persona; Resources, Subjective Norms, Extension Services, have already been discussed in chapter 2 and are the constituent component of the proposed conceptual model shown in Fig 4.6. The remaining 3 variables namely, Institutional Support, Market Infrastructure and New Ecological Paradigm are the new themes and that are brought forward through the qualitative study. The presence of these new variables necessitates revision of proposed conceptual model and is done through extension of decomposed theory of planned behaviour.

4.6.2 Proposed Conceptual Model before the Qualitative study

The proposed conceptual model is adopted from Zeweld et al.,(2017) and is based on the decomposed theory of planned behaviour given by Taylor & Todd (1995). As per the model, the attitudinal beliefs, control beliefs and normative beliefs that led to behavioural intention

Figure 4.6 ***Proposed Conceptual Model***



Note: PU -Perceived Usefulness, PEOU-Perceived Ease of Use, PC-Perceived Compatibility, NEP-New Ecological Paradigm, SE-Self Efficacy, PR-Perceived Resources, TT- Technical Training, MI- Media Influence, SI-Social Influence, ES-Extension Services ,AT-Attitude, PBC-Perceived Behaviour Control, SN-Subjective Norms, BI-Behavioural Intention. Adapted from (Zeweld et. al, 2017)

are further broken down into constituent parts namely Perceived usefulness (of SAP), Perceived Ease of Use (of carrying out SAP) and Perceived Compatibility (of SAP with existing system), Self-Efficacy (to perform SAP), Perceived Resources (availability), Technical Training (Capacity building workshops, field days), Media Influence (formal information channels like TV, News etc), Social Influence (of peers, colleagues, family, friends, leaders) and Extension Services (role of agricultural advisory experts) in rice cultivation. The qualitative analysis of rice growers in Punjab gave results congruent to many of the assumptions in the proposed model. The same have also been found to be validated by the literature support.

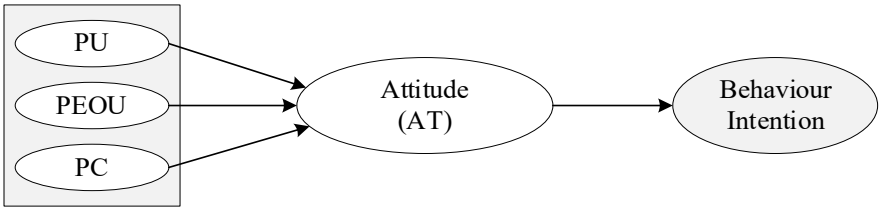
4.6.2.1 Attitudinal Beliefs and behaviour Intention

The qualitative results clearly bring out that Perceived Usefulness, Perceived Ease of Use and Perceived Compatibility lead to Behavioural Intention to adopt. In addition, farmer's positive Attitude also leads to Behavioural Intention to adopt. The same has been corroborated by the LR support too. The research reflects that Attitude positively and significantly impacts the Behavioural Intention (Huat et al., 2017; Yazdanpanah & Fourozani, 2015). A positive and significant impact of Perceived Usefulness on Behaviour Intention is affirmed by (Cheng,

2019; Herrero-Crespo et al., 2021; Herzallah & Mukhtar, 2016; Sharifzadeh et al., 2017; Zeweld et al., 2017)

The positive influence of Perceived Ease of Use on Behaviour Intention is supported by (Chang & Yang, 2012; Cheng, 2019; Herrero-Crespo et al., 2021; Meng, 2011; Oluwajana et al., 2019; Sharifzadeh et al., 2017; Shroff et al., 2011). The positive and significant impact of Perceived Compatibility on Behaviour Intention is supported by (Al-Rahmi et al., 2019; Faqih, 2016; Makanyeza, 2017; Schmidthuber et al., 2020). Therefor the attitudinal belief variables as taken in the proposed model are being retained in the final conceptual model (Fig 4.7).

Figure 4.7 ***Attitudinal beliefs leading to Behaviour Intention***

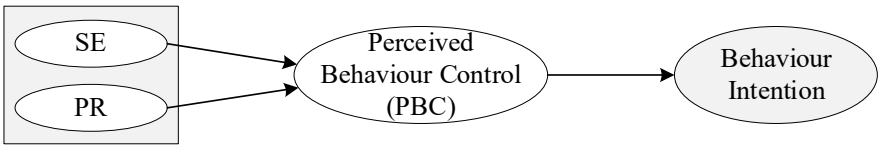


Note: Author's representation

4.6.2.2 Control Beliefs and Behaviour Intention

Perceived Behaviour Control as per the theory of planned behaviour defines the control a subject may have to make a favourable decision. Its primarily boils down to one's capacity to take an action and facilitating conditions that either allow or smoothen the process of decision making for an intended innovation. In broader context, it leads to one's belief in one's ability which acts favourably. In addition, the facilitating conditions can be on account of resources available in personal capacity or available non-personal resources hence called as perceived resources. A significant positive influence of Self-Efficacy on Behaviour Intention has been supported by (Al-Saedi et al., 2020, 2020; Cobelli et al., 2021; Kim et al., 2011; Lavidas et al., 2022). Furthermore, a positive impact of Perceived Resources has been endorsed by (Irani et al., 2009; Lee, 2008; Zeweld et al., 2017). This in fact posits that more a person feels control over his his behaviour (ability to choose to take action) the more his behaviour intention gets significantly impacted which has been confirmed by (Budovska et al., 2020; Klöckner, 2013; Lau & Hashim, 2019; Mohamed et al., 2016; T'ing et al., 2020). Hence the stated variables related to control beliefs have been retained in the final research model (Fig 4.8.)

Figure 4.8 *Control Beliefs and Behaviour Intention*

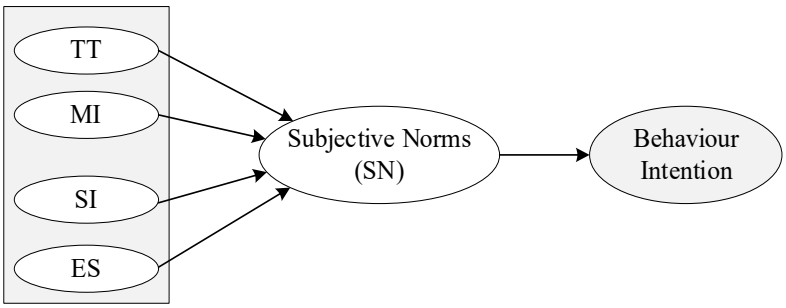


Note: Author's representation

4.6.2.3 Normative Beliefs and Behaviour Intention

Normative Beliefs refers to influence of social situations, one's peers, colleagues, family and friends, and leaders on an individual strong enough to make one take or restrain a behaviour. In the proposed model, based on Zeweld et al.,(2017), the constituent components chosen were Media Influence, Technical Trainings, Social Influence and Extension Services (Fig 4.9). Though there is Literature support available for all the four arms of normative beliefs however the qualitative analysis did not bring about any evidence in support of influence of media i.e. the official news channels like TV, radio or newspapers. Nor did it show any inclination to show any importance to technical trainings However, role of extension services was greatly stressed and a need to have more of support from extension services are expressed freely. There for Media Influence and technical Training are being removed from the study and extension services is being retained. While Social influence did not emerge as a stand-alone factor, but Subjective Norms did make its presence strongly hence both of these variables are being retained in the final version of the research model.

Figure 4.9 *Normative Beliefs and Behaviour Intention*



Note: Author's representation

4.6.2.4 Variables removed from the model after Qualitative Study:

In our proposed conceptual model, which was adopted from the study of Zeweld et al.,(2017), the Subjective Norms had four arms which comprised of Media Influence, Technical training, Social Influence and Extension Services. Social Influence and Extension Services did find its reference and relevance during qualitative research however the Media Influence and Technical Training were found to not have much influence in the study sample group. The

aspect of technical training converged under the support from extension services and therefore variables Media Influence and Technical Training were removed from the proposed conceptual model.

4.6.2.5 Variables added to the study after Phase I of the study

New Ecological Paradigm: Pro-environmental belief system was a strong characteristic that emerged in the qualitative analysis, affirming that those growers who had a strong personal pro-environmental belief chose to adopt Sustainable agricultural practices despite the challenges they faced. The same has been affirmed by Literature as well (Jeong et al., 2021; Moghimehfar et al., 2020; Stern et al., 1995). There for a new variable called "New Ecological Paradigm" which assess the pro ecological viewpoint of the subject is being introduced in the study. The emergent themes in the qualitative study, pro-environmental values and Sustainability, revealed an inherent belief system of the respondent about ecology. To take it further to a wider audience to measure their internal approaches towards environment, "New Ecological Paradigm" was chosen as an exogenous construct that contributes to attitude of the subject. New Ecological Paradigm (NEP) is a scale that is a revised and updated version of "New Environmental Paradigm" developed by Dunlap and Van Liere in 1978. However, in 2000, they came up with a revised version that covers more facets of the construct and has 15 items in place of the original 12 items. The facets covered by the construct are, the reality of limits to growth, anti-anthropocentrism, the fragility of nature's balance, rejection of exceptionalism, and possibility of an eco-crisis. For the sake of this study, an operational definition of the construct, "the extent to which a person holds pro-ecological view as his inherent belief."

Institutional Support: The latent theme behind this construct is the support expectation of farmers, be it government agencies, corporate or private players. The policies related to procurement, MSP, availability of farming related subsidies and its access are some of the prominent themes. Furthermore, covering up of transition period and special focused approach for sustainable farming are ideas that farmers have projected repeatedly in their discussion. Hence, in this research, the operational definition of the construct is defined to be, "Institutional commitment to support and empower the participants to adopt innovation in desired arena."

Market Infrastructure: The respondents across the spectrum were vociferous regarding lack of proper market for sustainable produce. Adding that there hardly were any

incentives for farmers to put in extra efforts as the markets and consumers lack necessary understanding and awareness. This lack of apathy and trust on part of consumers and market forces also play an important role in farmers choosing to stay away from sustainable agricultural practices. So, the operational definition of Marlet Infrastructure for this project has been defined as, "the range of public or private services that facilitate production, procurement, processing, preservation and trade related to the desired innovation."

Social Influence: The theme of Social Influence though did not come up directly in the qualitative research, it was over all subjective norms that was brought forward under the ideas of, social apathy for environmental degradation, lack of collective initiative, references to social capital. Moreover, the role of Extension Services got highlighted by many respondents. Hence to capture the Normative beliefs in a better way, the construct of Social Influence was chosen as it plays a definitive role in decision making.

4.6.3 Literature Support for all the final variables of the research study

Thus, PU, PEOU, PC, Self-Efficacy, Perceived Resources, Social Influence, Extension Services, Attitude, Perceived Behaviour Control, and Subjective Norms were retained in the study. Moreover, New Ecological Paradigm, Institutional Support, and Market Infrastructure were added to the study. Fig 4.10 reflects the revised conceptual model. The scholarly articles concerning the behavioural intention of adoption (of a certain technology) have shown significant positive relation with all the variables used in the study. Table 4.4 presents citation of these positive references in the tabular form.

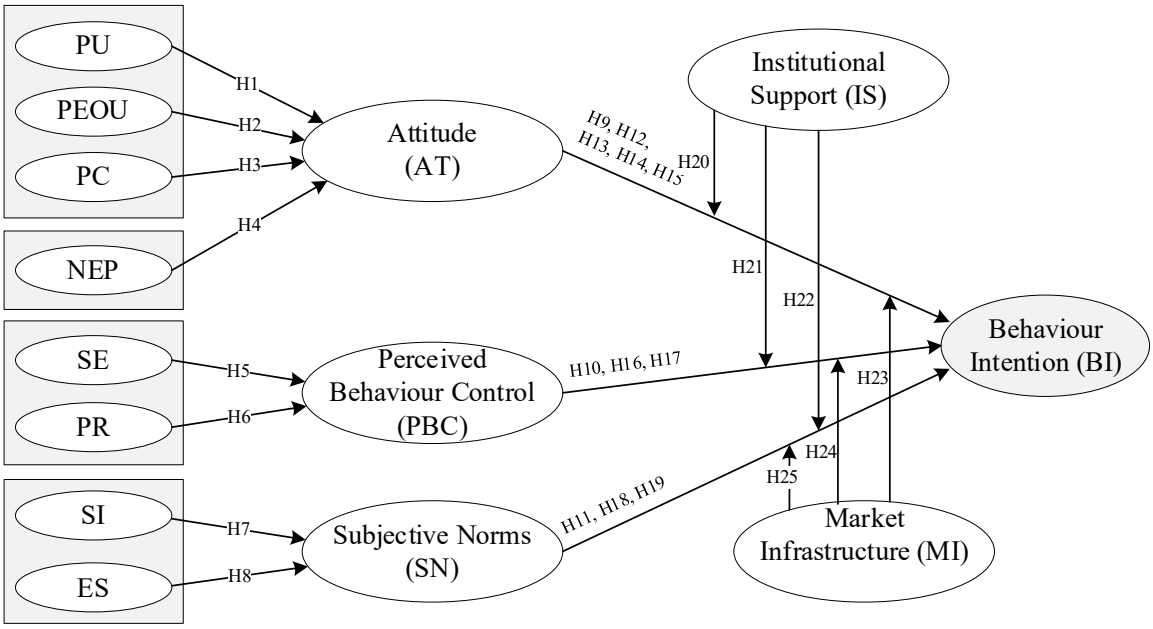
Table 4.4 ***LR Support of the variables of study***

Factors influencing Behaviour Intention	Supported by Authors
Perceived Usefulness	(Cheng, 2019; Herrero-Crespo et al., 2021; Herzallah & Mukhtar, 2016; Sharifzadeh et al., 2017; Zeweld et al., 2017)
Perceived Ease of Use	(Chang & Yang, 2012; Cheng, 2019; Herrero-Crespo et al., 2021; Meng, n.d.; Oluwajana et al., 2019; Sharifzadeh et al., 2017; Shroff et al., 2011)
Perceived Compatibility	(Al-Rahmi et al., 2019; Faqih, 2016; Makanyeza, 2017; Schmidthuber et al., 2020)
New Ecological Paradigm	(Jeong et al., 2021; Moghimehfar et al., 2020; Stern et al., 1995)
Self-Efficacy	(Al-Saedi et al., 2020; Cobelli et al., 2021; Kim et al., 2011; Lavidas et al., 2022)
Perceived Resources	(Irani et al., 2009; Lee, 2008; Zeweld et al., 2017)

Social Influence	(Gursoy et al., 2019; Kammerer & Namhata, 2018; Tarhini et al., 2017)
Extension Services	(Aryal et al., 2015; Myeni et al., 2019; Norton & Alwang, 2020; Sinha & Verma, 2020; Tama et al., 2021)
Attitude	(Huat et al., 2017; Yazdanpanah & Fourozani, 2015; Zeweld et al., 2017)
Perceived Behaviour Control	(Budovska et al., 2020; Klöckner, 2013; Lau & Hashim, 2019; Mohamed et al., 2016; T'ing et al., 2020)
Subjective Norms	(C. Wang et al., 2019; Zeweld et al., 2017)
Institutional Support	(Nikou & Economides, 2019; Umrani & Ghadially, 2003; Yuhua et al., 2022)
Market Infrastructure	(Carrer et al., 2020; Chianu et al., 2007; Kena et al., 2022; Mariyono, 2019)

Note: Collated by author

Figure 4.10 ***Revised Conceptual Framework***



Note: PU -Perceived Usefulness, PEOU-Perceived Ease of Use, PC-Perceived Compatibility, NEP-New Ecological Paradigm, SE-Self Efficacy, PR-Perceived Resources, SI-Social Influence, ES- Extension Services, AT-Attitude, PBC-Perceived Behaviour Control, SN-Subjective Norms, IS-Institutional Support, MI-Market Infrastructure, BI-Behavioural Intention

4.7 Revised Conceptual Model and Hypothesis Formulation:

Based on the proposed conceptual model and findings of the qualitative research, the revised conceptual model (Fig 4.10) is created and following hypothesis are proposed.

Hypothesis:

H1: There is a significant and positive relationship between Perceived Usefulness (PU) to Attitude (AT).

H2: There is a significant and positive relationship between Perceived Ease of Use (PEOU) to Attitude (AT).

H3: There is a significant and positive relationship between Perceived Compatibility (PC) to Attitude (AT).

H4: There is a significant and positive relationship between New Ecological Paradigm (NEP) to Attitude (AT).

H5: There is a significant and positive relationship between Self Efficacy (SE) to Perceived Behaviour Control (PBC).

H6: There is a significant and positive relationship between Perceived Resources (PR) to Perceived Behaviour Control (PBC).

H7: There is a significant and positive relationship between Social Influence (SI) to Subjective Norms (SN).

H8: There is a significant and positive relationship between Extension Services (ES) to Subjective Norms (SN).

H9: There is a significant and positive relationship between Attitude (AT) to Behaviour Intention (BI).

H10: There is a significant and positive relationship between Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

H11: There is a significant and positive relationship between Subjective Norms (SN) to Behaviour Intention (BI).

H12: There is a significant mediation effect of Attitude (AT) in between Perceived Usefulness (PU) to Behaviour Intention (BI).

H13: There is a significant mediation effect of Attitude (AT) in between Perceived Ease of Use (PEOU) to Behaviour Intention (BI).

H14: There is a significant mediation effect of Attitude (AT) in between Perceived Compatibility (PC) to Behaviour Intention (BI).

H15: There is a significant mediation effect of Attitude (AT) in between New Ecological Paradigm (NEP) to Behaviour Intention (BI).

H16: There is a significant mediation effect of Perceived Behaviour Control (PBC) in between Self Efficacy (SE) to Behaviour Intention (BI).

H17: There is a significant mediation effect of Perceived Behaviour Control (PBC) in between Perceived Resources (PR) to Behaviour Intention (BI).

H18: There is a significant mediation effect of Subjective Norms (SN) in between Social Influence (SI) to Behaviour Intention (BI).

H19: There is a significant mediation effect of Subjective Norms (SN) in between Extension Services (ES) to Behaviour Intention (BI).

H20: There is a significant moderation effect of Institutional Support (IS) on Attitude (AT) to Behaviour Intention (BI).

H21: There is a significant moderation effect of Institutional Support (IS) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI)

H22: There is a significant moderation effect of Institutional Support (IS) on Subjective Norms (SN) to Behaviour Intention (BI)

H23: There is a significant moderation effect of Market Infrastructure (MI) on Attitude (AT) to Behaviour Intention (BI).

H24: There is a significant moderation effect of Market Infrastructure (MI) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

H25: There is a significant moderation effect of Market Infrastructure (MI) on Subjective Norms (SN) to Behaviour Intention (BI).

4.8 Chapter Summary

The chapter describes the components and procedures involved in the Qualitative Research. The chapter commences by delineating the sample frame of farmers, comprising a heterogeneous group that includes both practitioners of sustainable methods and adherents of conventional practices. The specifics regarding the interview schedule and data collection

methodology were communicated; the briefest session lasted 30 minutes, while the most extensive, yielding profound insights, lasted 80 minutes. Subsequently, each stage of theme analysis was illustrated with visual representations from MAXQDA, emphasizing code clouds and code matrices. The study identified 13 variables: Perceived Usefulness, Perceived Ease of Use, Perceived Compatibility, and New Ecological Paradigm as Attitudinal beliefs; Self-Efficacy and Perceived Resources as Perceived Behaviour Control beliefs; and Social Influence and Extension Services as Subjective Norm beliefs. Institutional Support and Market Infrastructure have been incorporated as moderators in the study. The chapter finishes by reworking the conceptual framework considering newly emerging topics and presents hypothesis formulation.

5. Chapter 5 - Research Instrument, Sampling Design, Data Collection

"80% of your work is done with 20% of your tools." - Joseph Juran

5.1 Overview

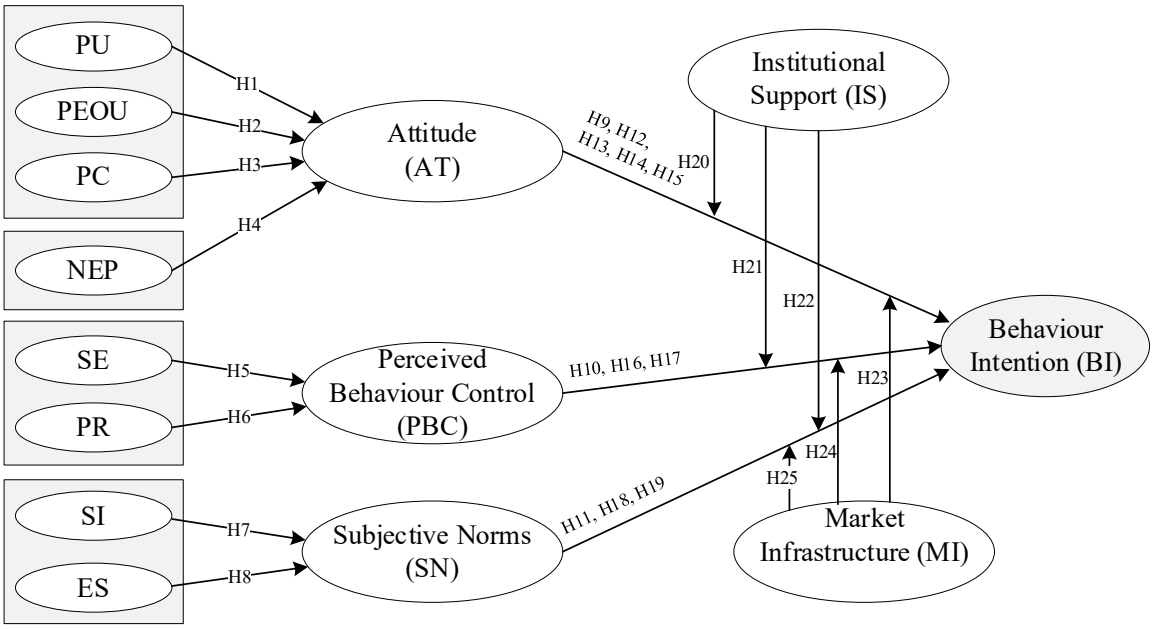
The chapter commences with an examination of the completed conceptual model. The subsequent section presents the construct specification through an operational definition for the current study, followed by the scale designing. The chapter subsequently details the procedure for finalizing the research instrument, commencing with face validity assessed by expert opinion, followed by content validity evaluation. The designed questionnaire was utilized for a pilot survey, leading to reliability assessment of the instrument. The final section of the chapter presents the sampling plan and procedure adopted for quantitative data collection.

5.2 Research Model of the study

The Decomposed Theory of Planned Behaviour (DTPB), presented by Taylor and Todd (1995), served as the theoretical foundation for the conceptual model that was proposed, as was discussed in Chapter 2. This model was made with an extensive literature review. As per DTPB, in the suggested model, the attitude is further decomposed into its constituents' elements being Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and Perceived Compatibility (PC). The Behavioural Control beliefs are further categorised into Self-Efficacy and Perceived Resources. Whereas the Normative beliefs under Subjective Norms are taken to be Media Influence (MI), Technical Training (TT), Social Influence (SI) and Extension Services (ES). The model postulates that these constituent variables lead to Behavioural Intention and are mediated by variables Attitude, Perceived Behaviour Control and Subjective Norms. As the research design involved a mix of different research methods. In the first part of the qualitative research, interviews were carried out, and a grounded theory approach was utilized to conduct thematic analysis of the data. The results of the qualitative research led to the discovery of new themes, which were then incorporated into the proposed conceptual model. The emergent variables were New Ecological Paradigm (NEP), Institutional Support (IS) and Market Infrastructure (MI). The NEP represents the ecological disposition of the respondents, Institutional Support is all about the facilitating environment available from the government or NGOs like the policies or subsidies or support prices etc. The Market Infrastructure refers to the availability of government agency, and private player that influence the prices and procurement of the final produce. The findings of the first phase also required the elimination of certain variables from the model as the respondents did not find those variables to be of great value. Media Influence and Technical Training found no merit with the farmer. In the interview

discussions, neither of the participants agreed to getting influenced by official news channels or radio in decision making. Therefore, both these variables were removed from the Normative beliefs. Furthermore, the variable Social Influence, which was a part of the Normative Beliefs, though did not emerge as a separate variable but it did make its presence felt covertly as Subjective Norms got repeated multiple times hence this variable was retained as Normative Beliefs. The revised conceptual model of the study, fig 5.1 has four attitudinal components, PU, PEOU, PC and NEP. The Control and Normative beliefs each have two components each SE and PR, and SI, ES respectively. These beliefs lead to behavioural intention and are mediated by Attitude, Perceived Behaviour Control and Subjective Norms. In addition, Institutional Support and Market Infrastructure moderates the mediating relationships from Attitude, PBC and SN to BI respectively.

Figure 5.1 ***Revised conceptual model***



Note: PU -Perceived Usefulness, PEOU-Perceived Ease of Use, PC-Perceived Compatibility, NEP-New Ecological Paradigm, SE-Self Efficacy, PR-Perceived Resources, Si-Social Influence, AT-Attitude, PBC-Perceived Behaviour Control, SN-Subjective Norms, IS-Institutional Support, MI-Market Infrastructure, BI-Behavioural Intention

5.3 Formalising the Constructs

The constructs utilized in the research model have been systematically established in the study via operational definitions and scale development. The support has been derived from the literature review and the findings of Phase I of the study, which involved qualitative research. Furthermore, the study aimed to address a significant inquiry regarding the awareness

and frequency of SAP usage among the rice growers of Punjab. Chapter 2 presents comprehensive insights into a range of sustainable methods and their advantages that can be implemented in rice cultivation. It is essential to establish a fixed set of practices to evaluate awareness and frequency of use. The following section outlines the details related to this matter.

5.3.1 The SAP Chosen for the study

It can clearly be surmised that there exist a lot of alternatives to conventional farming system which when adopted can bring about a sea change. India has almost 60% of its population dependant on agriculture directly or indirectly but this profession has not remained profitable anymore. Even the most productive states like Punjab are grappling with adverse effects of ecological degradation and economic losses today. Rightly called as Father of Green Revolution, M. S. Swaminathan, gave the clarion call for "Evergreen Revolution" which implies productivity improvement in perpetuity without ecological and social harm. The evergreen revolution involves the integration of ecological principles in technology development and dissemination. The mode at the core of this approach is minimum intervention with the ecosystem. This study is being undertaken with the understanding and belief that Punjab can once again take the lead and be a pioneer for "Evergreen Revolution". And since Rice the major crop for which Punjab is one of the biggest contributors in the central pool, it would make sense to see the potential of the same. Of the many options available, for the sake of this study, we have chosen certain set of practices (See Table 5.1) in accordance with 6 major themes out of the total eight given in the SRP standard. The SRP Standards have been discussed at length in chapter 2. This includes Farm Management, Pre-planting, Water Use, Nutrient Management, Integrated Pest Management, Harvest and Post Harvest. There is additional LR validation for choosing these practices in table 5.1. These practices have been chosen since they have maximum impact, are comparatively easier to adopt, do not have any agency problems as farmers can source the inputs on their own and have the franchise to make decisions for themselves rather depend on someone else. As part of the study, we wish to find out of farmers are aware of these practices and do they know the advantages of these practices. Furthermore, if they know, are they practicing it. The final statements chosen for the research instrument have been listed under table 5.2.

Table 5.1 *Literature Support for the SAP chosen for the study*

SRP Theme	SRP Theme Requirement	Practice Chosen for study	LR
Farm Management	Crop Calendar	Basmati (Short duration seed variety), Delayed Transplantation	(Akenroye et al., 2021; Anibaldi et al., 2021; Manda et al., 2015; Piñeiro et al., 2020; Zeweld et al., 2017)
Pre-planting	Levelling, Land Conversion and biodiversity, Pure Seed Quality	Use of Land Leveller, Minimum Tillage, Seed Quality	
Water Use	Groundwater Extraction	Direct Seeding of Rice (DSR)	
Nutrient Management	Organic Fertilizer Choice, Inorganic Fertilizer Choice	Use of Farmyard Manure, Use of Compost, Optimum use of Urea, Cover crop (legumes)	
Integrated Pest Management	Integrated Pest Management	Using Biological Pesticides	
Harvest and Post-harvest	Rice Stubble, Rice Straw	Stubble burning, Direct Seeding of Wheat	

Note. Author's representation based on Literature Review

Table 5.2 *Awareness and Frequency of Use Statements*

S No	Statement
AW1	I am aware that using a Land Leveller helps in water and soil conservation.
FOU1	I use land leveller in my field every year or alternate year.
AW2	I know that applying Farmyard manure in farm enriches soil fertility.
FOU2	I use farm-yard manure in my farm every year.
AW3	I think compost is best way to manage waste and enhance health of farm soil.
AW4	I think reduced tillage helps in maintaining productivity of farm soil.
FOU3	I do minimum of four times or more tilling in my rice field.
AW5	I am aware that excessive usage of Urea deteriorates the quality of soil nutrients and leaches to water bodies and contaminate them.
FOU4	I broadcast Urea more than 3 times in my rice farms
AW6	I know that green manure like Jantar/Legumes can help in Nitrogen fixation and lead to lesser need of urea broadcast.
FOU5	I grow Jantar/Moong in field before rice crop.
AW7	I think that Basmati cultivation could help to prevent decline of ground water in Punjab.
FOU6	I grow Basmati every year.
AW8	I think that direct seeding of rice can help in saving water and labour cost.
FOU7	I grow rice with direct seeding method.
AW9	I feel that delayed transplantation helps in saving ground water by making good use of monsoon water.

S No	Statement
FOU8	I always grow rice as per the recommended date of transplantation.
AW10	I am aware that crop residue acts as natural nutrient for soil and following crop.
FOU9	I burn the paddy crop residue after harvest.
FOU10	I use seed variety which gives maximum yield.
FOU11	I use biological pesticides in my rice farm.
FOU12	I grow wheat using direct method/happy seeder.

Note. Author's representation

5.3.2 Latent Constructs: Operational Definitions and Scale Designing

5.3.2.1 Attitudinal Beliefs

Perceived Usefulness is the extent to which a person believes that using the system will enhance his or her job performance. The scale has been adapted from Venkatesh & Davis 2000 and is re-worded to suit the farming community. The usefulness of the SAP has been equated with soil fertility, saving of ground water, more savings on the input and thus being advantageous. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Perceived Usefulness (PU)	Statements	Source
PU01*	I think rice cultivation using SAP helps in making the soil fertile and nutrient rich.*	(Venkatesh & Davis, 2000)
PU02	I feel that rice cultivation using SAP helps in increase in the ground water table.	
PU03	I think rice cultivation using SAP saves my cost by not spending on expensive agrochemicals.	
PU04	I think the advantages of rice cultivation using SAP are more than the disadvantages.	

Perceived Ease of Use is the extent to which a person believes that using the system will be free of effort and is adapted from Venkatesh & Davis 2000 and accommodates the farming context and some of the statements have been negatively worded to ensure an active engagement. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Perceived Ease of Use (PEOU)	Statements	Source
PE01	I feel it will be hard to do rice cultivation using SAP.	

Perceived Ease of Use (PEOU)	Statements	Source
PE02	I feel it will be difficult to do weeding in rice cultivation using SAP	(Venkatesh & Davis 2000)
PE03	I feel it will be tough to learn to do rice cultivation through SAP.	
PE04*	I feel Rice cultivation through SAP involves more labour as compared to conventional method.*	

Perceived Compatibility The degree to which the innovation fits with the potential adopter's existing values, previous experiences and current needs and is adapted from Taylor & Todd 1995. The farmer's understanding of Compatibility of SAP is checked by asking statement comparing it to the existing system. In addition, query about requirement of additional knowledge or machinery is also made. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Perceived Compatibility (PC)	Statements	Source
PC01	I can do Rice cultivation through SAP along with conventional farming.	(Taylor & Todd 1995)
PC02	I require additional tools or machinery for SRC.	
PC03	I need more knowledge about pest management and disease control in SAP.	
PC04	I need separate storage system for pesticide free rice produce.	
PC05*	I feel that a set of substantial buyers are required for sustainable produce.*	

New Ecological Paradigm is a measure of endorsement of a "pro-ecological" world view of the respondent and is adapted from Dunlap et. al 2000. The scale consists of 15 items however, for the study only 6 items were chosen. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

New Ecological Paradigm :	Statements	Source
NEP01*	I think Humans will naturally learn enough about how nature works to be able to control it.*	(Dunlap et al., 2000)
NEP02	We are approaching the limit of the number of people the earth can support.	

New Ecological Paradigm :	Statements	Source
NEP03	When humans interfere with nature it often produces disastrous consequences.	
NEP04	Human ingenuity will ensure that we do NOT make the earth unliveable.	
NEP05	The earth has plenty of natural resources if we just learn how to develop them.	
NEP06*	I think if things continue their present course, we will soon experience a major ecological catastrophe. *	

5.3.2.2 Behaviour Control Beliefs

Self-Efficacy is an individual's self confidence in his/her ability to perform the behaviour. The scale has been adapted from Bandura 1977 and catered to farmer's understanding. The statements have been suited to ask farmers if they feel confident to do rice cultivation in a sustainable manner

Self-Efficacy	Statements	Source
SEF01	I am confident that If I wish, I can do Sustainable Rice Cultivation.	(Bandura, 1977)
SEF02	I am confident that I can collect desired information and knowledge for SRC.	
SEF03	I feel it should be easy for me to learn this new method of rice farming with SAP.	
SEF04	I believe I can succeed at growing rice sustainably and making profit.	

Perceived Resources is defined as the degree to which the person feels he has necessary resources (money, time, labour etc) to carry out the innovation. The scale has been adapted from Taylor & Todd (1995). The statements chosen, cover the various aspects related to availability of land, technical knowledge, home-based inputs and access to extension services.

Perceived Resources	Statements	Source
PR01	I have land to experiment with SRC methods.	(Taylor & Todd 1995)
PR02	I can avail technical knowledge through seminars organised in my area.	
PR03	I am benefitted from extension service team regarding information and knowledge.	
PR04	I have most of the SAP inputs readily available at home.	

5.3.2.3 Normative Beliefs

Social Influence The extent to which participants feels socially influenced by one's peers, colleagues, superiors, leaders, family and or events of the surrounding and is adapted from Taylor & Todd 1995.

Social Influence	Statement	Source
SI01	I will adopt SAP in rice cultivation if other farmers in the village/block adopt it.	(Taylor & Todd 1995)
SI02	I would be interested to cultivate rice using SAP if there are more successful farmers doing so.	
SI03	I have often adopted new farming practices by observing other farmers.	
SI04	I will have to use SAP in rice cultivation if the traders insist on sustainable rice.	

Extension Services The degree of influence on behaviour and decisions by information or consultation with agricultural advisory experts and extension workers. The scale has been adapted from Zeweld et. al who have conducted an empirical study on similar grounds in Africa. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Extension Services (ES)	Statement	Source
	The degree of influence on behaviour and decisions by information or consultation with agricultural advisory experts and extension workers.	(Zeweld et al., 2017)
ES01	I think extension services can influence me in adopting sustainable methods in rice cultivation.	
ES02*	I have witnessed farm demonstrations and Field-days of SAP in rice cultivation.*	
ES03*	I feel there is need to enhance the number of technical training sessions regarding SAP in rice cultivation.*	
ES04	I have more trust on extension officials than private company representatives.	
ES05	I have the opportunity available to regularly attend training/workshop/seminar/webinar to get information and knowledge about SAP in rice cultivation.	

Extension Services (ES)	Statement	Source
ES06	I can conveniently reach out to extn office in my region and avail various products and services.	

5.3.2.4 Mediators

Attitude Reflects feelings of favourableness or unfavourableness towards performing a behaviour. It has been adapted from Taylor & Todd 1995. Their statements have been converted to reflect favourable behaviour attitudes for SAP in rice cultivation.

Attitude	Statements	Source
A01	I like the idea of adopting SAP in rice cultivation.	(Taylor & Todd, 1995)
A02	I think adopting SAP in rice cultivation is a wise decision.	
A03	I think adopting SAP in rice cultivation is a great idea.	
A04	I think adopting SAP in rice cultivation is a good step to save nature.	

Perceived Behaviour Control Reflects perceptions of internal and external constraints on behaviour. The statements have been worded such that it can be assessed if the farmer has the ability to afford and implement SAP in rice cultivation practices.

Perceived Behaviour Control	Statements	Source
PBC01	I have the resources and ability to afford SAP in rice cultivation.	Taylor & Todd 1995
PBC02	I have the resources and ability to implement SAP in rice cultivation.	
PBC03	I would be able to afford SAP in rice cultivation.	
PBC04	I would be able to implement SAP in rice cultivation.	

Subjective Norms Reflects perceptions that significant referents desire the individual to perform or not perform a behaviour. The scale has been adapted from Taylor & Todd 1995.

Subjective Norms	Statements	Source
SN01	I think I would adopt SAP in rice cultivation because there are successful farmers who expect me to do so.	(Taylor & Todd 1995)
SN02	I think I would adopt SAP in rice cultivation because my family members want me to do so.	
SN03	I think I would adopt SAP in rice cultivation because extension service officers expect me to do so.	

Subjective Norms	Statements	Source
SN04	I think I would adopt SAP in rice cultivation because the traders and exporters expect me to do so.	

5.3.2.5 Moderators

Institutional Support Institutional commitment to support and empower the participants to adopt innovation in desired arena. The scale is adapted from Busenitz W et. al, 2000 and covers the regulatory dimension of institutional support. The statements are converted in the context of farming support regulated by government efforts.

Institutional Support	Statements	Source
IS01	I know that govt is making many efforts for promoting Sustainable/Organic Agriculture by subsidies and other certification support.	(Busenitz W et al., 2000)
IS02	It is easy for me to avail services related to promotion of SAP in rice cultivation.	
IS03	I think govt should provide for the conversion/adoption cost. in the beginning years. (e.g. labour from MNREGA, or free bio-pesticides)	

Market Infrastructure The range of public or private services that facilitate production, procurement, processing, preservation and trade related to the desired innovation. The scale is adapted from Carrer et. al, 2020. The statements indicate the context for markets exclusively for Sustainable produce of rice. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Market Infrastructure	Statements	Source
MI01*	I feel there is not enough demand for sustainable rice.*	(Carrer et al., 2020)
MI02	I think the rice grower has no advantage for his pesticide free produce.	
MI03	I find that there is no price premium for sustainable produce of rice.	
MI04*	I feel, the rice industry needs to mature with more local rice business players.*	
MI05	I think that govt should develop infra structure for sustainable rice or/and Basmati.	
MI06	I could adopt rice cultivation with SAP If there are export oriented infrastructure.	

Market Infrastructure	Statements	Source
MI07	I find that there are many NGOs engaged in sustainable practices in my area.	

5.3.2.6 Final Dependant Variable

Behavioural Intention The intentions to use desired innovation, adapted from Taylor & Todd, 1995. The statement(s) marked * got eliminated in the process of checking reliability to improve the Cronbach Alpha reading.

Behavioural Intention :	Statements	Source
BI01	I intend to use SAP in rice cultivation.	(Taylor & Todd, 1995)
BI02	I have plans to move to SAP in coming few years.	
BI03*	The fear of yield loss prevents me from trying SAP. *	
BI04	I intend to adopt diversification even if there is no MSP	
BI05*	I intend to do rice cultivation using SAP on my own land and not on leased land.*	

5.4 Research Instrument: Validity Assessment

A structured questionnaire was created based on the Research Model devised post incorporation of findings of the qualitative study. The survey questionnaire incorporated 14 latent variables with 64 items and 2 variables of Awareness and Frequency of Use with 10 and 12 items respectively. Thus, a total of 86 items were incorporated in the instrument. All the statements were measured on 5-point Lickert Scale on agreeableness to the statements with 1.Strongly Disagree, 2.Disagree, 3. Neither Disagree Nor Agree, 4.Agree and 5.Strongly Agree . The instrument was thoughtfully crafted to ensure that farmers find it easy to comprehend and respond.

5.4.1 Face Validity

Validity assessment involves evaluating whether the instrument accurately measures the intended construct. The initial stage involves conducting Face Validity, which relies on subjective assessments by field experts. The items will be assessed according to criteria of vagueness, clarity, redundancy, fairness, and significance. Table 5.3 displays the suggestions received from the selected experts, comprising of established figures from the agricultural sector and academics. The research instrument incorporated all suggestions.

Table 5.3 *Suggestions for Face Validity*

S No	Suggestion
1	Suggested changes in the tone of the wording of the statement so that there is better coherence in communication.
2	Suggested that instrument is okay but will yield optimum results if only is self-administered and in local language.
3	In Perceived Usefulness construct - Simplify the statement by talking about useful advantages of SAP.
4	Suggested some wording change in Institutional Support which could lead to an agreeable response.
5	Suggested that In Perceived Resources statement need to create more specificity to imply personal resources too that are to be used in SAP
6	Suggested that instrument is okay but must be communicated in Punjabi to the growers.
7	1.Suggsested to draft all the questions in first person version on behalf of the respondent. 2.For level of awareness and frequency of use, combine the statements and use the same scale of agreement.
8	Suggested that other than govt institution other service delivery institutions should also be included.

Note. *Author's representation*

5.4.2 Content Validity

Content validity This validity assesses how well the items designed to operationalize a construct sufficiently and representatively encompass all possible measures of the construct in question. Content validity generally depends on expert judgment, given the absence of a statistical test to evaluate whether a measure adequately encompasses a content area or accurately reflects a construct (Kimberlin & Winterstein, 2008). The set of experts who helped in face validity were again engaged for assessing content validity. Participants were asked to assess the degree of relevance of each statement in the construct, which was clearly defined and explained, using a scale from 1 to 4, where 1 indicates not relevant, 2 somewhat relevant,

3 quite relevant, and 4 most relevant. The collected data was organized, with unanimity assigned a code of 1 and all other instances coded as 0. According to the CVI formula, all items with a value less than 0.83 were excluded. The final S-CVI was determined to be 0.88, which is deemed acceptable per Polit et al. (2007).

5.5 Pilot Study: Reliability of the Research Instrument

Small pilot studies are likely to produce inaccurate estimates of the standard deviation for power calculations. From a statistical perspective, the sample size for a pilot study should be established according to the desired confidence level for the standard deviation, as well as the chosen power and significance levels for the main analysis; generally, a pilot study with a minimum of n = 50 is advised under conditions of high confidence (Sim & Lewis, 2012). Hence Pilot research involving 50 participants was undertaken to elucidate potential concerns associated with the items of the various instruments being examined. A 10% of the sample size is recommended number. This facilitates the comprehension of concerns pertaining to response and inquiry formats, while also improving the clarity of measurement equipment. The questionnaire's reliability was evaluated by Cronbach's Alpha utilizing SPSS statistical software. The pilot study was conducted on a restricted sample, undertaken with significant caution, and the results have not been generalized beyond this sample. The main objective is to evaluate reliability without any other factors. The constructs PU, PEOU, PC, NEP, ES, MI and BI required removal of some items to improve the Cronbach's Alpha. The final research instrument had 14 variables with 53 items. In addition, along with demographic information, there were 22 items which captured their level of awareness and frequency of use of SAP in rice cultivation making the total number of items to be 75. The Table 5.4 presents the pre-testing results, demonstrating that the Cronbach alpha values for all constructs of the measurement instrument surpass the threshold of 0.7. In additional to measuring these constructs, some demographic information was also collected from the respondents. This included farmer and farm characteristics, perception on climate change and ground water depletion. The demographic section was placed at the end of the questionnaire. The final research instrument is available as Appendix B.

Table 5.4 ***Reliability Statistics of Pilot Study***

Reliability Statistics of Pilot Study			
S No	**Variable**	**Cronbach's Alpha**	**No. of Items**
1	Perceived Usefulness (PU)	0.700	3
2	Perceived Ease of Use (PEOU)	0.709	3
3	Perceived Compatibility (PC)	0.722	4

Reliability Statistics of Pilot Study			
S No	**Variable**	**Cronbach's Alpha**	**No. of Items**
4	New Ecological Paradigm (NEP)	0.722	4
5	Self-Efficacy (SE)	0.847	4
6	Perceived Resources (PR)	0.733	4
7	Social Influence (SI)	0.730	4
8	Extension Services (ES)	0.704	4
9	Attitude (AT)	0.704	4
10	Perceived Behaviour Control (PBC)	0.847	4
11	Subjective Norms (SN)	0.733	4
12	Institutional Support (IS)	0.781	3
13	Market Infrastructure (MI)	0.741	5
14	Behaviour Intention (BI)	0.740	3
	Total		53

Note: Author's representation

5.6 Sampling Design and Quantitative Data Collection

5.6.1 Sampling Plan – Frame and Method

The sampling procedure, size, and response rate influence the representativeness of the sample (Acharya et al., 2013). The study's target group comprises of rice growing farmers in Punjab. The objective of the study is to understand the perception of rice cultivating farmers to adopt Sustainable Agricultural Practices. In the Phase I of the study qualitative data collection was carried out through semi-structured scheduled interviews. In this phase II of quantitative data collection, findings of the Phase I have been incorporated into the research instrument and a large data set is to be created through survey method for generalizability of the findings. A sample frame precisely reflects the population. The target population is rice growers of Punjab. The intent is to check their inclination towards Behavioural Intention to adopt Sustainable Agricultural Practices (SAP) in rice cultivation. The sampling frame is, set of rice growers who are using only conventional methods in rice cultivation. The sample size calculation is based on the Yamen's formula. The farming population of Punjab is mentioned as 19,35,000 as per Punjab Statistical Abstract (Directorate of Statistics, Department of Planning, Govt of Punjab, 2023). The Yamen formula calculation with 95% confidence level sets the sample size at 400. A multistage sampling technique has been adopted for quantitative data collection. Rice cultivation is spread all over the state of Punjab. The sample selection was done according to the categorisation of Punjab into defined five Agroclimatic Zone (ACZ) which are based on terrain, type of soil, amount of rainfall etc. The sample proportion chosen from each zone was proportional to the area under rice production in each zone. ACZ III, the Central Plain grows

50% of rice of the state, followed by ACZ V, the Western Zone with 24%. ACZ IV, I and II respectively grow 13%, 9% and 4% and accordingly was covered in sample selection. Table 5.5 indicates that ACZ III have 50% representation in sample accounting for 201 participants. The rest of the ACZ V, IV, I and II had 24%,13%, 9% and 4% inclusion in the total sample size of 400 which translated to 102, 48, 33, 16 respectively.

Table 5.5 ***Sample Proportion as per Agro-Climatic Zones wise rice-production***

ACZ of Punjab	Total Production of Punjab (A) = 12675		Total Sample Size (D) = 400	
	Total Production of ACZ (B)	Total Production % of ACZ to State Production (C) = (B/A*100)	Sample Size for ACZ = (C * D)/100	Sample Size Contribution
1-SubMountain Undulating	1035	8.17	32.66	33
II-Undulating Plain	500	3.94	15.78	16
III-Central Plains	6381	50.34	201.37	201
IV-Western Plain	1518	11.98	47.91	48
V- Western Zone	3241	25.57	102.28	102

Note. Author's representation

Table 5.6 further proportionate the data according to the district wise rice production. The final step of the research project consisted of putting a validated research instrument through its paces on the chosen bigger sample size of 400 by the survey method. The survey was self-administered and communicated with the farmers in Punjabi language. The author has native proficiency in Punjabi language.

Table 5.6 *District wise sample distribution proportionate to rice production levels*

ACZ of Punjab	Total Production of Punjab (A) = 12675	Total Sample Size of Punjab (D) = 400					
ACZ	ACZ Rice Production (B) (000metric tonne)	Sample Size (E)	ACZ Distt	ACZ Distt Rice Production (F)	Production % of Distt to ACZ Production (G) =(F/B*100)	Distt Sample Size = (G *E)/100	Distt Sample Size (H)
ACZ 1-SubMountain Undulating	1035	33	Gurdaspur	637	62	20.31	20
			Pathankot	86	8	2.74	3
			Hoshiarpur	312	30	9.95	10
ACZ II-Undulating Plain	500	16	SBS Nagar	251	50	8.032	8
			Rupnagar	144	29	4.608	5
			SAS Nagar	105	21	3.36	3
III-Central Plains	6381	201	Amritsar	598	9	18.87	19
			Tarn Taran	707	11	22.31	22
			Kapurthala	496	8	15.65	16
			Jalandhar	713	11	22.50	22
			Ludhiana	1211	19	38.22	38
			Fatehgarh Sahib	366	6	11.55	12
			Sangrur	1362	21	42.98	43
			Patiala	928	15	29.29	29
IV-Western Plain	1518	48	Ferozepur	775	51	24.51	25
			Faridkot	436	29	13.79	14
			Fazilka	307	20	9.71	10
V-Western Zone	3241	102	Moga	826	25	26.00	26
			Barnala	525	16	16.52	17
			Mansa	489	15	15.39	15
			Bathinda	764	24	24.04	24
			Sri Muktsar Sahib	637	20	20.05	20

Note. Author's representation

5.6.2 Data Collection and Analysis

The data collection was self-administered. It was ensured that the farmer selected was engaged in rice cultivation for at-least last five years and had some land ownership that allows him franchisee to make decisions on his own. In addition, a welcoming approach in addition to consent was sought before engaging in the data collection process. The conversations were carried out in an informal manner and in vernacular to facilitate an ease of interaction with the respondents. The research instrument was communicated in Punjabi language to the farmer. The conceptual constructs and typical terms like "Sustainable Agriculture" or technologies like

“Precision Agriculture”, “Direct Seeding of Rice” etc were discussed and their meaning were explained to the farmers. An average survey administration took around 25 minutes. The collected data was carefully uploaded for analysis. A variety of statistical tools were utilized to analyse the quantitative data. The study employed an exploratory and descriptive approach, utilizing exploratory factor analysis via principal component analysis, confirmatory factor analysis, structural equation modelling (SEM), and descriptive statistics including percentage, mean, standard deviation, skewness, and kurtosis for data analysis. Microsoft Excel, SPSS version 27, and SmartPLS 4 were employed to evaluate the quantitative data acquired for the study. The steps involved in data analysis and results are discussed at length in the subsequent chapter

5.7 Ethical Considerations

All ethical considerations were kept in mind. The study has complied with research ethics to avoid any breaches of ethical standards. The questionnaire included items that clearly indicated the responses were collected for academic research purposes, and participants consented to provide their answers. The research objective was clearly communicated to all interview participants during the investigation. Some respondents expressed objections to the disclosure of their names, whereas others provided consent for their names to be recorded. The participants were adequately informed that the confidentiality of the data would be preserved and that there was no associated risk in participating in the survey. Additionally, participants were informed of their option to withdraw from the study at their discretion.

5.8 Chapter Summary

The chapter begins with highlighting the research model and then moves on to formalising the constructs. The standards from Sustainable Rice Platform have been the guiding force behind the SAP chosen to be tested for awareness and frequency of use for the study. Then the scale source and statements have been presented. The research instrument is put through validity and reliability criteria in a pilot study and have been found to be valid and reliable. In the end, sampling procedure for quantitative data collection with ethical considerations have been summarised.

6. Chapter 6 – Quantitative Data Analysis & Results

"Above all else, show the data." - Edward R. Tufte

6.1 Overview

The chapter begins with presenting the descriptives, highlighting demographic assessment of the sample set and then provides descriptive statics of the variables. The second section of the chapter describes the exploratory factor analysis. Third section of the chapter depicts measurement model assessment of the proposed conceptual model. The last section deals with Structural model assessment, moving from direct effect of key factors on the endogenous construct (BI) to Mediation analysis and concludes with moderation analysis.

6.2 Descriptive Analysis

6.2.1 Demographic Assessment

The demographic statistics provide a comprehensive overview of the participants' characteristics in this study and is presented in table 6.1.

Gender: The distribution of gender is of all male participants; there were no female farmers respondents across the state. The reason is that women in Punjab are not engaged actively as lead in the farming occupation. They, however, have a significant role to play in terms of a supportive partner for cattle rearing or allied activities.

Age: In terms of age distribution, the largest group falls within the 41 to 50 years category, comprising 29.76% (n = 122) of the respondents. This is followed by the 31 to 40 years age group at 24.88% (n = 102) and the 21 to 30 years group at 18.78% (n = 77). The 51 to 60 years category represents 16.10% (n = 66), while those aged 61 to 75 years account for 10.49% (n = 43).

Farming Experience: When examining farming experience, most participants have between 20 to 29 years (29%, n = 119) and 10 to 19 years (26.8%, n = 110) of experience, highlighting a strong presence of seasoned farmers. Those with 1 to 9 years of experience represent 17.56% (n = 72), while participants with 30 to 39 years, 40 to 49 years, and 50 or more years of experience comprise 13.90% (n = 57), 9.76% (n = 40), and 2.93% (n = 12), respectively.

Land Ownership: Regarding land ownership, the biggest category is 10-25 acres holders (38.78%, n = 159), followed by 5-10 acres holders (36.59%, n = 150). While 2.5-5

acres ranked third (14.15%, n = 58), the >25acres category followed the suit with 6.83% (n = 28). The 0-2 acres category was the lowest with 4% and (n=15)

Education: With respect to education level, the highest percentage of respondents (30.98%, n = 127) completed 12 years of education. Participants with matriculation (24.15%, n = 99) and primary education (17.56%, n = 72) follow. Graduates comprise 15.85% (n = 65), while those with middle class 8%, (n=33) and post-graduation were 3.4%, (n=14).

Overall, these demographic statistics reveal a diverse group of participants characterized by a strong representation of middle-aged, married individuals with substantial farming experience and varying educational backgrounds.

Table 6.1 ***Demographic Characteristics***

	Categories	**Frequency**	**Percent**
Age Category	21 - 30 Years	77	18.78
	31 - 40 Years	102	24.88
	41 - 50 Years	122	29.76
	51 - 60 Years	66	16.10
	61 - 75 Years	43	10.49
Land Ownership	Marginal	15	3.66
	Small	58	14.15
	Semi- Medium	150	36.59
	Medium	159	38.78
	Large	28	6.83
Farming Experience Categories	1 - 9 years	72	17.56
	10 - 19	110	26.83
	20 - 29	119	29.02
	30 - 39	57	13.90
	40 -49	40	9.76
	50 and above	12	2.93
Marital Status	Single	35	8.54
	Married	375	91.46

	Categories	Frequency	Percent
Education Level	Primary	72	17.56
	Middle	33	8.05
	Matric	99	24.15
	12 years	127	30.98
	Graduate	65	15.85
	Postgraduate	14	3.41
	Total	**410**	**100**

Note: Author's representation of demographic findings

6.2.2 Descriptive statistics

Awareness level of Sustainable Agricultural Practices in rice cultivation.

The descriptive statistics reveal insights into various constructs related to user perceptions and behavioural intentions. The sustainability performance of rice farming practice in Punjab was assessed based on the 14 proposed constructs. In this study, 410 farmers were sampled for data collection in quantitative terms for assessing the behavioural intention (BI) towards adopting sustainable agricultural practices for rice cultivation by Punjab. The BI covered key sustainability issues associated with rice cultivation. The intention to adopt such behaviour was selected according to the following criteria: relevance of sustainability issues for the farmer in the rice sector, applicability and possibility across diverse rice farming systems, social norms, ease of measurement (ease of use and complexity), ability to quantify performance. Table 6.2 provides the descriptive overview of the constructs used in investigating the behaviour intention of the farmers towards SAP for rice cultivation. The mean score of Awareness (M = 3.02, SD = 1.095) and Frequency of Use (M = 3.04, SD = 1.095) reflects a moderate level of understanding among conventional rice growers regarding Sustainable Agricultural Practices (SAP). This score suggests that while a portion of these growers possesses some awareness of SAP, there is considerable room for improvement. A standard deviation of 1.095 indicates variability in knowledge; thus, some growers may be significantly more informed than others. The mean score for perceived usefulness (PU) at 3.06, accompanied by a standard deviation of 1.078, suggests a moderate level of agreement among respondents regarding the usefulness of the SAP for growing Rice in Punjab. This indicates that participants generally view these practices as somewhat beneficial, but the standard deviation reflects a degree of variability in perceptions, suggesting that while many find the

subject useful, there is a notable divergence in individual assessments. The mean score for Perceived Ease of Use (PEOU) at M = 2.99, accompanied by a standard deviation of SD = 1.079, also suggests a moderate perception among participants regarding the usability of the

Table 6.2 ***Descriptive Analysis***

Descriptive Statistics				
	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Kurtosis Statistic
AW	3.02	1.095	-0.016	-1.340
FOU	3.04	1.095	-0.045	-1.298
PU	3.06	1.078	-0.014	-1.092
PEOU	2.99	1.079	0.073	-1.173
PC	3.10	1.068	-0.123	-1.209
NEP	3.28	1.069	-0.429	-0.943
SE	3.34	1.086	-0.375	-1.015
PR	3.23	1.005	-0.412	-0.919
SI	3.25	1.034	-0.342	-1.005
ES	3.12	1.047	-0.267	-1.044
AT	3.48	0.935	-0.758	-0.184
PBC	3.15	1.100	-0.225	-1.212
SN	3.16	1.056	-0.351	-1.015
IS	3.05	1.127	0.014	-1.255
MI	3.11	1.075	-0.066	-1.242
BI	3.42	1.036	-0.616	-0.59
Valid N (listwise)	410			

Note: Author's representation of descriptive findings

examined system or technology. Perceived compatibility (PC) received a mean score of 3.10 (SD = 1.068), reflecting a fair alignment with users' existing values and practices. The mean score of 3.10, accompanied by a standard deviation of 1.068, indicates a moderate level of perceived compatibility (PC) among users. This score suggests that while there is a recognition of some alignment with existing values and practices, the relatively low standard deviation highlights variability in user experiences and perceptions. The New Ecological Paradigm (NEP) scored higher (M = 3.28, SD = 1.069), and suggests a significant level of awareness and acceptance of environmental issues, reflecting a shift in perception towards sustainable practices. The score for self-efficacy (SE), with a mean of 3.34 and a standard deviation of 1.086, indicates a robust level of self-belief among respondents regarding their capabilities. This relatively high mean signifies a consensus that individuals perceive themselves as competent and effective in their endeavours. Perceived resources (PR) were rated at 3.23 (SD = 1.005), indicating a reasonable availability of resources to behavioural support. Social

influence (SI) scored 3.25 as mean value with a SD of 1.034 suggesting a moderate level of agreement among participants regarding the impact of social influences in the assessed context. Extension services (ES) and institutional support (IS) both averaged at 3.12 (SDs = 1.047 and 1.063, respectively), showing that support structures are perceived as somewhat effective. The average score of 3.12 for both extension services (ES) and institutional support (IS) indicates a consensus among participants that these support structures are indeed perceived to be moderately effective. With standard deviations of 1.047 and 1.063, respectively, this suggests a degree of variation in responses. Market infrastructure (MI) received a mean of 3.11 (SD = 1.075), suggesting moderate availability of market resources. The mean score of 3.11, accompanied by a standard deviation of 1.075, indicates a moderate availability of market infrastructure resources. The attitude (AT) towards the behaviour intention was notably higher (M = 3.48, SD = 0.935), indicating a generally favourable disposition. The reported mean score of 3.48 for attitude (AT) towards behavioural intention, coupled with a standard deviation of 0.935, clearly reflects a positive disposition among the respondents. Subjective Norms received a mean score of 3.16 (SD = 1.056), pointing to the importance of social norms in decision-making. The mean score of 3.16 (SD = 1.056) for Subjective Norms indicates a moderate level of agreement among individuals regarding the influence of social norms on their decision-making processes. Perceived Behavioural Control (PBC) averaged 3.15 (SD = 1.100), suggesting participants believe they have some control over their actions. Finally, the Behavioural Intention (BI) score of 3.42 (SD = 1.036) indicates a strong intention to engage in the desired behaviour, influenced by the preceding constructs. Overall, these results highlight key areas where user perceptions align positively with behavioural intentions, but also identify aspects that may require further attention and enhancement.

In summary, the statistical analysis of the mean scores reveals that while participants generally exhibit positive attitudes and appreciations toward several constructs shown in table 6.2, there remain opportunities for improvement, particularly in perceived ease of use. The data reflects not merely numerical scores but also the underlying trends that can facilitate targeted interventions. By addressing the perceived usability barriers indicated by lower scores in PEOU, stakeholders can enhance the overall awareness and effectiveness of technology integration, potentially leading to more robust engagement and satisfaction in utilizing these platforms. This analysis serves as a foundational inquiry into understanding how awareness levels can be optimized for better user experiences and outcomes. The descriptive statistics (see table 6.2) for the various constructs indicate a generally normal distribution, as evidenced by

skewness values ranging from -1 to +1 and kurtosis values within the acceptable range of -3 to +3. Specifically, awareness (AW) demonstrated negligible skewness (-0.016) and a kurtosis of -1.328, suggesting a symmetric distribution with light tails. Similarly, perceived usefulness (PU) showed a slight negative skew (-0.014) and a kurtosis of -1.092, indicating a balanced distribution pattern. Perceived ease of use (PEOU) exhibited a slight positive skew (0.073) with a kurtosis of -1.173, suggesting that while most responses cluster around the mean, there are a few higher values influencing the shape. Perceived compatibility (PC) had a skewness of -0.123 and kurtosis of -1.209, reinforcing the observation of a normal distribution. The New Ecological Paradigm (NEP) revealed a more noticeable negative skew (-0.429) and a kurtosis of -0.943, indicating a tendency toward lower scores, yet remaining within the acceptable range. Self-Efficacy (SE) and perceived resources (PR) both demonstrated negative skewness (-0.375 and -0.412, respectively) alongside kurtosis values of -1.015 and -0.919, which suggest that respondents generally felt capable and resourceful, with a slight clustering of responses at the lower end. Social influence (SI) also exhibited a negative skew (-0.342) and a kurtosis of -1.005, highlighting the influence of social norms on perceptions. Extension services (ES) and institutional support (IS) had skewness values of -0.267 and -0.058, respectively, with kurtosis figures of -1.044 and -1.234, indicating a consistent perception of support. Market infrastructure (MI) had a skewness of -0.066 and kurtosis of -1.242, reflecting a relatively even distribution of responses. Attitude (AT) presented a more significant negative skew (-0.758) and a kurtosis of -0.184, suggesting a stronger inclination towards favourable attitudes among participants. Subjective Norms (SN) had a skewness of -0.351 and kurtosis of -1.015, indicating a consensus on the importance of social norms. Lastly, perceived Behavioural control (PBC) displayed a negative skew (-0.225) and a kurtosis of -1.212, while Behavioural intention (BI) showed a skewness of -0.616 and kurtosis of -0.593, suggesting that respondents generally feel both capable and inclined to act positively. Overall, these results reflect a predominance of positive perceptions across the constructs, with a few dimensions indicating slight tendencies toward lower values, yet all remaining within the expected range for skewness and kurtosis.

6.3 Exploratory Factor Analysis

Exploratory factor analysis (EFA) is employed to uncover the underlying structure of the data, identifying distinct constructs or factors. Items that correspond to a specific construct are expected to exhibit high correlations with one another. In this study, EFA was performed using principal component analysis with varimax rotation.

6.3.1 KMO & Bartlet's Test of Sphericity

As reported in Table 6.3, the results include the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which yielded a value of 0.890, exceeding the recommended threshold of 0.7. Additionally, Bartlett's Test of Sphericity was significant, with a Chi-Square value of 10023.989 and 1378 degrees of freedom. The test was significant at the 5% level ($p < 0.001$), indicating that the data was appropriate for factor analysis.

Table 6.3 *KMO and Bartlett's Test*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.890
Bartlett's Test of Sphericity	Approx. Chi-Square	10023.989
	df	1378
	Sig.	0.000

Note: Author's representation taken from data analysis software SPSS

6.3.2 Total Variance Explained

Table 6.4 presents the results for the total variance explained, highlighting the common factors that can be derived from the data. Factors with eigenvalues greater than 1 were retained. The results revealed fourteen common factors with eigenvalues exceeding this threshold. The first factor had an initial eigenvalue of 11.478 accounting for 21.657% of the variance. The second factor had an eigenvalue of 4.025 explaining 7.595% of the variance. The third factor variance was 4.501% with eigenvalue of 2.386. The last fourteen factor explained variance 1.898 % (eigenvalue = 1.006). The fifteenth factor extracted shows an eigen value less than 1 , therefore it can be concluded that there are only 14 factors that can explain the behaviour intention of farmers.

Table 6.4 *Total Variance Explained*

Component	**Initial Eigen Values**		
	Total Eigen Value	**% of Variance**	**Cumulative %**
1	11.478	21.657	21.657
2	4.025	7.595	29.252
3	2.386	4.501	33.753
4	2.263	4.270	38.023
5	2.111	3.984	42.007
6	2.066	3.898	45.905
7	1.880	3.546	49.451

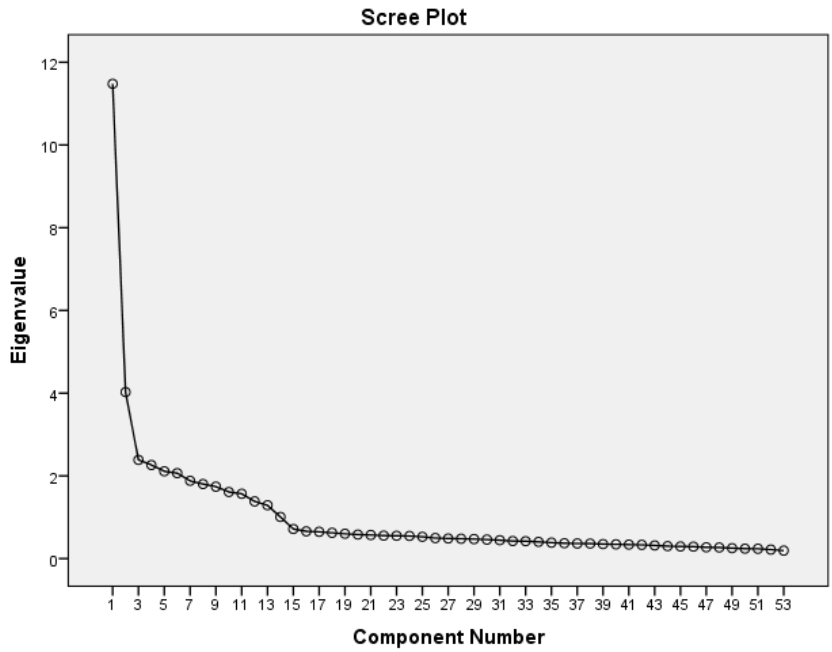
Component	Initial Eigen Values		
	Total Eigen Value	% of Variance	Cumulative %
8	1.802	3.400	52.851
9	1.739	3.281	56.131
10	1.611	3.039	59.170
11	1.567	2.957	62.127
12	1.382	2.607	64.734
13	1.289	2.432	67.167
14	1.006	1.898	69.065
15	0.716	1.351	70.415
Extraction Method: Principal Component Analysis.			

Note: Author's representation taken from data analysis software SPSS

6.3.3 Scree Plot

The Scree Plot (Figure 6.1) further supports this finding by showing that the first fourteen factors have eigenvalues greater than 1. In contrast, the eigenvalues for the fifteenth factor and beyond are all less than 1.

Figure 6.1 ***Scree Plot extracted in exploratory factor analysis***



Note: Author's representation taken from data analysis software SPSS

6.3.4 Factor Loadings

The factor loadings of the fourteen extracted factors are reported in table 6.5. Literature supports factor loadings greater than 0.6.All items have factor loadings greater than 0.670.

Table 6.5 Rotated Component Matrix

Rotated Component Matrix[a]														
Component														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MI1	0.827													
MI2	0.814													
MI3	0.812													
MI4	0.800													
MI5	0.811													
SI1		0.768												
SI2		0.809												
SI3		0.800												
SI4		0.764												
ES1			0.745											
ES2			0.778											
ES3			0.747											
ES4			0.839											
SE1				0.782										
SE2				0.761										
SE3				0.782										
SE4				0.794										
PC1					0.787									
PC2					0.680									
PC4					0.764									
PC3					0.755									
PBC1						0.791								
PBC2						0.730								
PBC3						0.774								
PBC4						0.697								
PR1							0.762							
PR2							0.786							
PR3							0.698							
PR4							0.776							
AT1								0.716						
AT2								0.766						
AT3								0.767						

Rotated Component Matrix[a]						
Component						
AT4	0.722					
NEP1		0.762				
NEP2		0.757				
NEP3		0.718				
NEP4		0.762				
IS1			0.825			
IS2			0.855			
IS3			0.854			
PEOU1				0.789		
PEOU2				0.785		
PEOU3				0.815		
PU1					0.762	
PU2					0.675	
PU3					0.813	
BI1						0.711
BI2						0.697
BI3						0.670
SN1						
SN2						
SN3						
SN4						

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 7 iterations.

Note: Author's representation taken from data analysis software SPSS

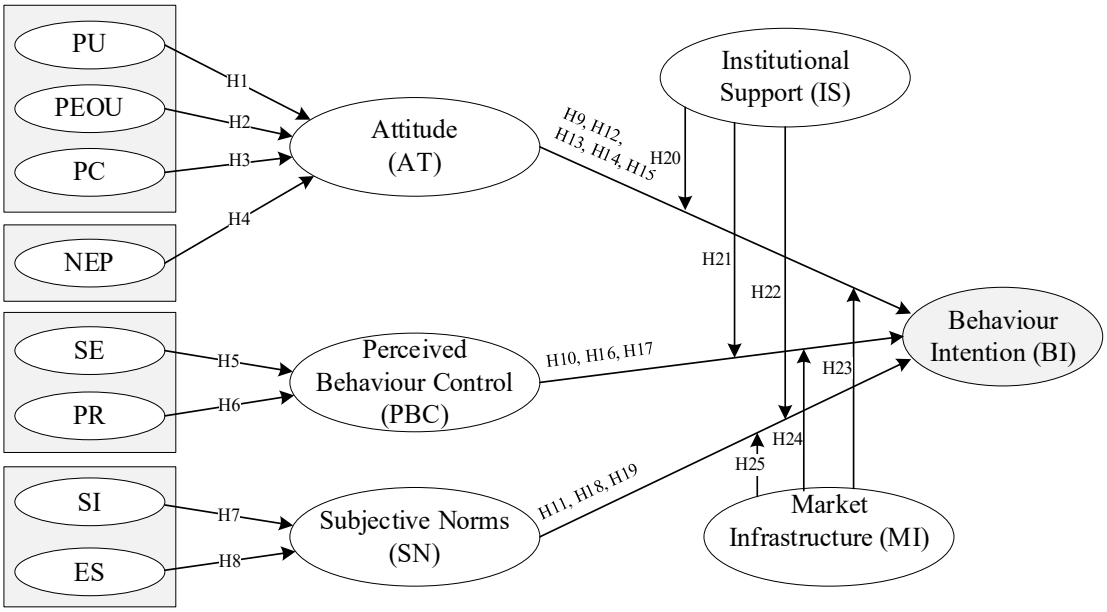
6.3.5 Common Method Bias using Harman's Single Factor Analysis

To overcome the issue of Common Method Bias, Harman's single-factor test (Harman, 1968) (See table 6.4) was carried out using SPSS with principal component analysis as the extraction method. The analysis revealed that the first factor accounted for only 21.657 % of the variance, which is below the 50% threshold. This result indicates that there is no significant bias or Common Method Bias affecting the statistical results (Arnold & Reynolds, 2009; Spralls et al., 2011) Also, the variance inflation factors (VIFs) result from a collinearity test also depicted values less than 3 (Table 6.7), therefore, it can be suggested that the model is free of any common method bias (Kock, 2015).

6.4 Measurement Model Assessment

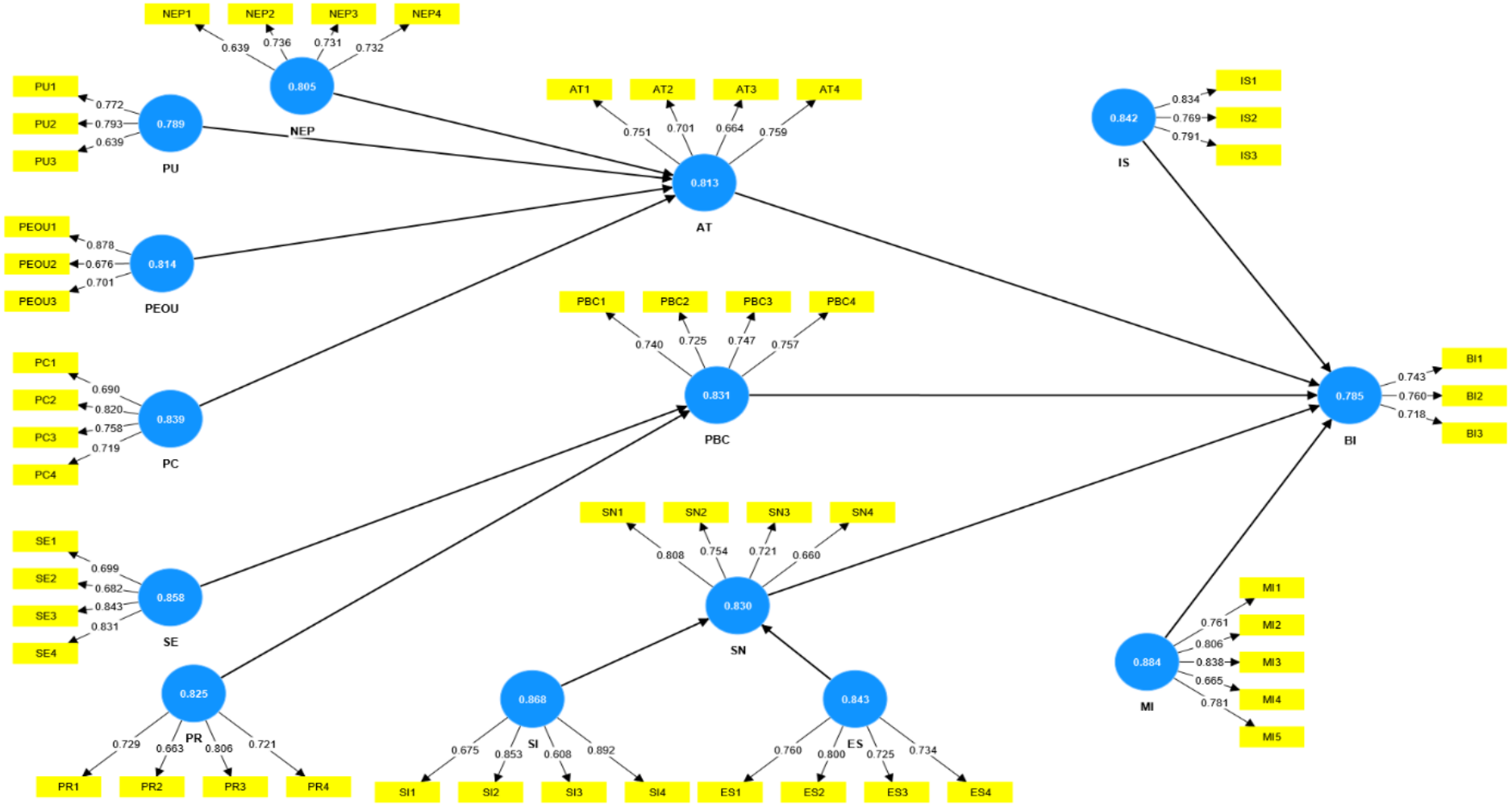
Based on the conceptual model (Fig 6.2), measurement model (Fig 6.3) was developed and tested to check model fit with software SmartPLS 4.

Figure 6.2 ***Conceptual Model of the study***



Note: PU -Perceived Usefulness, PEOU-Perceived Ease of Use, PC-Perceived Compatibility, NEP-New Ecological Paradigm, SE-Self Efficacy, PR-Perceived Resources, Si-Social Influence, AT-Attitude, PBC-Perceived Behaviour Control, SN-Subjective Norms, IS-Institutional Support, MI-Market Infrastructure, BI-Behavioural Intention

Figure 6.3 *Measurement Model Assessment with SmartPLS 4*



Note: *The indicators reflect the Outer Loadings, the constructs show the composite reliability. Measurement Model for the current study, image taken from software SmartPLS4.*

6.4.1 Outer Loadings

The factors extracted in EFA were further confirmed using confirmatory factor analysis. Confirmatory Factor Analysis (CFA) evaluates the degree to which the proposed structure of a specified set of factors aligns with the data (Nunnally & Bernstein, 1994). Pett et al., (2006) assert that CFA is employed when the researcher possesses knowledge regarding the fundamental structure of the construct being examined. Furthermore, they state that CFA may also be employed to evaluate the efficacy of the foundational dimensions of a construct identified using EFA, to compare factor structures across research, and to test hypotheses on the linear structural links among a group of factors related to a given theory or model. CFA requires a comprehensive analysis of covariance structures and is therefore done using sophisticated software intended for Structural Equation Modelling. Table 6.6 presets the outer loadings of the employed Latent Variables. The values are within the threshold range of being above 0.7 but for two values respectively one each of NEP 1 and PU 3 which are 0.639. However, these two items are being retained and not being deleted from the model because these both the items have valid composite reliability (Rho_a) and convergent validity (AVE) and the following descriptions will show.

Table 6.6 *Outer Loadings*

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
AT1	0.751													
AT2	0.701													
AT3	0.664													
AT4	0.759													
BI1		0.743												
BI2		0.760												
BI3		0.718												
ES1			0.760											
ES2			0.800											
ES3			0.725											
ES4			0.734											
IS1				0.834										
IS2				0.769										
IS3				0.791										

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
MI1					0.761									
MI2					0.806									
MI3					0.838									
MI4					0.665									
MI5					0.781									
NEP1						0.639								
NEP2						0.736								
NEP3						0.731								
NEP4						0.732								
PBC1							0.740							
PBC2							0.725							
PBC3							0.747							
PBC4							0.757							
PC1								0.690						
PC2								0.820						

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
PC3								0.758						
PC4								0.719						
PEOU1									0.878					
PEOU2									0.676					
PEOU3									0.701					
PR1										0.729				
PR2										0.663				
PR3										0.806				
PR4										0.721				
PU1											0.772			
PU2											0.793			
PU3											0.639			
SE1												0.699		
SE2												0.682		
SE3												0.843		

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
SE4												0.831		
SI1													0.675	
SI2													0.853	
SI3													0.608	
SI4													0.892	
SN1														0.808
SN2														0.754
SN3														0.721
SN4														0.660

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.4.2 Indicator Multicollinearity

To assess the indicator multicollinearity, VIF statistics is used. Hair et al., (2019) have suggested a threshold value of 5 for VIF. Table 6.7 provides VIF values ranging from 1.517 to 2.127, well within the threshold value 5, proving no multicollinearity concerns.

Table 6.7 VIF Statistics

Indicator	VIF	Indicator	VIF
AT1	1.597	PC1	1.883
AT2	1.719	PC2	1.697
AT3	1.696	PC3	1.936
AT4	1.633	PC4	1.791
BI1	1.762	PEOU1	1.682
BI2	1.691	PEOU2	1.663
BI3	1.517	PEOU3	1.766
ES1	1.754	PR1	1.870
ES2	1.859	PR2	1.712
ES3	1.768	PR3	1.573
ES4	2.107	PR4	1.804
IS1	1.920	PU1	1.679
IS2	2.028	PU2	1.527
IS3	2.018	PU3	1.715
MI1	2.081	SE1	1.915
MI2	2.126	SE2	1.788
MI3	2.127	SE3	2.033
MI4	2.001	SE4	1.931
MI5	2.012	SI1	1.913
NEP1	1.611	SI2	2.034
NEP2	1.694	SI3	2.042
NEP3	1.592	SI4	1.922
NEP4	1.625	SN1	1.771
PBC1	1.892	SN2	1.886
PBC2	1.796	SN3	1.585
PBC3	1.803	SN4	1.823
PBC4	1.635		

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.4.3 Construct Reliability and Convergent Validity

The goodness of fit for the measurement model was evaluated using construct composite reliability and convergent validity, and discriminant validity **(Hsu & Lin, 2008; Lim, 2024)**. Construct reliability was assessed through composite reliability as outlined by Fornell and Larcker **(1981)**. The composite reliability (rho_a) for all constructs ranged from 0.785 to 0.884, exceeding the threshold of 0.7 **(S. Liu & Wang, 2016)**. Additionally, Cronbach's alpha for each construct was greater than 0.70 with the lowest being 0.782 and highest 0.881 **(Hair et al., 2011)**. Convergent Validity refers to the extent to which many measures of the same construct are consistent with one another. Two or more measures of the same construct should have a high degree of covariation if they are valid indicators of the concept. When the Average Variance Extracted (AVE) is equal to or exceeds the recommended threshold of 0.50, items align to assess the underlying construct, hence establishing convergent validity (Fornell & Larcker, 1981). All constructs demonstrated AVEs between 0.518 and 0.637 (greater than 0.50) and factor loadings ranging from 0.608 to 0.892 (greater than 0.60). Thus, convergent validity was confirmed (See Table 6.8).

Table 6.8 ***Construct Reliability and Convergent Reliability***

Indicator	Cronbach's alpha	Composite reliability (rho_a)	Average variance extracted (AVE)
AT	0.812	0.813	0.518
BI	0.784	0.785	0.549
ES	0.842	0.843	0.571
IS	0.841	0.842	0.637
MI	0.881	0.884	0.597
NEP	0.803	0.805	0.505
PBC	0.831	0.831	0.551
PC	0.836	0.839	0.560
PEOU	0.798	0.814	0.573
PR	0.822	0.825	0.535
PU	0.782	0.789	0.545
SE	0.850	0.858	0.589
SI	0.851	0.868	0.587
SN	0.826	0.830	0.544

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.4.4 Construct Discriminant Validity

Discriminant validity refers to the extent to which a construct is truly distinct from other constructs, capturing unique phenomena that are not explained by other variables. The discriminant validity can be evaluated by using Fornell & Larcker criterion and Heterotrait-Monotrait (HTMT) ratio of correlation.

6.4.4.1 Fornell & Larcker Criterion

Discriminant Validity refers to the extent to which measurements of several concepts are differentiated. The premise is that if two or more concepts are distinct, their legitimate measurements should not have a high correlation. Fornell and Larcker's criteria are widely used to assess the discriminant validity of constructs in structural equation modeling (SEM), particularly when using latent variables. Fornell and Larcker (1981) assert that discriminant validity is confirmed when the square root of the Average Variance Extracted (AVE) for a construct exceeds its correlation with all other constructs. This implies that each construct shares more variance with its indicators than with any other construct. Table 6.9 shows the Fornell and Larcker Criterion, the square root of each AVE in the diagonal (bold and italicized) with the correlation coefficients (off-diagonal) for each construct in the relevant rows and columns.

6.4.4.2 Hetero-Trait Mono-Trait (HTMT) Ratio

Many researchers, however, do not think Fornell and Larcker (1981) is an appropriate method (Benitez et al., 2020) and therefore it was suggested by Henseler, Ringle, and Sarstedt (2015) to compute discriminant validity using the Heterotrait-Monotrait (HTMT) ratio. HTMT serves as a statistical measure that assesses the discrimination between constructs in a given model. Specifically, it is calculated as the ratio of the average correlations between indicators across different constructs (heterotrait correlations) to the average correlations among indicators within the same construct (monotrait correlations). The HTMT ratio value should be smaller than 0.85 (Benitez et al., 2020; Henseler et al., 2015; Ogbeibu et al., 2018).Furthermore, it was discovered that the constructs' HTMT ratios ranged from 0.281 to 0.550 (<0.85, See table 6.10), which further supports the existence of discriminant validity. This implied

that the HTMT criterion did not detect any collinearity problems among the latent constructs , so there is no problem of multicollinearity. HTMT Ratio is preferred as it is an advancement over Fornell and Larcker Criterion.

Table 6.9 *Discriminant Validity through Fornell & Larcker Criterion*

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
AT	***0.720***													
BI	0.551	***0.741***												
ES	0.351	0.415	***0.755***											
IS	-0.090	-0.190	-0.068	***0.798***										
MI	0.055	0.164	0.072	0.365	***0.772***									
NEP	0.465	0.477	0.326	-0.030	0.055	***0.711***								
PBC	0.406	0.624	0.397	-0.178	0.076	0.365	***0.742***							
PC	0.424	0.571	0.343	-0.053	0.101	0.334	0.489	***0.748***						
PEOU	0.353	0.475	0.328	-0.101	0.050	0.365	0.328	0.347	***0.757***					
PR	0.378	0.463	0.351	-0.115	-0.007	0.347	0.357	0.473	0.281	***0.731***				
PU	0.411	0.458	0.353	-0.050	-0.013	0.344	0.444	0.546	0.381	0.503	***0.738***			
SE	0.376	0.428	0.378	-0.095	-0.084	0.344	0.336	0.439	0.259	0.396	0.407	***0.767***		
SI	0.373	0.437	0.335	-0.070	-0.053	0.317	0.442	0.349	0.307	0.298	0.358	0.365	***0.766***	
SN	0.362	0.485	0.319	-0.190	-0.014	0.298	0.398	0.382	0.323	0.365	0.335	0.302	0.365	***0.737***

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.10 *Heterotrait-Monotrait (HTMT) ratio*

	AT	BI	ES	IS	MI	NEP	PBC	PC	PEOU	PR	PU	SE	SI	SN
AT														
BI	***0.550***													
ES	0.351	***0.416***												
IS	0.097	0.189	***0.074***											
MI	0.062	0.164	0.086	***0.365***										
NEP	0.463	0.478	0.327	0.057	***0.072***									
PBC	0.405	0.625	0.396	0.178	0.079	***0.363***								
PC	0.424	0.569	0.341	0.057	0.098	0.336	***0.490***							
PEOU	0.350	0.478	0.337	0.103	0.055	0.363	0.330	***0.352***						
PR	0.380	0.461	0.351	0.116	0.052	0.349	0.355	0.470	***0.281***					
PU	0.409	0.457	0.359	0.055	0.045	0.342	0.441	0.538	0.391	***0.498***				
SE	0.379	0.429	0.382	0.098	0.087	0.345	0.335	0.441	0.259	0.398	***0.407***			
SI	0.380	0.438	0.344	0.070	0.059	0.320	0.444	0.351	0.306	0.303	0.365	***0.372***		
SN	0.357	0.483	0.317	0.190	0.039	0.299	0.399	0.382	0.330	0.360	0.338	0.300	***0.359***	

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.5 Structural Model Assessment

The structural model assessment is presented below in a systematic way, beginning with checking the multicollinearity, followed by Model's Fit Indices, leading to assessing of R^2 for the explanatory power of the model and Q^2 for the predictive power of the model and eventually the significance and relevance of the structural relationships is explained.

6.5.1 Collinearity Statistics of the Structural Relationships

Assessing multi-collinearity issues among reflective constructs is essential. Elevated values increase standard errors in built-in regression procedures. This results in various tests being unreliable and diminishes the relative significance of independent variables (Garson, 2016). Variance Inflation Factor (VIF) is a statistical measure used to assess multicollinearity in regression analysis. Hair et al. (2011) suggested that a tolerance value exceeding 0.333 indicates potential multicollinearity issues that warrant attention. The data presented in table 6.11 indicates that all VIF values are below 3, suggesting the absence of collinearity issues among the reflective constructs.

Table 6.11 *VIF Values of Inner Model*

	VIF
AT -> BI	1.361
ES -> SN	1.126
IS -> BI	1.240
MI -> BI	1.186
NEP -> AT	1.249
PBC -> BI	1.409
PC -> AT	1.503
PEOU -> AT	1.285
PR -> PBC	1.186
PU -> AT	1.547
SE -> PBC	1.186
SI -> SN	1.126
SN -> BI	1.337
IS x AT -> BI	1.400
IS x PBC -> BI	1.431
IS x SN -> BI	1.609
MI x SN -> BI	1.576

	VIF
MI x PBC -> BI	1.499
MI x AT -> BI	1.498

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.5.2 Structural Model: Goodness of fit

The appropriateness of the structural model is evaluated through three model fitting parameters: Standardized Root Mean Square Residual (SRMR), Normed Fit Index (NFI), and the precise model fit utilizing bootstrapped statistical inference. The SRMR quantifies the difference between the observed correlation and the correlation matrix that the model predicts. Hu and Bentler (1998) indicate that a value below 0.08 signifies a strong match. Henseler et al. (2015) introduced the SRMR as a metric for assessing the goodness of fit in PLS-SEM models, aiding in the identification and prevention of model misspecification. Table 6.12 displays that the saturated model's SRMR value is 0.037 and the estimated model's value of 0.069 which is well below the threshold of 0.08 indicating model's goodness of fit.

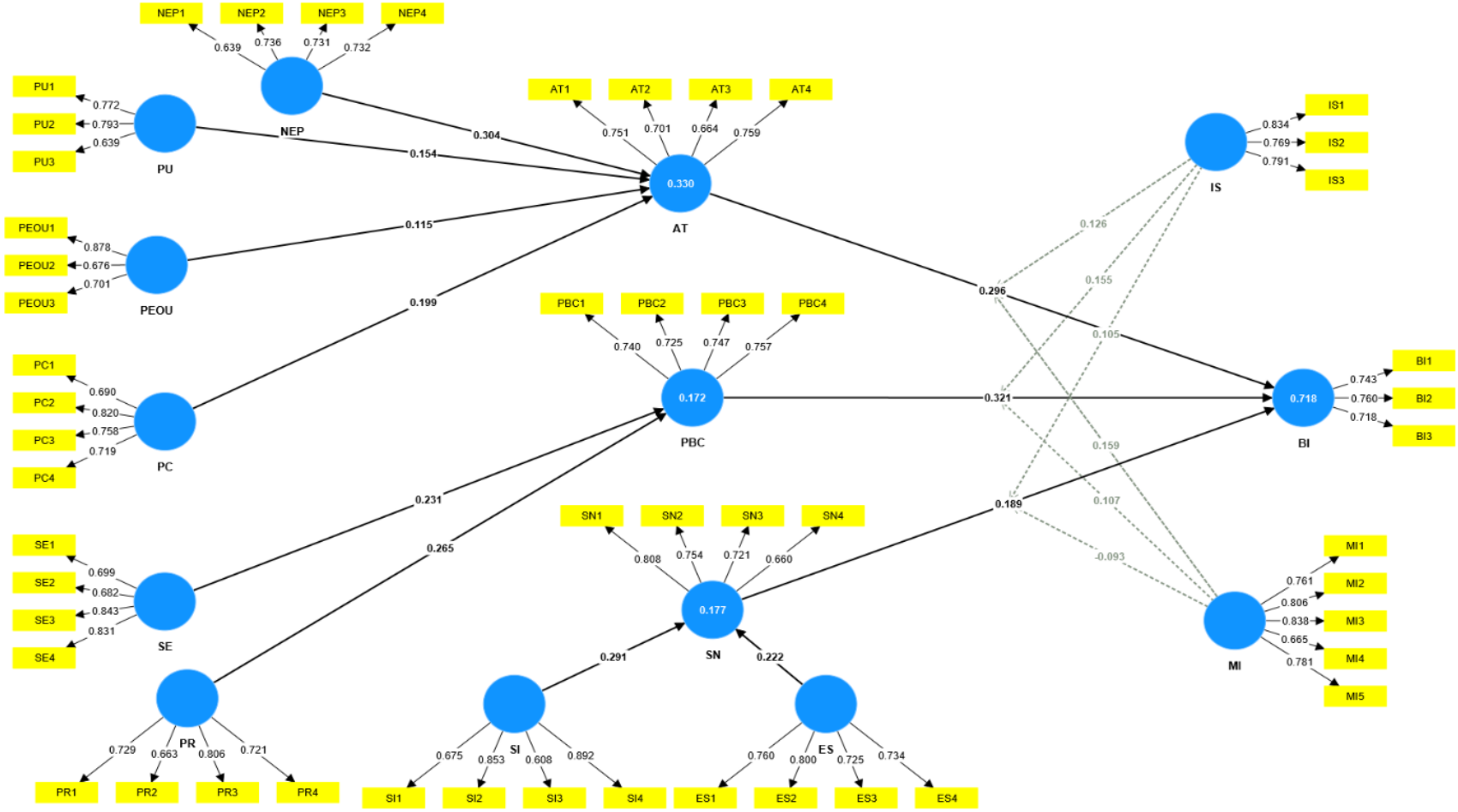
The normed fit index (NFI) serves as a secondary fit index that assesses the Chi-square value of the proposed model and juxtaposes it against a significant benchmark (Bentler & Bonett, 1980). A model is deemed to have an acceptable fit when the SRMR value is under 0.08 and the Normed Fit Index (NFI) value exceeds 0.9 (Ringle et al., 2024). Typically, the NFI value is expected to be greater than 0.9. Nonetheless, a value near (below) 0.9 indicates that the model has potential for enhancement but may still be deemed acceptable (Bentler & Bonett, 1980). The table 6.12 shows NFI for both saturated and estimated models are 0.844 and 0.826 respectively, which lies in the acceptable range, further validating goodness of fit of the model. The d_ULS <bootstrapped H195%of d_ULS and d_G<bootstrapped H1 95% of d_G indicating that data fits the model well.

Table 6.12 *Model Fit Indices*

	Saturated model	**Estimated model**
SRMR	0.037	0.069
d_ULS	1.925	6.810
d_G	0.797	0.905
Chi-square	1645.902	1836.032
NFI	0.844	0.826

Note: *Author's representation, taken from the findings through SmartPLS 4*

Figure 6.4 *Structural Model Assessment with SmartPLS 4*



Note: The constructs reflect the variance with R^2 value. *Author's representation, taken from the findings through SmartPLS 4*

6.5.3 Explanatory and Predictive Power of the Structured Model

In structural models, the explanatory power is measured by coefficient of determination (denoted with $R^{2)}$ and Effect Size (denoted with F^2)· R^2 represents variance in endogenous constructs explained by exogeneous construct is further a measure of goodness of fit. Falk and Miller (1992) indicated that R^2 values must be equal to or exceed 0.10 for the variance explained of a specific endogenous construct to be considered adequate. Cohen (2013) proposed that R^2 values for endogenous latent variables should be evaluated as 0.26 (substantial), 0.13 (moderate), 0.02 (weak). Chin Chin (1998) proposed R^2 values for endogenous latent variables as 0.67 indicates substantial, 0.33 indicates moderate, and 0.19 indicates weak. Hair et al. (2011) indicated in their scholarly research on marketing issues that R^2 values of 0.75, 0.50, or 0.25 for endogenous latent variables can be categorized as substantial, moderate, or weak, respectively, as a general guideline. The R^2 value of the chosen research model is 0.718 thereby meaning 71.8% of the variance in Behavioural Intention can be explained by the proposed structural relations of the model. However, the reliance on R^2 as a definitive measure is problematic, as the inclusion of additional variables typically results in a rise in R^2. To address this issue, the adjusted R^2 is utilized, which controls the model complexity by adjusting the degrees of freedom. The adjusted R^2 value is 0.710 or 71%. The respective R^2 and adjusted R^2 values for Attitude (0.330, 0.323), PBC (0.172, 0.168) and SN (0.177, 0.173) provide the explanatory power for the contributing exogeneous constructs. In addition, an evaluation of the F^2 is done to understand the role of a particular construct in the model. A variable in a structural model may be influenced by multiple other variables. The removal of an exogenous variable may influence the dependent variable. F^2 represents the variation in R^2 resulting from the exclusion of an exogenous variable from the model. F-square represents effect size, with thresholds indicating small (≥0.02), medium (≥0.15), and large (≥0.35) effects (Cohen, 2013). The maximum effect is reflected by the removal of PBC (0.260) followed by AT (0.228) and SN (.095), and as per the criteria accepted, both the former variables fall in the medium effect range being above 15% while SN is in the range of small to medium effect. A model also needs to pass the test of predictive power. Q-square indicates predictive accuracy of the model. Its calculated using blindfolding algorithm in SmartPLS. Q^2 predict is a feature in PLS SEM that reflects

predictive relevance, assessing whether a model possesses predictive significance (> 0 is favourable). Additionally, Q^2 demonstrates the predictive significance of the endogenous components. Q-square values over zero signify that the values are accurately recreated and that the model possesses predictive relevance. Furthermore, a Q^2 value exceeding 0 indicates that the model possesses predictive relevance. For the study at hand, the model shows Q^2 value of BI to be 0.330 means it can explain with 33% predictive accuracy for Behavioural Intention and the Q^2 predict value is 0.335 meaning a predictive relevance of 33.5% for BI. Table 6.13 presents the model's explanatory and predictive indices for the study at hand.

The R^2 value of the selected research model is 0.718, indicating that 71.8% of the variance in Behavioural Intention is accounted for by the proposed structural relationships of the model. The dependence on R^2 as a conclusive metric is problematic, as adding more variables generally leads to an increase in R^2. The adjusted R^2 is employed to address this issue, as it accounts for model complexity by modifying the degrees of freedom. The adjusted R^2 value is 0.710, representing 71%. The R^2 and adjusted R^2 values for Attitude (0.330, 0.323), PBC (0.172, 0.168), and SN (0.177, 0.173) indicate the explanatory power of the contributing exogenous constructs. A variable within a structural model can be affected by several other variables. The elimination of an exogenous variable may affect the dependent variable. F^2 indicates the change in R^2 due to the removal of an exogenous variable from the model. The maximum effect is indicated by the removal of PBC (0.260), followed by AT (0.228) and SN (0.095). According to the accepted criteria, the former two variables fall within the medium effect range, exceeding 15%, while SN is categorised within the small to medium effect range. Peer pressure and social norms significantly influence the closely connected communities of Punjabi farmers. Nevertheless, the findings of the current study indicate that farmers may disregard social norms, influenced by Extension Services and Social Influence, if the profitability or productivity of their farming activities is affected. The construct of Perceived Behavioural Control is identified as the most significant predictor of Behavioural Intention outcomes. The perceived independence and skill of farmers in implementing sustainable practices are essential, as evidenced by the increased effect size associated with perceived behavioural control

(PBC). This realisation indicates that empowering farmers requires the removal of obstacles, including monetary, informational, or structural barriers. To alter individuals' perspectives and bolster their confidence in adopting these behaviours, it is crucial to implement interventions that enhance skills, provide resources, and improve access to sustainable technologies.

Table 6.13 ***Explanatory and Predictive Indices of the model***

	R-square	R-square adjusted	F-Square	Q-Square	Q-Square (Predict)
BI	0.718	0.710	---	0.330	0.335
AT	0.330	0.323	0.228	0.146	0.217
PBC	0.172	0.168	0.260	0.080	0.111
SN	0.177	0.173	0.095	0.083	0.115

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.6 Significance and Relevance of Structural Relationships

To begin with corelation analysis is conducted between the constructs. It provides a comprehensive overview of the associations through correlation coefficients among different variables, including BI and other key variables in this study. The main relationships are presented below:

6.6.1 Correlation Analysis

These corelation values are used to assess the discriminant validity of the constructs in as PLS path model as shown in Table 6.9 above. In other words, it shows that each construct is distinct in its form. Thus, the correlation matrix of constructs is constructed that shows how each construct correlates with others in the model. Behavioural Intention (BI) was significantly positively correlated with several predictors. The highest correlation was found with Perceived Behavioural Control (PBC) (r = .624), indicating a strong positive relationship between control perceptions and Behavioural intentions. Attitude (ATT) was also strongly correlated with BI (r = .551), suggesting that positive attitudes are associated with higher intentions to perform

the Behaviour. Perceived Compatibility (PC) (r = .571) and New Ecological Paradigm (NEP) (r = .477) also showed moderate positive correlations with BI, reflecting the importance of system compatibility and ecological beliefs in shaping Behavioural intentions. Similarly, Perceived Usefulness (PU) (r = .458), Perceived Ease of Use (PEOU) (r = .475), and Perceived Resources (PR) (r = .463) were positively associated with BI, indicating that perceptions of usefulness, ease, and personal resources contribute to Behavioural intentions. Other notable correlations include Social Influence (SI) (r = .437), Self-Efficacy (SE) (r=.428), Extension Services (ES) (r = .415), and Subjective Norm (SN) (r = .485), demonstrating the role of social and normative factors in driving Behavioural intentions. On the other hand, Institutional Support (IS) was negatively correlated with BI (r = -.191), although this relationship was weak, suggesting that institutional support alone may not significantly enhance Behavioural intentions. Market Infrastructure (MI) showed a weak positive correlation with BI (r = .164).

In terms of relationships between the other constructs, Attitude (ATT) was strongly correlated with New Ecological Paradigm (NEP) (r = .465) and Perceived Compatibility (PC) (r = .425), highlighting the importance of these factors in shaping attitudes. Perceived Behavioural Control (PBC) was most strongly correlated with Perceived Compatibility (PC) (r = .489), reflecting the influence of compatibility on perceptions of control. The correlation between PU and PEOU is positive and moderate, r = 0.381, suggesting that individuals who find a system easy to use also perceive it as useful. Perceived Compatibility (PC) has a stronger positive correlation with PU, r = 0.546, than with PEOU, r = 0.347, indicating that compatibility is more closely associated with perceptions of usefulness than ease of use. New Ecological Paradigm (NEP) shows a moderate correlation with both PU, r = 0.344, and PEOU, r = 0.365, suggesting a similar association with both variables. Self-Efficacy (SE) correlates more strongly with PU, r = 0.407, than with PEOU, r = 0.259, showing that those who feel personally capable tend to perceive the system as more useful. Perceived Resources (PR) has a moderate positive correlation with both PU, r = 0.503, and PEOU, r = 0.281, indicating that individuals with more personal resources are more likely to perceive both usefulness and ease of use. Social variables such as Social Influence (SI) and

Extension Services (ES) also show positive associations with both PU and PEOU, with correlations ranging from r = 0.307 to r = 0.358, though the relationship is slightly stronger with PU. Attitude (ATT) is more strongly correlated with PU, r = 0.411, than with PEOU, r = 0.353, implying that those who have a positive attitude towards the system tend to see it as more useful. Similarly, Perceived Behavioural Control (PBC) correlates higher with PU, r = 0.444, than with PEOU, r = 0.328, indicating that perceived control over the system relates more to perceived usefulness. Subjective Norms (SN) and Institutional Support (IS) show weaker relationships with PU and PEOU. SN has a small positive correlation with PU, r = 0.335, and PEOU, r = 0.323, while IS shows a negative, albeit weak, correlation with PU, r = −0.050, and a slightly stronger negative correlation with PEOU, r = −0.101, suggesting that IS may not be a significant factor in perceived usefulness or ease of use. Lastly, Market Infrastructure (MI) shows negligible correlations with both PU, r = −0.013, and PEOU, r = 0.050, indicating little to no relationship between MI and these two constructs. The relationship between PEOU and Perceived Compatibility (PC) is moderately positive, r = 0.347, indicating that those who find the system compatible with their values and needs are likely to also perceive it as easy to use. Similarly, New Ecological Paradigm (NEP) shows a moderate positive correlation with PEOU, r = 0.365, suggesting that individuals with pro-environmental views are more likely to find the system easy to use.

Self-Efficacy (SE) has a smaller positive correlation with PEOU, r = 0.259, indicating that individuals who feel capable in managing personal challenges tend to perceive the system as somewhat easier to use, though the relationship is weaker compared to other variables. Perceived Resources (PR) shows a moderate positive correlation with PEOU, r = 0.281 suggesting that having greater personal resources is associated with finding the system easier to use. In terms of social influences, Social Influence (SI) and Extension Services (ES) both exhibit positive associations with PEOU, with correlations of r = 0.307 and r = 0.328, respectively. This suggests that those who are influenced by social networks or who receive extension services are more likely to perceive the system as easy to use. Attitude (ATT) has a moderate positive correlation with PEOU, r = 0.353, indicating that a positive attitude towards the system

is linked to higher perceptions of ease of use. Likewise, Perceived Behavioural Control (PBC) also correlates moderately with PEOU, r = 0.328, implying that individuals who feel in control of using the system are likely to perceive it as easier to use. The relationship between Subjective Norms (SN) and PEOU is also positive but slightly lower, r = 0.323, indicating that normative influences are moderately related to how easy the system is perceived. For Institutional Support (IS), a weak negative correlation with PEOU is observed, r = −0.101, suggesting that higher institutional support might not necessarily make the system appear easier to use, or this relationship might not be significant. Finally, Market Infrastructure (MI) shows a very weak positive correlation with PEOU, r = 0.050, indicating little to no association between MI and the perception of ease of use. Perceived Compatibility (PC) exhibits a positive correlation with most of the variables in the table. Specifically, New Ecological Paradigm (NEP) has a moderate positive relationship with PC, r = 0.334, indicating that individuals with stronger ecological beliefs tend to perceive the system as more compatible with their values. The correlation between Self-Efficacy (SE) and PC is stronger, r = 0.439, suggesting that individuals who feel capable in managing challenges are more likely to perceive the system as compatible with their personal needs and values. Similarly, Perceived Resources (PR) shows a strong positive correlation with PC, r = 0.473, indicating that those with greater personal resources perceive the system as more compatible. Social factors, such as Social Influence (SI) and Extension Services (ES), also have moderate positive correlations with PC, r = 0.349 and r = 0.343, respectively. This implies that people influenced by their social circles or receiving extension services perceive the system as more compatible. Attitude (ATT) has a moderate positive correlation with PC, r = 0.424, suggesting that individuals with a positive attitude towards the system are likely to find it compatible with their values. Perceived Behavioural Control (PBC) exhibits an even stronger relationship with PC, r = 0.489, indicating that those who feel they have control over using the system tend to perceive it as highly compatible. Subjective Norms (SN) also shows a positive relationship with PC, r = 0.382, indicating that normative beliefs play a role in how compatible the system is perceived to be. Institutional Support (IS) has a very weak negative correlation with PC, r = −0.053, suggesting that institutional support may not significantly influence perceived compatibility. Lastly, Market Infrastructure (MI) shows a weak positive

correlation with PC, r = 0.101, indicating a slight positive relationship between market infrastructure and the perception of compatibility. NEP shows moderate correlations with several variables, indicating that individuals with stronger pro-environmental beliefs tend to have particular perceptions about the system and related constructs. Self-Efficacy (SE) has a moderate positive correlation with NEP, r = 0.344, suggesting that individuals who believe in their ability to manage personal challenges are more likely to hold strong ecological beliefs. Similarly, Personal Resources (PR) also shows a moderate positive correlation with NEP, r = 0.347, implying that individuals with greater personal resources are more likely to endorse pro-environmental views. The correlation between Social Influence (SI) and NEP is slightly lower but still positive, r = 0.317, indicating that those who are influenced by their social circles tend to hold stronger ecological beliefs. Similarly, Extension Services (ES) shows a moderate positive correlation with NEP, r = 0.326, suggesting that people who benefit from extension services also tend to have pro-environmental attitudes. Attitude (ATT) demonstrates a stronger positive relationship with NEP, r = 0.465 indicating that individuals with positive attitudes towards the system tend to align with ecological beliefs. Perceived Behavioural Control (PBC) also correlates moderately with NEP, r = 0.365, implying that those who feel they have control over using the system are more likely to hold pro-environmental views. The correlation between Subjective Norms (SN) and NEP is lower, r = 0.298, but still positive, suggesting that individuals who perceive normative pressures also tend to hold pro-environmental views. Institutional Support (IS), on the other hand, has a weak negative correlation with NEP, r = −0.030, indicating that institutional support might not be a significant factor in influencing ecological beliefs. Lastly, Market Infrastructure (MI) shows a weak positive correlation with NEP, r = 0.055, suggesting little to no association between market infrastructure and ecological beliefs.

Self-Efficacy (SE) shows moderate positive relationships with several variables, suggesting that individuals who feel capable in managing personal challenges are influenced by other factors related to system use and perception. The correlation between Personal Resources (PR) and SE is moderate, r = 0.396, indicating that individuals with greater personal resources tend to have higher self-efficacy. This

suggests a close relationship between the availability of resources and the belief in one's ability to manage personal and system-related challenges. Social Influence (SI) also shows a moderate positive correlation with SE, r = 0.365, implying that individuals who feel socially supported or influenced by others are likely to have higher personal efficacy. Extension Services (ES) similarly has a moderate positive correlation with SE, r = 0.378, suggesting that access to services and support systems contributes to a higher sense of self-efficacy. Attitude (ATT) has a moderate positive relationship with SE, r = 0.376, indicating that those with a positive attitude towards the system are more likely to believe in their own efficacy. Likewise, Perceived Behavioural Control (PBC) shows a moderate correlation with SE, r = 0.336, suggesting that individuals who feel they have control over their behaviour in using the system also tend to have higher personal efficacy. The correlation between Subjective Norms (SN) and SE is lower but still positive, r = 0.302, indicating that normative pressures are somewhat related to personal efficacy, though the influence is weaker compared to other factors. On the other hand, Institutional Support (IS) shows a weak negative correlation with SE, r = −0.095, suggesting that higher levels of institutional support might not significantly enhance an individual's sense of personal efficacy, or might even slightly detract from it. Similarly, Market Infrastructure (MI) has a weak negative correlation with SE, r = −0.084, implying little to no relationship between market infrastructure and personal efficacy. Perceived Resources (PR) demonstrates moderate positive correlations with several variables, indicating that individuals with more personal resources tend to perceive the system and related factors more positively. Social Influence (SI) has a moderate positive correlation with PR, r = 0.298, suggesting that individuals who feel influenced by their social environment are likely to have greater personal resources. This reflects the idea that social networks can contribute to an individual's resources, either through direct support or through encouragement. The correlation between Extension Services (ES) and PR is also moderate, r = 0.351 implying that those who benefit from extension services are more likely to possess greater personal resources. This could indicate that external support systems play a role in resource accumulation or perception. Attitude (ATT) shows a moderate positive relationship with PR, r = 0.378, suggesting that individuals with more resources tend to have a more favourable attitude toward the system. Similarly, Perceived Behavioural Control (PBC) has a moderate correlation

with PR, r = 0.357, indicating that those with more resources also feel greater control over their Behaviour regarding system use. The relationship between Subjective Norms (SN) and PR is also moderate, r = 0.365, suggesting that individuals with more resources are more likely to perceive normative pressures related to the system. This might indicate that those with resources are more attuned to societal expectations and norms. On the other hand, Institutional Support (IS) has a weak negative correlation with PR, r = −0.115 indicating that institutional support may not be strongly related to personal resource levels or may even slightly reduce the perception of personal resources. Market Infrastructure (MI) shows an almost negligible correlation with PR, r = −0.007, suggesting no meaningful relationship between market infrastructure and personal resources. Social Influence (SI) exhibits moderate positive correlations with several variables. Extension Services (ES) shows a moderate positive relationship with SI, r = 0.335, indicating that individuals who feel supported by social networks are likely to engage with extension services, perhaps due to encouragement or shared information. The correlation between Attitude (ATT) and SI is also moderate, r = 0.373, suggesting that individuals who feel socially influenced tend to have more favourable attitudes toward the system. Perceived Behavioural Control (PBC) has a stronger correlation with SI, r = 0.442, indicating that individuals who are influenced by their social environment tend to feel a greater sense of control over their Behaviour regarding system use. Subjective Norms (SN) shows a moderate positive correlation with SI, r = 0.365, suggesting that individuals who are more socially influenced are also more aware of or responsive to societal norms and expectations. On the other hand, Institutional Support (IS) has a weak negative correlation with SI, r = −0.070, suggesting that social influence and institutional support are not strongly related and may even slightly counteract each other. Market Infrastructure (MI) shows a weak negative correlation with SI, r = −0.053, indicating little to no relationship between social influence and market infrastructure. Extension Services (ES) shows moderate correlations with several other variables. It has a positive relationship with ATT, r = 0.351, indicating that individuals who benefit from extension services tend to have favourable attitudes towards the system. PBC shows a moderate positive correlation with ES, r = 0.397, suggesting that those who receive support from extension services also feel more control over their Behaviour. Similarly, SN correlates positively with ES, r = 0.319

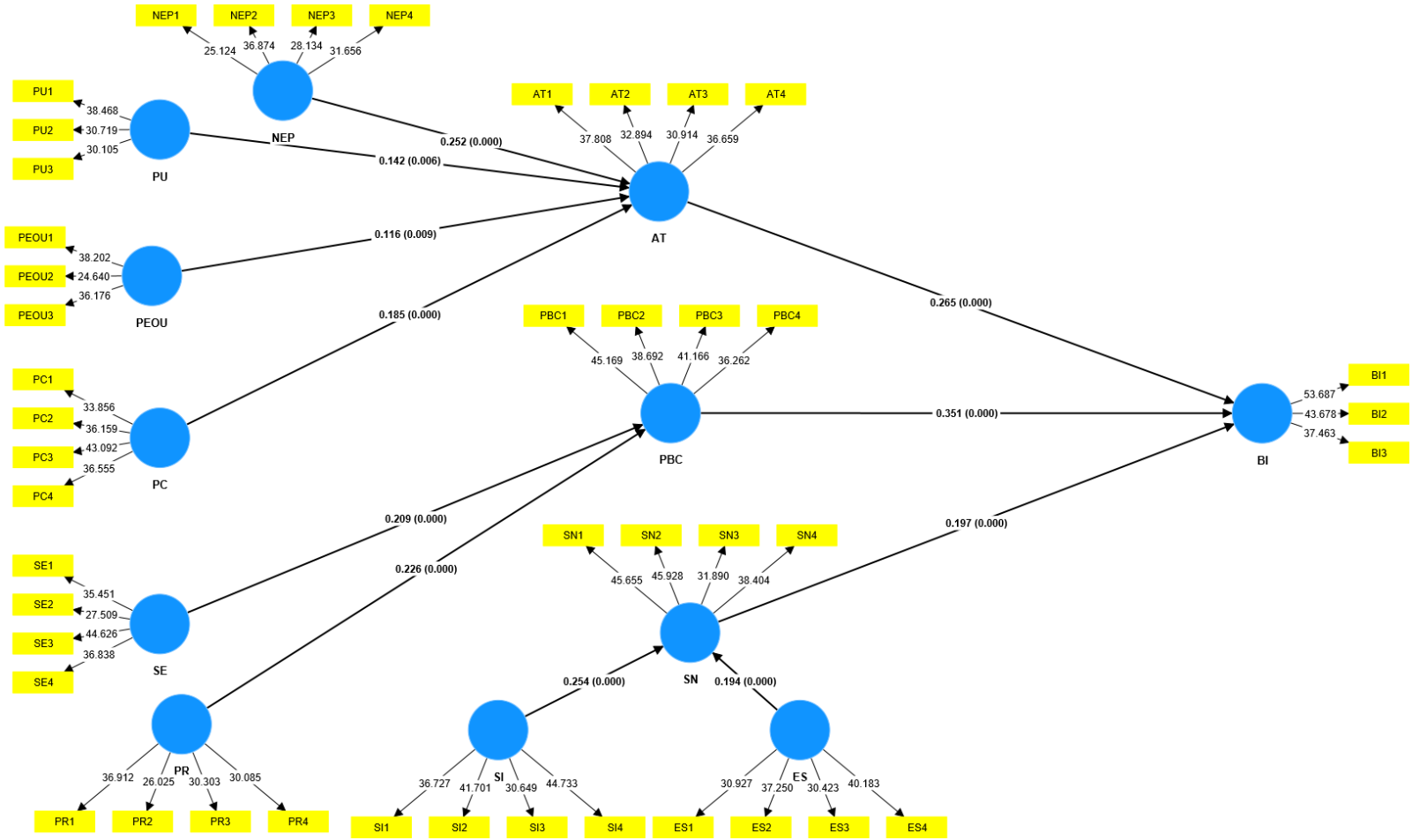
indicating that extension services may make individuals more aware of or responsive to normative pressures. IS shows weak negative correlations with several variables, including ATT, r = −0.090, PBC, r = −0.178, and SN, r = −0.190, indicating that higher institutional support is associated with lower perceptions of control, attitude, and awareness of norms. However, MI shows a moderate positive correlation with IS, r = 0.365, suggesting that institutional support and market infrastructure tend to align, possibly due to shared systemic factors. Lastly, Market Infrastructure (MI) has weak positive correlations with PBC, r = 0.076, and ATT, r = 0.055, indicating that better market infrastructure slightly increases the sense of control and positive attitude towards system use. There is a near-zero relationship between MI and SN, r = −0.014, suggesting minimal influence of market infrastructure on normative issues.

6.6.2 Multivariate Analysis – Hypothesis Testing

6.6.2.1 Direct Effect Analysis

The bootstrapping method demonstrates the path significance through path coefficients (β) and p-values (P). β is degree of change in the endogenous variable for every unit change in the exogeneous variable and ranges from +/- 1. The p-values are employed for hypothesis verification. This also presents the empirical t statistics, calculated by dividing the β-value by the standard error. T-value shows the distance between the observed data and the null hypothesis. A value of 1.96 shows significant relationship at 5% confidence interval. The p values of significance for this model for all the hypothesised direct effects, as indicated by the bootstrapping reports, are presented in Fig 6.5 and Table 6.14.

Figure 6.5 *Direct effect of Key factors on BI*



Note. Author's representation taken from the findings through SmartPLS4

Impact of key factors on Attitude

The current study examines multiple hypothesis as per the revised conceptual model (6.2) formulated post the Phase 1 (Qualitative Research). It was hypothesised (H1 to H4) that attitude is significantly and positively influenced by Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Perceived Compatibility (PC) and New Ecological Paradigm (NEP).

H1: There is a significant and positive relationship between Perceived Usefulness (PU) to Attitude (AT).

H2: There is a significant and positive relationship between Perceived Ease of Use (PEOU) to Attitude (AT).

H3: There is a significant and positive relationship between Perceived Compatibility (PC) to Attitude (AT).

H4: There is a significant and positive relationship between New Ecological Paradigm (NEP) to Attitude (AT).

The results reveal that attitude (AT) was significantly influenced by Perceived Usefulness (PU) ($\beta = 0.142$, $p = .006$, $t=2.751$), Perceived Ease of Use (PEOU) ($\beta = 0.116$, $p = .009$, $t=2.609$), Perceived Compatibility (PC) ($\beta = 0.185$, $p < .001$, $t=3.528$) and New Ecological Paradigm (NEP) ($\beta = 0.252$, $p < .001$, $t=5.505$) and all the sated hypothesis H1-H4 are accepted.

The results highlight the critical factors influencing farmers' behaviour intention attitudes towards the adoption of sustainable agricultural practices in rice cultivation in Punjab. Each identified variable demonstrates a statistically significant impact on attitude (AT), which is pivotal for understanding the overall adoption process.

Impact of key factors on Perceived Behaviour Control

The below hypothesis examines the influence of Self-Efficacy (SE) and Perceived Resources (PR) on PBC

H5 : There is a significant and positive relationship between Self Efficacy (SE) to Perceived Behaviour Control (PBC).

H6: There is a significant and positive relationship between Perceived Resources (PR) to Perceived Behaviour Control (PBC).

Results reveal that Perceived Behaviour Control (PBC) was significantly affected by Self-Efficacy (SE) ($\beta = 0.209$, $p < .001$, $t= 4.013$) and Perceived Resources (PR) ($\beta = 0.226$, $p < .001$, $t= 4.723$) , suggesting that personal capacities and available resources are crucial determinants of perceived control over the Behaviour.

Impact of key factors on Subjective Norms

The hypothesis below examines how Social Influence (SI) and Extension Services (ES) influence Subjective Norms (SN)

H7: There is a significant and positive relationship between Social Influence (SI) to Subjective Norms (SN).

H8: There is a significant and positive relationship between Extension Services (ES) to Subjective Norms (SN).

The results reveal that Subjective Norm (SN) was positively associated with Social Influence (SI) ($\beta = 0.254$, $p < .001$, $t=5.271$) and Extension Services (ES) ($\beta = 0.194$, $p < .001$, $t=3.695$) indicating that social and institutional factors play important roles in shaping perceptions of norms.

Impact of key factors on Behaviour Intention to adopt SAP

The next part examines the factors that impact Behaviour Intention to adopt SAP in rice cultivation. According to the proposed model, it is hypothesized that Attitude (AT) leads to Behaviour Intention (BI) (H9), Perceived Behaviour Control (PBC) leads to Behaviour Intention (BI) (H10), and Subjective Norms (SN) lead to Behaviour Intention (H11). They are mentioned below:

H9: There is a significant and positive relationship between Attitude (AT) to Behaviour Intention (BI).

H10: There is a significant and positive relationship between Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

H11: There is a significant and positive relationship between Subjective Norms (SN) to Behaviour Intention (BI).

The results reveal that Behavioural Intention (BI) was significantly predicted by Attitude (ATT) ($\beta = 0.265$, $p < .001$, $t= 5.879$) Perceived Behaviour Control (PBC) ($\beta = 0.351$, $p < .001$, $t=7.824$) and Subjective Norm (SN) ($\beta = 0.197$, $p < .001$, $t=4.309$) . The largest effect size was observed for PBC, indicating it plays a particularly strong role in shaping BI. The significant predictive relationships identified between Behavioural Intention (BI) and the constructs of Attitude (AT), Subjective Norm (SN), and Perceived Behavioural Control (PBC) provide compelling insights into the adoption of sustainable agricultural practices among rice farmers in Punjab. The results suggest that these psychological and social factors are instrumental in shaping farmers' intentions to engage with sustainable methodologies. First and foremost, the positive relationship between Attitude ($\beta = 0.265$, $p < .001$,) and BI indicates that a favourable evaluation of sustainable practices substantially enhances the likelihood of their adoption. Further, the influence of Subjective Norm ($\beta = 0.197$, $p < .001$,) further reinforces the social dimensions impacting farmers' decisions. Farmers in Punjab belong to closed communities where peer influence and societal expectations play crucial roles. However, it is the construct of Perceived Behavioural Control ($\beta = 0.351$, $p < .001$,) that stands out as the most robust predictor of BI. The larger effect size associated with PBC indicates that farmers' perceptions of their autonomy and competence in adopting sustainable practices are paramount. This insight implies that barriers—be they financial, informational, or infrastructural—must be addressed to empower farmers. Interventions that enhance skills, provide resources, and improve access to sustainable technologies are crucial for shifting perceptions and fostering confidence in adopting these practices.

f-Square

Table 6.14 presents the key metrics obtained from PLS-SEM analysis. The f-squared (f^2) value indicates effect size and elucidates the predictive capabilities of the

construct, highlighting its importance in assessing the strength of relationships within a structural model. The f-squared value quantifies the effect size of an exogeneous variable on an endogenous variable, evaluating the contribution of a specific predictor variable to the model's explanatory power. The f-squared (f^2) value quantifies the proportion of variation in a dependent variable attributable to a specific independent variable within the overall model. The f-squared (f^2) values are interpreted according to established thresholds: small (0.02), medium (0.15), and large (0.35) (Cohen, 1988). The results reveal that based on the threshold, The f^2 value of 0.015 in the relationship between (PEOU -> AT), indicates a **very small effect size,** indicating that that perceived ease of use (PEOU) plays a negligible role in shaping attitudes (AT). Furthermore, PU -> AT ($f^2 = 0.023$), PC -> AT ($f^2 = 0.039$), ES -> SN ($f^2 = 0.053$), SE -> PBC ($f^2 = 0.054$), PR -> PBC($f^2 = 0.072$, SI -> SN ($f^2 = 0.091$), SN -> BI ($f^2 = 0.073$), NEP-> AT ($f^2 = 0.110$),) range in the threshold value of being close to 0.02 asserting **small effect size**, indicating modest influence. It's the value of AT -> BI ($f^2 = 0.158$) that indicates a **medium size effect** asserting that it has a significant contribution. The highest contribution is shown by PBC -> BI ($f^2 = 0.282$) with assertion of **medium size effect**. This suggests that perceived Behavioural control (AT) and (PBC) play a substantial role in forming Behavioural intentions (BI), making these two of the more significant predictors in this framework due to their largest effect size in shaping up BI.

Table 6.14 *Direct Effect Table*

Hypothesis	Path	Beta	(STDEV)	T statistics	P values	Boot LLCI	Boot ULCI	VIF	f-square	Decision
H1	PU -> AT	0.142	0.052	2.751	0.006	0.043	0.245	1.547	0.023	Supported
H2	PEOU -> AT	0.116	0.045	2.609	0.009	0.03	0.206	1.285	0.015	Supported
H3	PC -> AT	0.185	0.052	3.528	0.000	0.084	0.287	1.503	0.039	Supported
H4	NEP -> AT	0.252	0.046	5.505	0.000	0.164	0.344	1.249	0.11	Supported
H5	SE -> PBC	0.209	0.052	4.013	0.000	0.107	0.312	1.186	0.054	Supported
H6	PR -> PBC	0.226	0.048	4.723	0.000	0.137	0.323	1.186	0.072	Supported
H7	SI -> SN	0.254	0.048	5.271	0.000	0.164	0.352	1.126	0.091	Supported
H8	ES -> SN	0.194	0.052	3.695	0.000	0.095	0.302	1.126	0.053	Supported
H9	AT -> BI	0.265	0.045	5.879	0.000	0.178	0.355	1.27	0.158	Supported
H10	PBC -> BI	0.351	0.045	7.824	0.000	0.26	0.438	1.311	0.282	Supported
H11	SN -> BI	0.197	0.046	4.309	0.000	0.107	0.285	1.261	0.073	Supported

Note: *Author's representation, taken from findings through SmartPLS 4*

6.6.2.2 Indirect Effect Analysis: Mediation Analysis

Specific Indirect effects of Mediation

Table 6.15 presents indirect effects of various mediations, highlighting significant relationships between predictor and outcome variables through mediators in the model. The standardized path coefficients (β), standard deviations, t-statistics, and p-values are reported for each mediation pathway. The hypothesis for mediation is presented below with the results:

H12: There is a significant mediation effect of Attitude (AT) in between Perceived Usefulness (PU) to Behaviour Intention (BI).

PU significantly affects BI through Attitude (β = 0.038, t = 2.477, p = .013), showing that the usefulness of a behaviour or system influences attitudes, which in turn affect behavioural intentions. This suggests that PU is not merely a direct predictor of BI; rather, it operates through the intermediary of Attitude, underscoring the critical role that perceived benefits play in shaping individuals' dispositions towards a particular behaviour or system The positive regression coefficient (β = 0.038) implies that increases in PU correspond to favourable changes in Attitude, signalling that when individuals perceive a behaviour or system as beneficial, their attitudes towards it become more positive. This aligns with established theories in behavioural psychology and technology acceptance models, which posit that perceived value is instrumental in driving individual motivations and intentions. Further, specifically, a t-value above 2 generally suggests that the Hypothesis 12 can be accepted, reinforcing the assertion that PU contributes meaningfully to changes in Attitude. Therefore, it is reasonable to conclude that the influence of PU on BI, mediated by Attitude, reflects a genuine behavioural phenomenon rather than statistical artifact

H13: There is a significant mediation effect of Attitude (AT) in between Perceived Ease of Use (PEOU) to Behaviour Intention (BI).

The indirect effect of PEOU on BI via Attitude is significant (β = 0.031, t = 2.291, p = .022). This indicates that Attitudes mediate the relationship between the ease of use of a system and the intention to engage in a behaviour. The findings indicate a

significant indirect effect of Perceived Ease of Use (PEOU) on Behavioural Intention (BI) through Attitude, as evidenced by a standardized regression coefficient (β) of 0.031, a t-value of 2.291, and a p-value of 0.022. This statistical significance, particularly the p-value falling below the conventional threshold of 0.05, substantiates the view that attitudes serve as a critical mediating factor in the relationship between PEOU and BI, thus H13 is accepted. The results affirm that when users perceive a system as easy to use, they are more likely to form positive attitudes toward that system. This positive attitudinal shift, in turn, enhances their intention to engage in the associated behaviour, which could range from adopting new technology to participating in system-related activities. The mediation effect underscores the importance of fostering a user-friendly environment in system design.

H14: There is a significant mediation effect of Attitude (AT) in between Perceived Compatibility (PC) to Behaviour Intention (BI).

The mediation effect of Attitude in the relationship between PC and BI is significant ($\beta = 0.049$, $t = 2.786$, $p = .005$). This implies that when individuals find behaviour compatible with their values and experiences, their positive attitudes enhance their intention to act. H14 is accepted.

H15: There is a significant mediation effect of Attitude (AT) in between New Ecological Paradigm (NEP) to Behaviour Intention (BI).

The indirect effect of NEP on Behavioural Intention via Attitude is significant ($\beta = 0.067$, $t = 3.837$, $p < .001$). This demonstrates that positive attitudes shaped by ecological awareness mediate the relationship between environmental beliefs and behavioural intentions. H15 is accepted.

H16: There is a significant mediation effect of Perceived Behaviour Control (PBC) in between Self Efficacy (SE) to Behaviour Intention (BI).

The indirect effect of Self-Efficacy on Behavioural Intention through Perceived Behavioural Control is significant ($\beta = 0.073$, $t = 3.451$, $p = .001$). This indicates that PBC mediates the relationship between SE and BI, suggesting that individuals with

higher self-efficacy are likely to have stronger behavioural intentions when they also perceive higher control over their behaviour. H16 is accepted.

H17: There is a significant mediation effect of Perceived Behaviour Control (PBC) in between Perceived Resources (PR) to Behaviour Intention (BI).

PR significantly influences BI through PBC ($\beta = 0.079$, $t = 3.687$, $p < .001$), showing that the availability of personal resources increases behavioural intentions when individuals perceive greater control over their actions. H17 is accepted.

H18: There is a significant mediation effect of Subjective Norms (SN) in between Social Influence (SI) to Behaviour Intention (BI).

The path from Social Influence on Behavioural Intention through Normative Issue is significant ($\beta = 0.050$, $t = 3.259$, $p = .001$). This suggests that social influences affect behavioural intentions by shaping normative perceptions. H18 is accepted.

H19: There is a significant mediation effect of Subjective Norms (SN) in between Extension Services (ES) to Behaviour Intention (BI).

The mediation effect of Subjective Norms between ES and BI is significant ($\beta = 0.038$, $t = 2.501$, $p = 0.012$), suggesting that extension services influence Behavioural Intentions by shaping normative perceptions. H19 is accepted.

Table 6.15 *Indirect Effect - Mediation*

Hypothesis	Path	Beta	Std Err	T-stat	p-value	Boot LLCI	Boot ULCI	Decision
H12	PU -> AT -> BI	0.038	0.015	2.477	0.013	0.011	0.071	Supported
H13	PEOU -> AT -> BI	0.031	0.013	2.291	0.022	0.007	0.060	Supported
H14	PC -> AT -> BI	0.049	0.018	2.786	0.005	0.019	0.088	Supported
H15	NEP -> AT -> BI	0.067	0.017	3.837	0.000	0.037	0.105	Supported
H16	SE -> PBC -> BI	0.073	0.021	3.451	0.001	0.035	0.118	Supported
H17	PR -> PBC -> BI	0.079	0.021	3.687	0.000	0.043	0.126	Supported
H18	SI -> SN -> BI	0.050	0.015	3.259	0.001	0.024	0.084	Supported
H19	ES -> SN -> BI	0.038	0.015	2.501	0.012	0.014	0.073	Supported

Note: *Author's representation, taken from findings through SmartPLS 4*

Table 6.16 *Mediation: Total Effect Table*

	Beta (O)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
PU -> AT	0.142	0.052	2.751	0.006
PU -> BI	0.038	0.015	2.477	0.013
PEOU -> AT	0.116	0.045	2.609	0.009
PEOU -> BI	0.031	0.013	2.291	0.022
PC -> AT	0.185	0.052	3.528	0.000
PC -> BI	0.049	0.018	2.786	0.005
NEP -> AT	0.252	0.046	5.505	0.000
NEP -> BI	0.067	0.017	3.837	0.000
SE -> PBC	0.209	0.052	4.013	0.000
SE -> BI	0.073	0.021	3.451	0.001
PR -> PBC	0.226	0.048	4.723	0.000
PR -> BI	0.079	0.021	3.687	0.000
SI -> SN	0.254	0.048	5.271	0.000
SI -> BI	0.050	0.015	3.259	0.001
ES -> SN	0.194	0.052	3.695	0.000
ES -> BI	0.038	0.015	2.501	0.012
AT -> BI	0.265	0.045	5.879	0.000
PBC -> BI	0.351	0.045	7.824	0.000
SN -> BI	0.197	0.046	4.309	0.000

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.17 *Mediation: Variance Accounted For (VAF) Mediation Paths*

Total Effect Path	Total Effect (TE)	Indirect effect (IE)	VAF = TE/IE	%age
PU-AT X AT-BI +PU-BI	0.076	0.038	0.502	50.2
PEOU-AT X AT-BI + PEOU-BI	0.129	0.031	0.240	24.0
PC-AT X AT-BI +PC-BI	0.054	0.049	0.910	91.0
NEP-AT X AT-BI +NEP-BI	0.185	0.067	0.362	36.2
SE-PBC X PBC-BI + SE-BI	0.146	0.073	0.499	49.9
PR-PBC X PBC-BI + PR-BI	0.240	0.079	0.329	32.9
SI-SN X SN-BI + SI-BI	0.100	0.050	0.500	50.0
ES-SN X SN-BI + ES-BI	0.194	0.038	0.196	19.6

Note: *Author's representation through calculations based on findings from SmartPLS4*

Table 6.18 *Explanatory and Predictive Indices of the Mediation Model*

	R-square	R-square adjusted	Q^2	Q^2Predict
BI	0.530	0.527	0.254	0.242
AT	0.330	0.323	0.146	0.217
PBC	0.172	0.168	0.080	0.111
SN	0.177	0.173	0.083	0.115

Note: *Author's representation, taken from the findings through SmartPLS 4*

6.6.2.3 Explanatory and Predictive Power of the Mediation Model

The R-square values represent the proportion of variance explained by the independent variables for each dependent variable.

- Behavioural Intention (BI) had an R-square of 0.530, meaning that 53% of the variance in BI is explained by the predictor variables in the model. The adjusted R-square (0.527) is slightly lower, adjusting for the number of predictors in the model. The Q^2 value is 0.254 and Q^2Predict is 0.242 indicating a predictive relevance of the model to be around 24%.

- Attitude (AT) had an R-square of 0.330, indicating that 33.0% of the variance in AT is explained by its predictors. The adjusted R-square for AT is 0.323, showing a slight reduction when accounting for the number of predictors. The Q^2 value is 0.146 and Q^2Predict is 0.217 indicating a predictive relevance of the effect of AT in the model to be around 21%.

- Perceived Behavioural Control (PBC) had an R-square of 0.172, suggesting that 17.2% of the variance in PBC is explained by its predictors, with an adjusted R-square of 0.168. The Q^2 value is 0.080 and Q^2Predict is 0.111 indicating a predictive relevance of the effect of PBC in the model to be around 11.1%.

- Finally, Subjective Norms (SN) had an R-square of 0.177, meaning that 17.7% of the variance in SN is explained by its predictors, with an adjusted R-square of 0.173. The Q^2 value is 0.083 and Q^2Predict is 0.115 indicating a predictive relevance of the effect of SN in the model to be around 11.5%.

6.6.2.4 Moderation Analysis

Based on the findings of qualitative research done in the phase 1 of this project, two moderators, namely Institutional Support (IS) and Market Infrastructure (MI) were introduced in the conceptual model. A structural model analysis was conducted through bootstrapping to assess the moderating role of IS and MI on paths leading to behaviour intention.

IS as moderator

Following hypothesis are proposed to be tested to assess the interaction effects of IS on AT->BI, PBC->BI, and SN->BI.

H20: There is a significant moderation effect of Institutional Support (IS) on Attitude (AT) to Behaviour Intention (BI).

H21: There is a significant moderation effect of Institutional Support (IS) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI)

H22: There is a significant moderation effect of Institutional Support (IS) on Subjective Norms (SN) to Behaviour Intention (BI)

Hypothesis Testing:

H20: There is a significant moderation effect of Institutional Support (IS) on Attitude (AT) to Behaviour Intention (BI).

The study assessed the moderating role of Institutional Support on the relationship between Attitude (AT) and Behaviour Intention (BI). Without the inclusion of moderating effect of IS, the value of R^2 for Behaviour Intention was 0.53, which translates to that 53% change in BI is accounted by Attitude. With the inclusion of IS, the value of R^2 for BI enhanced to 61.1%. This reflects 8.1% variance explained by presence of IS on BI. Further, significance of moderating effect was analyzed, the results revealed a positive and significant impact of IS on the relationship between Attitude and Behaviour Intention (($\beta = 0.209$, $p < .001$, $t = 6.137$, $f^2 = 0.201$, VIF = 1.029). Hence the H20 is accepted. (Table 6.19)

H21: There is a significant moderation effect of Institutional Support (IS) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

This study evaluated the moderating effect of Institutional Support on the relationship between PBC and BI. The R^2 value for Behaviour Intention, excluding the moderating effect of IS, was 0.53, indicating that 53% of the variance in BI is explained by Attitude. The incorporation of IS increased the R^2 value for BI to 61.9%. This indicates an 8.9% variance explained by the presence of Institutional Support on Behaviour Intention. The analysis of the moderating effect indicated a positive and significant influence of Institutional Support (IS) on the relationship between PBC and BI ($\beta = 0.230$, $p < .001$, $t = 5.757$, $f^2 = 0.229$, VIF = 1.036). Therefore, H21 is accepted. (Table 6.19)

H22: There is a significant moderation effect of Institutional Support (IS) on Subjective Norms (SN) to Behaviour Intention (BI)

This research assessed the moderating influence of Institutional Support on the link between Subjective Norms (SN) and Behaviour Intention (BI). The R^2 value for Behaviour Intention, without the moderating influence of IS, was 0.53, signifying that 53% of the variance in BI is accounted for by Attitude. The integration of IS elevated the R^2 value for BI to 59.1.%. This signifies an 6.1% variance accounted for by the influence of Institutional Support on the relationship between Subjective Norms and Behavioural Intention. The examination of the moderating effect revealed a positive and significant impact of Institutional Support (IS) on the association between Subjective Norms (SN) and Behaviour Intention (BI) with ($\beta = 0.190$, $p < .001$, $t = 4.820$, $f^2 = 0.144$, VIF = 1.027). Consequently, H22 is accepted. (Table 6.19)

Table 6.19 ***Significance Table of Moderation analysis of IS***

Interaction Term	Beta	Std Dev	T Stat	P Value	Boot LLCI	Boot ULCI	f-Square	VIF	Decision
IS X AT - BI (H20)	0.209	0.034	6.137	0.000	0.140	0.273	0.201	1.029	Supported
IS X PBC - BI (H21)	0.230	0.040	5.757	0.000	0.150	0.304	0.229	1.036	Supported

Interaction Term	Beta	Std Dev	T Stat	P Value	Boot LLCI	Boot ULCI	f-Square	VIF	Decision
IS X SN - BI (H22)	0.190	0.039	4.820	0.000	0.112	0.266	0.144	1.027	Supported

Note: *Author's representation, taken from the findings through SmartPLS 4*

Finally, the effect of IS on all the three relationships is assessed together in structural model (Fig 6.6) and significance of the same is presented in table 6.20 and with variance in explanatory and exploratory factors reflected in table 6.21.

Table 6.20 ***Significance Table of Moderation analysis of IS***

	Beta	STDEV	T-stat	P-Values	Boot LLCI	Boot ULCI	f-Square	VIF
IS x AT -> BI	0.145	0.038	3.783	0.000	0.067	0.216	0.091	1.229
IS x PBC -> BI	0.163	0.045	3.654	0.000	0.076	0.250	0.105	1.278
IS x SN -> BI	0.083	0.043	1.923	0.055	0.000	0.169	0.016	1.368

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.21 ***Effect of IS as moderator on the*** **R^2**, ***Q^2 and Q^2 Predict***

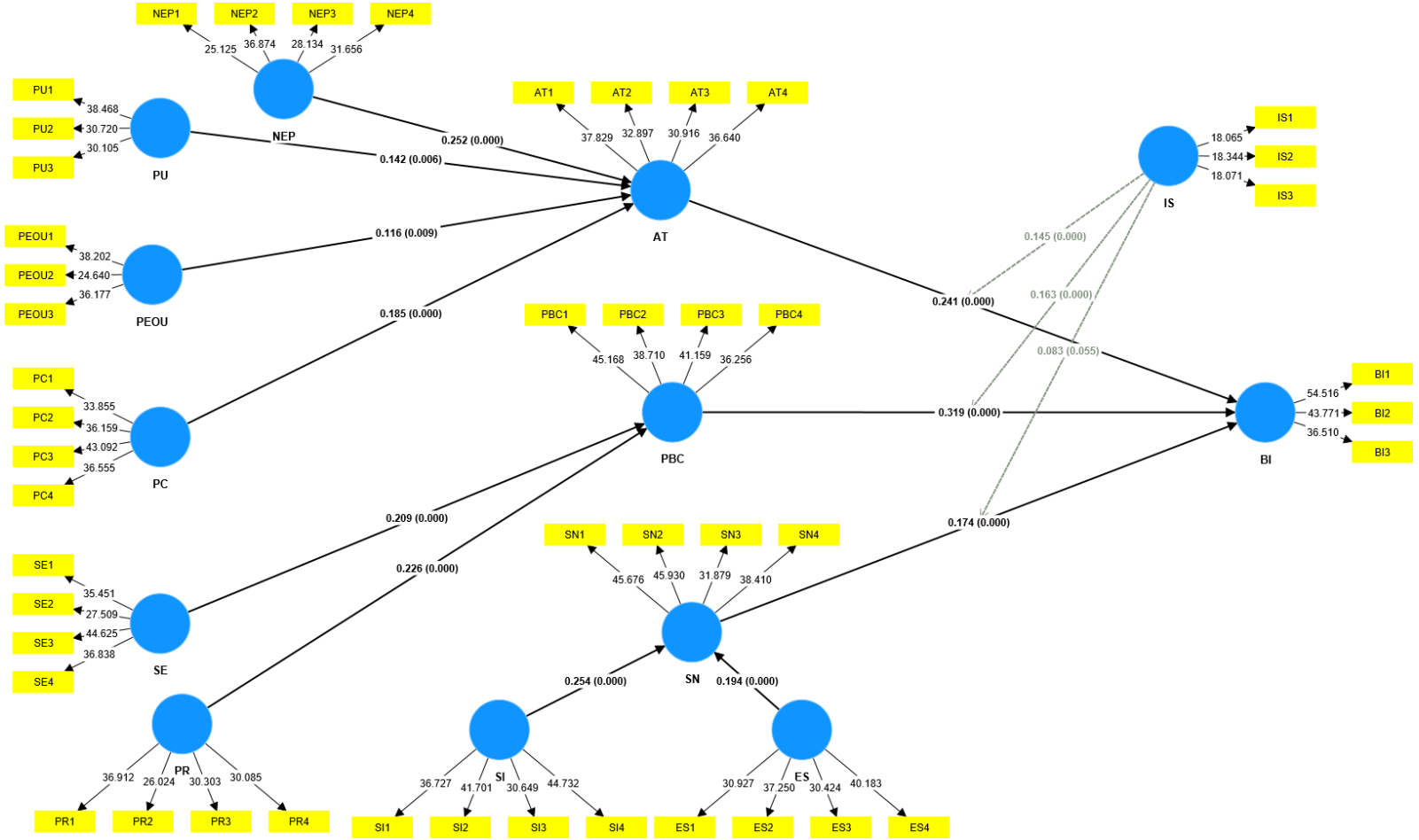
	R^2		R^2 adjusted		Q^2		Q^2 Predict	
	Without IS	With IS	Without IS	With IS	Without IS	With IS	Without IS	With IS
BI	0.530	0.667	0.527	0.661	0.254	0.309	0.242	0.298
AT	0.330	0.330	0.323	0.323	0.146	0.146	0.217	0.217
PBC	0.172	0.172	0.168	0.168	0.080	0.080	0.111	0.111
SN	0.177	0.177	0.173	0.173	0.083	0.083	0.115	0.115

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.21 shows that with the presence of IS as moderator in the structural model, the variance in R^2 value of the model gets enhanced by 13.7%, Q^2 is influenced 5.5% and Q^2 predict gets enhanced by 5.6%. However, there is another peculiar aspect to note here that while the P-value of IS, when tested on the relationship between SN and BI, separately, was significant but in the model when it moderates all the relations collectively, the value gets insignificant. This makes sense as when Institutional Support becomes available for everyone, the influence of normative aspect probably

won’t matter as the accessibility (of IS) itself could lead directly to BI without the influence of any intermediary.

Figure 6.6 *Moderation analysis of IS*



Note. Author's representation taken from findings through SmartPLS4

Moderation Graphs

The moderation graphs illustrate the interaction effects between Institutional Support (IS) and three different variables—Attitude (AT), Perceived Behavioural Control (PBC) and Subjective Norms (SN), —on Behavioural Intention (BI). Each graph examines how BI changes as a function of these predictors at three levels of IS: -1 standard deviation (SD), mean, and +1 SD.

1. **IS x AT Interaction**: The interaction between Institutional Support (IS) and Attitude (AT) on Behavioural Intention (BI) is depicted in the first graph, in Figure 6.7. The slope of the effect that AT has on BI is relatively shallow when the IS is at low levels (-1 standard deviation). The effect of AT on BI gets more pronounced when IS increases to the mean and subsequently to +1 standard deviation, as shown by the steeper slopes observed in the graph. It appears from this that the favourable association that exists between AT and BI is strengthened when IS is at a higher percentage.
2. **IS x PBC Interaction**: This interaction between Institutional Support (IS) and Perceived Behavioural Control (PBC) on Behavioural Intention (BI) is depicted in the second graph, in Figure 6.8. Its evident that the slope of the association between PBC and BI increases when the standard deviation (IS) moves from -1 SD to +1 SD. This demonstrates that a greater IS intensifies the favourable influence that PBC has on BI.
3. **IS x SN Interaction**: A representation of the relationship between Institutional Support (IS) and Subjective Norms (SN) on Behavioural Intention (BI) is seen in the third graph, is illustrated in Figure 6.9. The slope is steeper at greater levels of IS, which indicates that the influence of SN on BI is more evident when IS is higher. This is similar to the interaction between IS and ATT. The association between SN and BI is weak while IS is at low levels (-1 SD), but it grows stronger as IS increases. SN and BI are related to one another.

Across all three interactions, higher levels of Institutional Support (IS) consistently strengthen the positive effects of Attitude (AT), Perceived Behavioural Control (PBC),and Subjective Norm (SN), on Behavioural Intention (BI). This

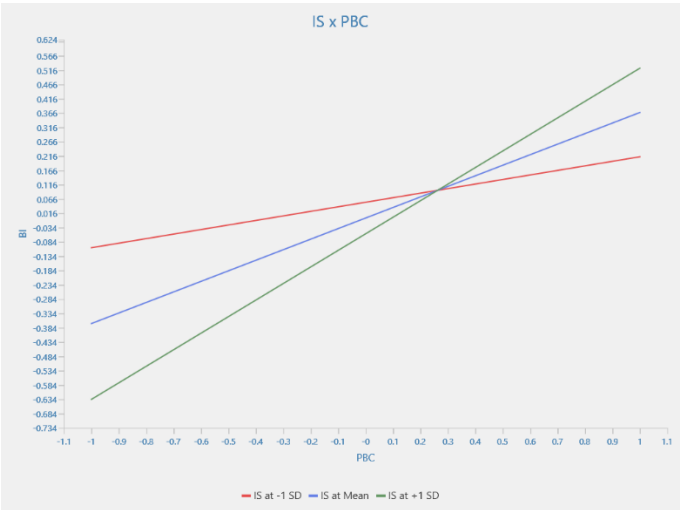
indicates that when individuals perceive stronger institutional backing, the impact of their attitudes, norms, and perceived control over Behaviour becomes more influential in determining their Behavioural intentions.

These findings highlight the moderating role of IS, suggesting that supportive institutional contexts can enhance the predictive power of psychological and social factors on individuals' intentions to act in a certain manner.

Figure 6.7 ***Slope Analysis – IS x AT -> BI***

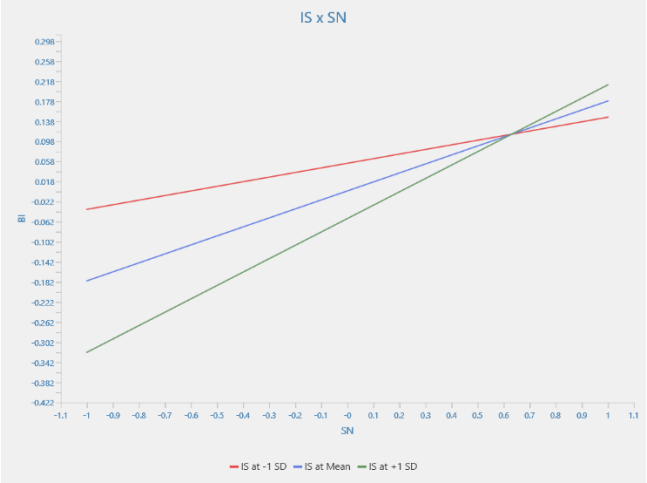
Note. *Author's representation, taken from the findings through SmartPLS 4*

Figure 6.8 ***Slope Analysis – IS x PBC -> BI***



Note. *Author's representation, taken from the findings through SmartPLS4*

Figure 6.9 ***Slope Analysis – IS x AT -> SN***



Note. *Author's representation, taken from the findings through SmartPLS*

MI as moderator

Following hypothesis are proposed to be tested to assess the interaction effects of MI on AT->BI, PBC->BI, and SN->BI.

H23: There is a significant moderation effect of Market Infrastructure (MI) on Attitude (AT) to Behaviour Intention (BI).

H24: There is a significant moderation effect of Market Infrastructure (MI) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

H25: There is a significant moderation effect of Market Infrastructure (MI) on Subjective Norms (SN) to Behaviour Intention (BI).

Hypothesis Testing:

H23: There is a significant moderation effect of Market Infrastructure (MI) on Attitude (AT) to Behaviour Intention (BI).

The study assessed the moderating role of MI on the relationship between Attitude (AT) and Behaviour Intention (BI). Without the inclusion of moderating effect of MI, the value of R^2 for Behaviour Intention was 0.53, which translates to that 53% change in BI is accounted by Attitude. With the inclusion of MI, the value of R^2 for BI enhanced to 62.5%. This reflects 9.5% variance explained by presence of MI on BI.

Further, significance of moderating effect was analysed, the results revealed a positive and significant impact of MI on the relationship between Attitude and Behaviour Intention (($\beta = 0.222$, $p < .001$, $t = 5.362$, $f^2 = 0.214$, VIF = 1.030). Hence the H20 is accepted. (Table 6.22)

H24: There is a significant moderation effect of Market Infrastructure (MI) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI).

This study evaluated the moderating effect of Market Infrastructure on the relationship between PBC and BI. The R^2 value for Behaviour Intention, excluding the moderating effect of MI, was 0.53, indicating that 53% of the variance in BI is explained by Attitude. The incorporation of MI increased the R2 value for BI to 59.9%. This indicates an 6.9% variance explained by the presence of Market Infrastructure on Behaviour Intention. The analysis of the moderating effect indicated a positive and significant influence of MI on the relationship between PBC and BI ($\beta = 0.182$, $p <= .001$, $t = 5.026$, $f^2 = 0.135$, VIF = 1.022). Therefore, H24 is accepted. (Table 6.22)

H25: There is a significant moderation effect of Market Infrastructure (MI) on Subjective Norms (SN) to Behaviour Intention (BI).

This research assessed the moderating influence of Institutional Support on the link between Subjective Norms (SN) and Behaviour Intention (BI). The R^2 value for Behaviour Intention, without the moderating influence of IS, was 0.53, signifying that 53% of the variance in BI is accounted for by Attitude. The integration of MI elevated the R^2 value for BI to 55.7.%. This signifies an 2.7% variance accounted for by the influence of Market Infrastructure on the relationship between Subjective Norms and Behavioural Intention. The examination of the moderating effect revealed a positive and significant impact of (MI) on the association between Subjective Norms (SN) and Behaviour Intention (BI) with ($\beta = 0.088$, $p = 0.024$, $t = 2.251$, $f^2 = 0.027$, VIF = 1.032). Consequently, H25 is accepted. (Table 6.22)

Table 6.22 *Significance Table of Moderation analysis of MI*

Interaction Term	Beta	Std Dev	T Stat	P Value	Boot LLCI	Boot ULCI	F^2	VIF	Decision
MI X AT -BI (H23)	0.222	0.041	5.362	0.000	0.136	0.295	0.214	1.030	Supported
MI X PBC-BI (H24)	0.182	0.036	5.026	0.000	0.105	0.242	0.135	1.022	Supported
MI X SN-BI (H25)	0.088	0.039	2.251	0.024	0.008	0.162	0.027	1.032	Supported

Note: *Author's representation, taken from the findings through SmartPLS 4*

Finally, the effect of MI on all the three relationships is assessed together in structural model (Fig 6.10) and significance of the same is presented in table 6.23 and with variance in explanatory and exploratory factors reflected in table 6.24.

Table 6.23 ***Significance Table of Moderation analysis of MI***

	Beta (O)	STDEV	T-stat	P-Values	Boot LLCI	Boot ULCI	f-square	VIF
MI x AT -> BI	*0.177*	*0.048*	*3.675*	*0.000*	*0.079*	*0.267*	*0.127*	*1.29*
MI x PBC -> BI	*0.132*	*0.042*	*3.115*	*0.002*	*0.042*	*0.208*	*0.054*	*1.367*
MI x SN -> BI	*-0.017*	*0.042*	*0.394*	*0.694*	*-0.097*	*0.072*	*0.005*	*1.348*

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.24 ***Effect of MI as moderator on the R^2, Q^2 and Q^2 Predict***

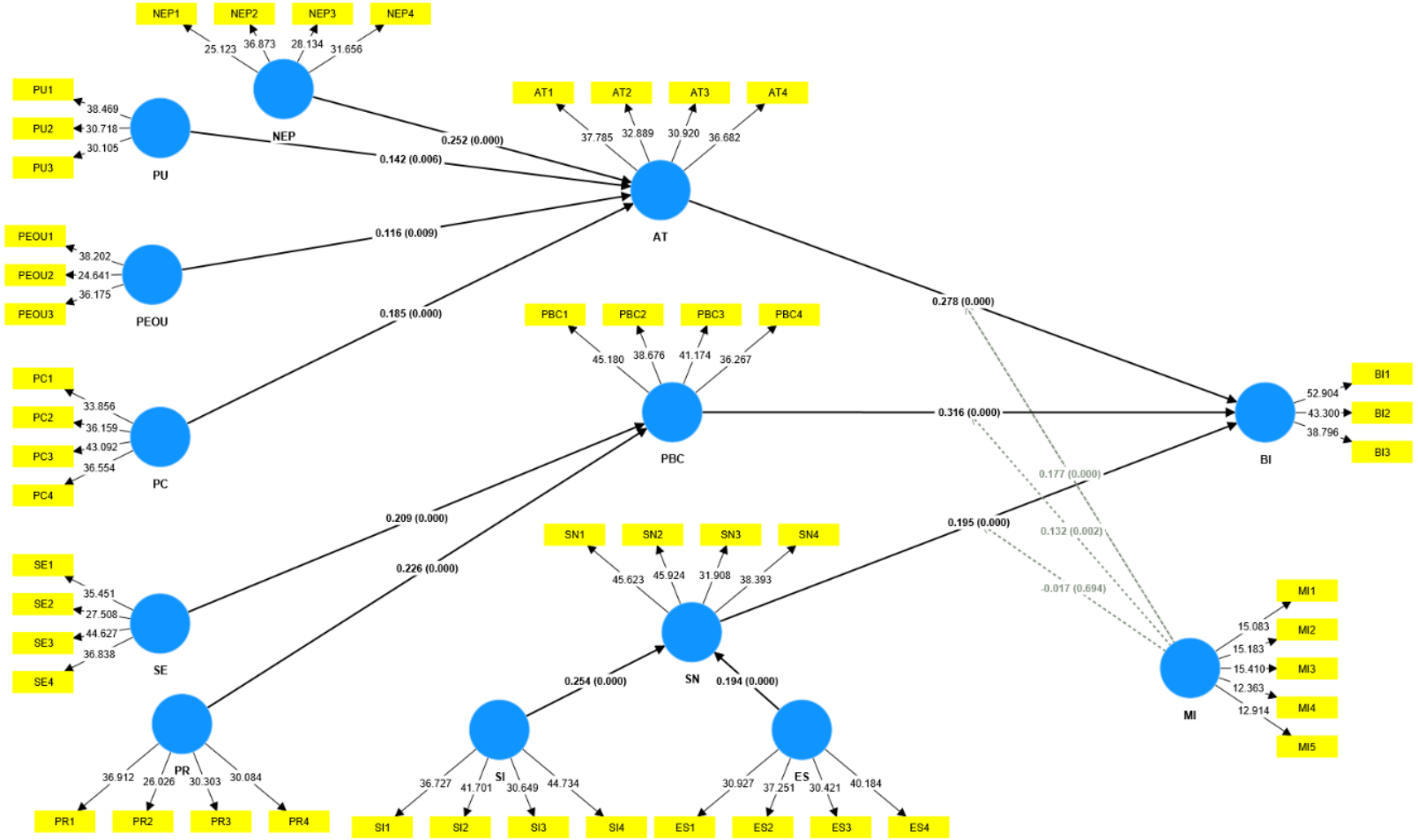
	R^2		R^2 adjusted		Q^2		Q^2 Predict	
	Without MI	With MI	Without MI	With MI	Without MI	With MI	Without MI	With MI
BI	0.530	0.644	0.527	0.638	0.254	0.296	0.242	0.289
AT	0.330	0.330	0.323	0.323	0.146	0.146	0.217	0.217
PBC	0.172	0.172	0.168	0.168	0.080	0.080	0.111	0.111
SN	0.177	0.177	0.173	0.173	0.083	0.083	0.115	0.115

Note: *Author's representation, taken from the findings through SmartPLS 4*

Table 6.24 shows that with the presence of MI as moderator in the structural model, the variance in R^2 value of the model gets enhanced by 11.4%, Q^2 is influenced

38.4% and Q^2 predict gets enhanced by 4.7%. However, there is another peculiar aspect to note here that while the P-value of MI, when tested on the relationship between SN and BI, separately, was significant but in the model when it moderates all the relations collectively, the value gets insignificant (P=0.694, T=0.394). This makes sense as when Market Infrastructure becomes available for everyone, the influence of its effect aspect probably won't matter as the accessibility (of market) itself could lead directly to BI without the influence of any intermediary.

Figure 6.10 *Moderation effect of MI*



Note: *Author's representation, taken from the findings SmartPLS 4*

Moderation Graphs

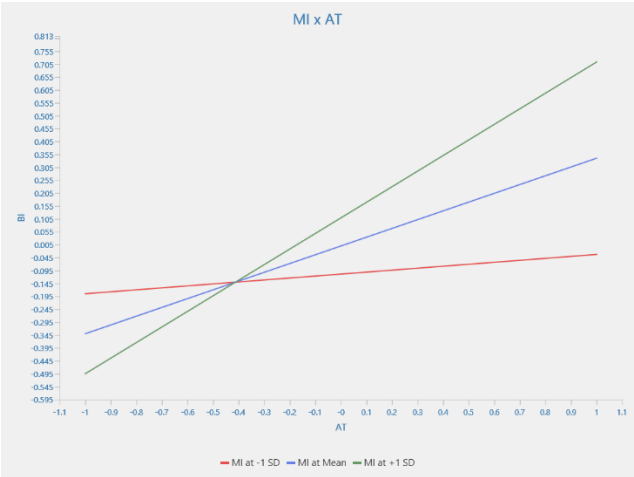
The three moderation graphs illustrate how **Market Infrastructure (MI)** interacts with **Attitude (AT)**, **Perceived Behavioural Control (PBC)**, and Subjective **Norms (SN)** to influence **Behavioural Intention (BI)**. Here's an interpretation of each graph that how it brings change in BI -1 SD, Mean and +1SD

1. **MI x AT Interaction**: The first graph, in Figure 6.11, illustrates the moderating effect that Market Infrastructure (MI) has on the link between Attitude (AT) and Behavioural Intention (BI). A steeper slope is evidence that the positive link between AT and BI strengthens at higher levels of MI (+1 SD), as indicated by the slopes. This is evidenced by the fact that the slopes are steeper. There is a positive association, however it is not as pronounced when the mean level of MI is considered. The association between AT and BI continues to be favourable even at lower levels of MI (-1 standard deviation), but the slope of the relationship is substantially flatter. It may be deduced from this that a greater MI magnifies the beneficial effect that AT has on BI, whilst a lower MI diminishes the strength of this effect.
2. **MI x PBC Interaction**: A similar moderating effect of MI on the PBC-BI association is depicted in the second graph (Fig. 6.12), which can be found here. A steep slope indicates that there is a larger positive correlation between PBC and BI when the levels of MI are high (+1 standard deviation). In spite of the fact that it is less steep, the connection continues to be favourable at the mean level of MI. The association is still positive at low levels of MI (-1 standard deviation), but it is substantially weaker. This suggests that MI amplifies the impact of PBC on BI, with higher MI resulting in greater BI as PBC increases.
3. **MI x SN Interaction**: In the third graph, which is referred to as Figure 6.13, the interaction between MI, SN, and BI is drawn out. When compared to the mean and lower levels of MI (-1 SD), the positive relationship between SN and BI gets greater at higher levels of MI (+1 SD). This is in contrast to the mean and lower levels of MI. As was the case with the interactions that came before it, the steepest slope was recorded at a standard deviation of +1 of MI, while the flattest slope was observed

at a standard deviation of -1 of MI. This indicates that MI amplifies the influence of SN on BI.

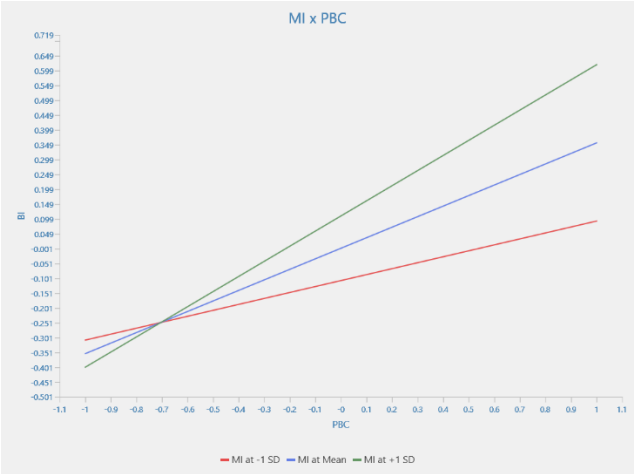
The overall effect of MI is that it acts as a substantial moderator in all three connections (ATT-BI, PBC-BI, and SN-BI), and it consistently strengthens the beneficial effects that these predictors have on BI when MI is at greater levels. When MI is low, on the other hand, the associations are reduced in strength but continue to be favourable. Based on this interaction, it appears that a robust market infrastructure has the ability to amplify the influence of attitude, perceived behavioural control, and normative concerns on behavioural intentions.

Figure 6.11 ***Slope Analysis MI x AT -> BI***



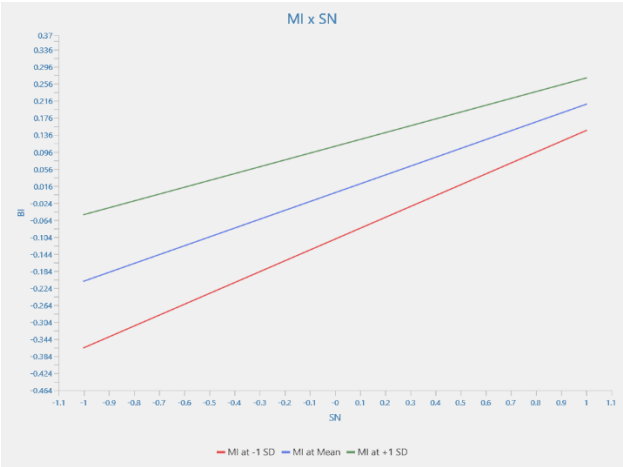
Note: *Author's representation, taken from the findings through SmartPLS 4*

Figure 6.12 *Slope Analysis MI x PBC -> BI*



Note: *Author's representation, taken from the findings through SmartPLS 4*

Figure 6.13 ***Slope Analysis MI x SN -> BI***



Note: Author's representation, taken from the findings through SmartPLS 4

6.7 Chapter Summary

The chapter summarises the detailed analysis of the quantitative study. The findings are based on two data analysis software, SPSS 27 and SmartPLS 4. The initial section presents the demographics of the respondents leading to descriptives of the various variables. Further Exploratory Factor Analysis 'EFA' is presented. Thereon, the chapter moves to findings based on SmartPLS4, measurement model and structural model analysis are carried out which presents that all the hypothesis formulated for the study are significant and accepted. The study is free from any collinearity issues and software confirms absence of bias along with showcasing goodness of model fit. The

chapter also brings about the explanatory and predictive power of the hypothesised research model. The last section presents the moderation role played by Institutional Support and Market Infrastructure.

7. Chapter 7 – Summary & Conclusion

"The goal is to turn data into information, and information into insight."

- Carly Fiorina

7.1 Overview

The principal objective of this research is to study the Sustainable Agricultural Practices in rice cultivation amongst the growers of Punjab. The objective has been achieved by exploring the following research questions identified after a comprehensive literature review.

RQ1 To examine the challenges faced in growing rice using sustainable agricultural practices.

RQ2 To examine the level of awareness and frequency of use of Sustainable Agricultural Practices?

RQ3 To assess the perception towards adoption of Sustainable Agricultural Practices in rice cultivation amongst the growers of Punjab?

RQ4 To examine the moderating effect of institutional support and market infrastructure with respect to behavioural intention

The study used an exploratory sequential Mix Method Research Design. RQ1 was explored through qualitative method while rest of the three RQs were investigated through quantitative survey. The sample set was rice growers from five Agroclimatic zones of Punjab based on proportionate rice production. The chapter presents the summary of findings from each research question followed by a discussion on impact of demographic characteristics and moves on present the conclusions. The last section reflects the limitations and future research directions.

7.2 Challenges in growing rice using SAP: Findings from Qualitative Study

The study conducted qualitative interviews with both set of farmers who used sustainable practices in rice farming and those who used conventional methods. The farmers expressed their positive attitude towards sustainability and associated practices, but also shared concerns about adoption, particularly in rice cultivation. They compared the usefulness of conventional practices, such as productivity and profitability, to the

complexity of Sustainable Agriculture Practices (SAP) in rice cultivation. The farmers who have adopted sustainable practices shared anecdotes about the harmful effects of chemicals on crop protection and the importance of embracing organic farming. They cited Guru Nanak Dev ji's sakhis, the preciousness of all life forms around them, and the declining variety of life forms. They also mentioned the need for collective initiatives to curb ecological damages and the role of state agricultural universities and extension services in facilitating change. Farmers who are engaged in chemical-free agriculture but opt not to pursue certification procedures face challenges such as extensive formalities, costs, and complexity. Organic Certification has two routes either third-party certification through registered regulated agencies or through the Participatory Guarantee Scheme (PGS), which have both advantages and disadvantages. The former allows farmers to export their produce but requires a three-year field fallow to ensure it is free of chemicals before starting organic farming. The farmers in the sample who have achieved greater success in organic farming come from higher social strata, with extensive land holdings, personal resources, and marketing networks. The Participatory Guarantee Scheme (PGS) enables a collective of farmers to unite and commit to chemical-free practices, but its susceptibility to exploitation by unscrupulous individuals is a significant barrier. In conclusion, profitability, complexity, compatibility, environmental commitment, self-efficacy, resource availability, social influence, and extension services play significant roles in defining attitudes, behaviour control, and subjective norms that impact the behavioural intention towards adoption of sustainable farming. The farmers insist that this intention can grow multi-fold if there is institutional support and market infrastructure available. The set of farmers who have already adopted some or other form of sustainable practices indicated steadfast commitment towards the environmental cause.

7.3 Level of Awareness & Frequency of Use

A study was conducted to assess the awareness and frequency of use of Sustainable Agriculture Practices (SAP) among farmers. The practices included Land Levelers, Tillage practices, Seed quality, Direct Seeding of Rice, Cultivar choice (Basmati and delayed transplantation), farmyard manure, optimal use of Urea, row-crop plantation, biological pesticides, stubble burning, and direct seeding of wheat. The

results showed a mean score of 3.02 and 3.04 respectively with SD being 1.095, indicating a fair level of awareness and usage of SAP. However, there was significant variability in responses, suggesting the need for educational initiatives to improve farmers' understanding. The study suggests an average level of awareness and frequency of use of selected practices, with some farmers being more knowledgeable than others.

7.4 Farmer Perception towards SAP Adoption in Rice Cultivation

To understand farmer perception, the study of structural relationships was carried out based on the Literature Review and findings of the qualitative study as per the hypothesis model. Through the results, we can see that all the hypotheses have shown significant results.

Direct Paths in the Structural Relationships

The direct path of Perceived Usefulness (PU) to Attitude (AT) with $\beta = 0.142$, and $t=2.751$ and $p = 0.006$, of Perceived Ease of Use (PEOU) to Attitude (AT) with $\beta = 0.116$, and $t=2.609$ and $p = 0.045$, of Perceived Compatibility (PC) to Attitude (AT) with $\beta = 0.185$, and $t=3.528$ and $p <0.001$ is significant, leading to acceptance of H1 to H3. These findings are in line with (Arkorful et al., 2022; Husin et al., 2023; Pliatsikas & Economides, 2022; Ruslim & Herwindiati, 2024). The direct path of New Ecological Paradigm (NEP) to Attitude (AT) with $\beta = 0.252$, and $t=5.505$ and $p <0.001$ is significant hence H4 is accepted. The results are in congruence with (M. Chen & Martens, 2023; Gansser & Reich, 2023). The direct path of Self Efficacy (SE) to Perceived Behaviour Control (PBC) with $\beta = 0.209$, and $t=4.013$ and $p <0.00$, is significant hence H5 is accepted. The study results are in accordance with (Alam et al., 2024; L. Chen et al., 2024; Oluwadamilola Olufemi Rotimi et al., 2024) The direct path of Perceived Resources (PR) to Perceived Behaviour Control (PBC) with $\beta = 0.226$, and $t=4.723$ and $p <0.001$ is significant hence H6 is accepted. The findings are in line with the results from (Zeweld et al., 2017). The direct path of Social Influence (SI) to Subjective Norms (SN) with $\beta = 0.254$, and $t=5.271$ and $p = 0.006$ is significant hence H7 is accepted. The results find validity with the similar findings in the studies (Al Khasawneh & Irshaidat, 2017; Omulo et al., 2024).The direct path of Extension Services to Subjective Norms (SN) with $\beta = 0.194$, and $t=3.695$ and $p <0.001$ is

significant hence H8 is accepted. The findings are corroborated with findings from (Cammarata et al., 2024; Nugraha et al., 2024; Timpanaro et al., 2023). The direct path of Attitude (AT) to Behavioural Intention (BI) with $\beta = 0.265$, and $t=5.879$ and $p <0.001$, is significant hence H9 is accepted. The direct path of Perceived Behavioural Control (PBC) to Behavioural Intention (BI) with $\beta = 0.351$, and $t=7.824$ and $p <0.001$, is significant hence H10 is accepted. The direct path of Subjective Norms (SN) to Behavioural Intention (BI) with $\beta = 0.197$, and $t=4.309$ and $p <0.001$, is significant hence H11 is accepted. These results are concurrent with (K. et al., 2022; J. Liu et al., 2022; Taherpour et al., 2022)

The study reveals that perceived usefulness, ease of use, compatibility, New Ecological Paradigm, self-efficacy, resources, social influence, extension services, and subjective norms are all significant factors influencing farmers' attitudes and intentions towards adopting sustainable agricultural methods in rice farming in Punjab. These findings are consistent with previous studies and are in line with previous research. The study also found that social influence, extension services, and subjective norms also have a significant impact on farmers' attitudes and intentions towards adopting sustainable agricultural methods. The study concludes that these factors are crucial for understanding the adoption process of sustainable agricultural methods in rice farming. The findings highlight the importance of understanding these factors in promoting sustainable agricultural practices.

Key Influences on Attitude, PBC and SN: The study reveals that farmers in Punjab are more likely to engage in sustainable agricultural practices if they receive tangible benefits such as improved yields and reduced costs. Perceived Usefulness (PU) with a standardized coefficient (β) of 0.142 and a p-value of .006, is a key factor, with a direct correlation between perceived usefulness and positive attitude towards sustainable practices. Perceived Ease of Use (PEOU) with $\beta= 0.116$, $p = .009$ is also crucial, as making sustainable practices easy to adopt can alleviate apprehension and promote acceptance. Perceived Compatibility (PC) having β valued at 0.185 ($p < .001$) is another important factor, as aligning farmers' practices with sustainable techniques and community norms can encourage adoption without causing disruption. The New

Ecological Paradigm (NEP) with β of 0.252 and a p-value less than .001, is a strong influence, with farmers' environmental awareness and positive orientation significantly shaping their attitudes towards sustainable practices. Self-Efficacy (β = 0.209, p <.001, t= 4.013) and Perceived Resources (β = 0.226, p <.001, t= 4.723) also play a significant role in Perceived Behavior Control. The study also shows a positive correlation between Subjective Norm (SN) and Social Influence (SI), (β = 0.254, p < .001, t=5.271), and Extension Services (ES) (β = 0.194, p < .001, t=3.695), suggesting that social and institutional elements significantly influence normative judgements.

Key Influences on BI: The study reveals that Behavioural Intention (BI) is significantly influenced by Attitude (ATT) (β = 0.265, p < .001, t = 5.879),, Perceived Behavioural Control (PBC) (β = 0.351, p < .001, t = 7.824),, and Subjective Norm (SN) (β = 0.197, p < .001, t = 4.309). Farmers with a positive attitude towards sustainability are more likely to integrate sustainable practices into their rice cultivation methods. Social norms that support sustainable practices also influence farmers' intentions. The concept of Perceived Behavioural Control (β = 0.351, p < .001) is the most significant predictor of BI, indicating that farmers' opinions of their autonomy and competence in implementing sustainable practices are crucial. By enhancing positive attitudes, leveraging subjective norms, and bolstering perceived behavioral control, stakeholders can increase the adoption of sustainable agricultural practices, contributing to environmental resilience and economic stability.

In-Direct Paths in the Structural Relationships

Mediation by Attitude: Attitude plays a crucial role in shaping individuals' dispositions towards a particular behavior or system. It is a mediator between perceived usefulness and behavioral intention, (β = 0.038, t = 2.477, p =.013), indicating that attitudes are influenced by the practicality of a behavior or system. The study also found a significant mediation effect of perceived ease of use (PEOU) with β of 0.031, a t-value of 2.291, and a p-value of 0.022, on behavioral intention (BI). The mediation effect of attitude in the relationship between Perceived Compatibility (β = 0.049, t = 2.786, p = .005) and Behavioural Intention is significant, indicating that positive attitudes enhance intention to act. The New Ecological Paradigm has a substantial

indirect effect on BI through attitude with (β = 0.067, t = 3.837, p <.001), indicating that positive attitudes shaped by ecological knowledge play a critical role in shaping individuals' dispositions towards a particular behavior or system. The influence of PU, PEOU, PC, and NEP on BI is mediated by attitude, reflecting a genuine behavioral phenomenon rather than statistical artifact. These findings are in line with the results of (Guo et al., 2024a; Shao et al., 2022a)

Mediation by Perceived Behaviour Control: The study found that self-efficacy with (β = 0.073, t = 3.451, p =.001) indirectly influences behavioral intention through perceived behavioural control. This suggests that people with more control over their actions have stronger intentions to act. The study also found that perceived resources PBC (β = 0.079, t = 3.687, p <.001, also influence behavioral intentions. The agricultural community in Punjab, for example, has a strong belief in their capabilities and confidence in their abilities. Perceptions of resource availability or scarcity also influence individuals' perceived control over their behavior, enhancing their behavioral intention to adopt. These findings are in line with the studies (Guo et al., 2024b; Y.-M. Wang et al., 2023; Zahid et al., 2022a)

Mediation by Subjective Norms: The study reveals a significant relationship between social influence (β = 0.050, t = 3.259, p =.001) and behavioral intention, through normative issues shaping normative beliefs. Extension services (β = 0.038, t = 2.501, p = 0.012), as a key factor in shaping normative views, also play a significant role in shaping behavioral intentions. The findings align with previous research on the impact of social influences on decision-making in Punjabi communities, emphasizing the importance of community leaders and extension agencies. The findings are in line with the research work and previous studies (Puah et al., 2022; Shao et al., 2022b; Zahid et al., 2022b).

7.5 Role of Moderators: Institutional Support and Market Infrastructure

Institutional Support

The findings indicated that IS had a positive and substantial impact on the relationship (β = 0.209, p <.001, t = 6.137, f^2 = 0.201, VIF = 1.029), Consequently, the hypothesis H20, “There is a significant moderation effect of Institutional Support (IS) on Attitude (AT) to Behaviour Intention (BI)” is accepted. In addition, the value of R^2

in the conceptual model gets enhanced to 61.1% from 53% thereby causing a positive 8.1% of variance by its presence. The examination of the moderating effect of Institutional Support (IS) on the association between Perceived Behavioural Control (PBC) and Behavioural Intention (BI) revealed a positive and significant impact (β = 0.230, $p < .001$, $t = 5.757$, $f^2 = 0.229$, VIF = 1.036). Consequently, H21, there is a significant moderation effect of Institutional Support (IS) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI)" gets accepted. In this case the R^2 gets improved by 8.9% elevating to 61.9% from 53% without the presence of IS as moderator. Furthermore, it was discovered that Institutional Support (IS), as a moderator, had a positive and substantial impact on the association between Subjective Norms (SN) and Behaviour Intention (BI). This was demonstrated by the following statistical measurements: $\beta = 0.190$, $p < .001$, $t = 4.820$, $f^2 = 0.144$, and VIF = 1.027. The conclusion is that H22, "There is a significant moderation effect of Institutional Support (IS) on Subjective Norms (SN) to Behaviour Intention (BI)" is accepted. The impact of IS on this relationship path is expressed by R^2 becoming 59.1% from 53%, getting a hike of 6.1%. These results have further been validated by the slope analysis; the slope shows a steeper elevation with higher levels of Institutional Support. Concludingly, the three factors i.e. Attitude (AT), Perceived Behavioural Control (PBC), and Subjective Norm (SN) all have a favourable impact on Behavioural Intention (BI), but higher levels of Institutional Support (IS) further amplify this effect. What this means is that people's beliefs, norms, and sense of control over their behaviour have a greater impact on shaping their behavioural intentions when they perceive stronger institutional backing.

Market Infrastructure

Analysis determines the positive significance of the moderating effect of Market Infrastructure (MI), on the relationship between Attitude and Behaviour Intention through statistical findings as ($\beta = 0.222$, $p < .001$, $t = 5.362$, $f^2 = 0.214$, VIF = 1.030). Because of this, the H23, "There is a significant moderation effect of Market Infrastructure (MI) on Attitude (AT) to Behaviour Intention (BI)" is accepted. In addition. presence of MI increases the value of R^2 by 9.5% raising it from from 53% to

62.5% A positive and substantial influence of MI on the association between PBC and BI was shown by the study of the moderating effect ($\gamma = 0.182$, $p <= .001$, $t = 5.026$, $f^2 = 0.135$, VIF = 1.022). Hypothesis H24 that, "There is a significant moderation effect of Market Infrastructure (MI) on Perceived Behaviour Control (PBC) to Behaviour Intention (BI)" is therefore accepted. This is further validated by 6.9% increased R^2 that reaches 59.9% from 53% with MI as moderator. Investigating the moderating effect of MI on the relationship between Subjective Norms (SN) and Behaviour Intention (BI), showed that (MI) had a positive and statistically significant effect with the following results: $\beta = 0.088$, $p = 0.024$, $t = 2.251$, $f^2 = 0.027$, VIF = 1.032. As a result, H25, "There is a significant moderation effect of Market Infrastructure (MI) on Subjective Norms (SN) to Behaviour Intention (BI)" is approved. Presence of MI on this relationship also elevates R^2 by 2.7% taking it to 55.7% from 53%. The slope analysis further validates these findings with steeper graphical slope with increased levels of MI. The analysis of moderators is in accordance with the findings of (Alkhowaiter, 2022; Ishaq et al., 2024; Ma et al., 2024).

7.6 Demographics and Descriptives

The study reveals a gender bias in agriculture, with male farmers dominating the majority of respondents. The majority of respondents are aged 41-50, with experienced farmers making up the majority. The sample size only includes 18% of young adults, indicating a waning enthusiasm among the younger generation for agriculture. This trend is a major cause of migration overseas, as young adults tend to opt for alternative career paths. The study reveals that most farmers have 20-29 years of experience, with seasoned farmers being the most prevalent. The age demographic of individuals aged 21-30 with 1-9 years farming experience is diminishing, indicating a need for better understanding of age dynamics in farming. The largest category of land ownership consists of holders with 10-25 acres, comprising 38.78% (n = 159), followed by those with 5-10 acres at 36.59% (n = 150). In the analysis, the 2.5-5 acres category ranked third with 14.15% (n = 58), while the >25 acres category accounted for 6.83% (n = 28). The category of 0-2 acres represented the lowest proportion at 4% (n=15). The majority of respondents (30.98%) have completed a twelve-year education

level, followed by primary and matriculation. Graduates make up 15.85% of the population, while middle-class individuals and post-graduates make up 3.4%. Farming doesn't require a certain level of education, but educated individuals may pursue careers outside farming. Migrating overseas requires a minimum knowledge level equivalent to a post-secondary student, allowing young adults to meet immigration requirements. Agriculture is given less priority.

7.7 Conclusion

7.7.1 Conclusion from Qualitative Study RQ1

RQ1 Challenges in growing rice using SAP: Qualitative interviews conducted with farmers using sustainable practices and conventional methods revealed perceptions and attitudes towards sustainability in rice cultivation. In conclusion, while farmers recognize the productivity and profitability of conventional agricultural practices, there is a growing commitment to sustainable agricultural practices (SAP) driven by personal experiences with chemical harm and environmental concerns. However, the transition to SAP is hindered by challenges such as high costs, complexity, and the need for skilled labour, particularly in regions like Punjab. Despite these obstacles, many farmers exhibit resilience and a willingness to learn, often opting for simpler certification processes like the Participatory Guarantee Scheme. The need for institutional support and improved market infrastructure is critical to facilitate the adoption of sustainable practices. Ultimately, farmers' dedication to environmental sustainability reflects their personal sacrifices and commitment to ecological health, underscoring the importance of addressing the barriers they face in this transition.

7.7.2 Conclusion from Quantitative Study RQ 2

RQ 2 Level of awareness and Frequency of Use of SAP in rice cultivation: A systematic assessment was conducted to evaluate the level of awareness and frequency of use of Sustainable Agricultural Practices (SAP) among farmers. Selected practices included land levelling, tillage practices, seed quality, direct seeding of rice, cultivar choice, farmyard manure, urea usage, row-crop plantation, biological pesticides, stubble burning, and direct seeding of wheat.

In conclusion, the study reveals that farmers exhibit a moderate level of awareness and usage of sustainable agricultural practices, as indicated by mean scores of 3.02 and 3.04. However, there is considerable variability in knowledge and understanding among the farmers surveyed. The mixed responses to specific statements highlight the presence of misconceptions, particularly regarding the impacts of urea, the benefits of direct seeding, and minimum tillage practices. Additionally, the majority of farmers recognize that factors beyond maximum yield influence seed selection. These findings underscore the necessity for targeted educational initiatives to improve farmers' understanding of sustainable practices and address prevalent misconceptions, ultimately fostering better agricultural outcomes.

7.7.3 Conclusion from Quantitative Study RQ 3

RQ3 Farmer Perception towards SAP adoption in rice cultivation: Investigation of farmer perceptions and structural relationships affecting the adoption of sustainable agricultural practices in Punjab, with all hypotheses showing significant results.

In conclusion, the study highlights the multifaceted influences on attitudes and behaviours related to sustainable practices in agriculture. Key factors such as perceived usefulness, ease of use, and compatibility significantly shape attitudes, while a pro-environmental belief system plays a crucial role in fostering a positive attitude towards sustainable agriculture. Perceived behavioural control, driven by self-efficacy and resource availability, emerges as the most significant predictor of behavioural intention, underscoring the importance of perceived control in adopting sustainable practices. Additionally, subjective norms, influenced by social factors and effective communication, are vital for farmer engagement. The mediation effects observed indicate that attitudes, perceived behavioural control, and subjective norms significantly influence behavioural intentions, emphasizing the interconnectedness of these factors in promoting sustainable agricultural practices.

7.7.4 Conclusion from Quantitative Study RQ 4

RQ4 Institutional Support and Market Infrastructure as moderators: Both the factors, individually as well as collectively impact the whole model positively and

significantly. In conclusion, the analysis demonstrates that both Information Systems (IS) and Market Intelligence (MI) significantly enhance the relationships between Attitude (AT), Perceived Behavioural Control (PBC), Subjective Norms (SN), and Behavioural Intentions (BI). The improvements in R^2 values indicate that these factors contribute to a greater understanding of variance in BI, with IS showing notable increases across all relationships and MI further amplifying these effects. The findings suggest that stronger institutional and market support can lead to more favourable behavioural intentions, highlighting the importance of integrating IS and MI in strategies aimed at influencing consumer behaviour.

7.7.5 Conclusion from Demographics

In conclusion, the data highlights a significant gender disparity in the farming occupation, with men predominantly holding leadership roles while women provide essential support. The age demographics reveal a concerning trend, as the majority of respondents are aged 31-75, indicating a decline in youth interest in agriculture. Additionally, the experience levels suggest that younger adults are increasingly moving away from farming, with a notable lack of young individuals entering the field. The educational background of respondents further supports this trend, as many educated individuals seem to prefer careers outside of agriculture. Overall, these findings suggest a need for initiatives to engage younger generations and promote gender equality within the farming community.

7.7.5 Conclusion from Research Model Findings

In conclusion, the analysis of the model's explanatory power, effect size, and predictive accuracy reveals significant insights into the factors influencing Behavioural Intention. The model demonstrates a strong overall explanatory power with an R^2 value of 0.718, indicating that a substantial portion of the variance in Behavioural Intention is accounted for. Among the individual predictors, Attitude, Perceived Behavioural Control, and Subjective Norm contribute varying degrees of influence, with Perceived Behavioural Control exhibiting the largest effect size. The predictive power assessment further supports the model's relevance, with a Q^2 value indicating a 33% predictive accuracy for Behavioural Intention. These findings underscore the importance of understanding the dynamics of these factors in shaping Behavioural Intention.

7.8 Managerial Implications

In conclusion, the study highlights the critical role of understanding farmers' perceptions and challenges in adopting sustainable agricultural practices, particularly in rice cultivation, as a pathway to achieving the Zero Hunger goal. By introducing new variables such as the "New Ecological Paradigm" and emphasizing the importance of "Institutional Support" and "Market Infrastructure," the research underscores the necessity for targeted policy initiatives. The findings advocate for collaborative efforts among public and private entities to enhance awareness and education on Sustainable Agricultural Practices (SAP), which are vital for fostering positive attitudes and increasing adoption rates among farmers. Initiatives such as establishing model farms, organizing community events, and simplifying certification processes are essential strategies to promote sustainable practices effectively. Overall, the study calls for a comprehensive approach that includes awareness campaigns, supportive policies, and community involvement to facilitate the transition towards sustainable agriculture and improve food security.

7.9 Limitations

Although the study employed a sophisticated mixed methods research approach, which augmented its depth, yet, like any other study, it encountered constraints that may have impacted the process. The study pertains specifically to the state of Punjab, and due to the distinctive nature of the issue examined, the findings may not be generalisable to other states in India. The study utilized a cross-sectional approach, which impedes the assessment of causal relationships and long-term behavioural effects. The qualitative study's interview schedules were conducted via telephone during the epidemic, potentially limiting the insights often gained from face-to-face interactions. Although the qualitative sample set included some experts in the domain, the limited sample size may have restricted the findings. The prejudices of the respondents in the survey cannot be disregarded. While all hygiene measures were employed in the study but still response bias cannot be completely omitted. The primary limitation is the time constraints that require the study to be completed within a specified timeframe, so limiting access to numerous potential aspects of the research.

7.10 Future Research Directions

The findings of the current study may serve as a guide for further research. Since, the study on usage of SAP in rice cultivation in Punjab is a naïve area, there is great deal of room for future research. Future research could employ a longitudinal research approach to gather insights on long-term behaviour intention. A bigger and wider sample set for qualitative study with inclusion of academician, representatives from extension agencies and state agricultural universities in the qualitative could add further credence to the findings. The study was based on a select set of SAP, the future research can use different additional SAP in the research. In states with comparative wider SAP adoption in rice cultivation, segmentation of adopters and comparative analysis with non-adopters can provide good insights to foster adoption strategies. A deeper analysis of demographic factors like farmer and farm characteristics could bring further insights. Farmer's generic issues like mental health and debt scenario could also be explored. There is ample scope to research the Rice Value Chain and gather the impediments for sustainably produced rice.

7.11 Chapter Summary

The chapter summarises the findings of the research study. It gives a detailed interpretation of the qualitative and quantitative results which were presented in chapter 4 and chapter 6 respectively. Further the chapter recapitulates the conclusion from the findings of each research question and demographic factors, followed by the implications. The chapter finally sums up with limitations of the study and possible future research directions.

Bibliography

Abbott, S., Chahal, S., Sharma, J., & others. (2015). Sustainability of agriculture systems: Punjab's scenario. *Indian Journal of Economics and Development*, *11*(1), 89–99.

Acharya, A. S., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it? *Indian Journal of Medical Specialities*, *4*(2). https://doi.org/10.7713/ijms.2013.0032

Adnan, N., Md Nordin, S., Rahman, I., & Noor, A. (2017). Adoption of green fertilizer technology among paddy farmers: A possible solution for Malaysian food security. *Land Use Policy*, *63*, 38–52. https://doi.org/10.1016/j.landusepol.2017.01.022

Adnan, N., Nordin, S. M., & Anwar, A. (2020). Transition pathways for Malaysian paddy farmers to sustainable agricultural practices: An integrated exhibiting tactics to adopt Green fertilizer. *Land Use Policy*, *90*, 104255. https://doi.org/10.1016/j.landusepol.2019.104255

Adnan, N., Nordin, S. M., & Bin Abu Bakar, Z. (2017). Understanding and facilitating sustainable agricultural practice: A comprehensive analysis of adoption behaviour among Malaysian paddy farmers. *Land Use Policy*, *68*, 372–382. https://doi.org/10.1016/j.landusepol.2017.07.046

Akenroye, T. O., Dora, M., Kumar, M., Elbaz, J., Kah, S., & Jebli, F. (2021). A taxonomy of barriers to the adoption of sustainable practices in the coffee farming process. *Journal of Cleaner Production*, *312*, 127818. https://doi.org/10.1016/j.jclepro.2021.127818

Al Khasawneh, M. H., & Irshaidat, R. (2017). Empirical validation of the decomposed theory of planned behaviour model within the mobile banking adoption context. *International Journal of Electronic Marketing and Retailing*, *8*(1), 58–76. Scopus. https://doi.org/10.1504/IJEMR.2017.083553

Alam, S. S., Ho, Y.-H., Ahmed, S., & Lin, C.-Y. (2024). PREDICTING ECO-LABELED PRODUCT BUYING BEHAVIOR IN AN EMERGING ECONOMY THROUGH AN EXTENSION OF THEORY OF PLANNED BEHAVIOR. *Revista de Gestao Social e Ambiental*, *18*(9). Scopus. https://doi.org/10.24857/rgsa.v18n9-039

Alkhowaiter, W. A. (2022). To "D" or Not to "D"? Assessing Instructors' Intentions to Adopt Digital Learning in Saudi Arabia's Public Universities in the Wake of COVID-19. *International Journal of Electronic Government Research*, *18*(1). Scopus. https://doi.org/10.4018/IJEGR.315599

Al-Rahmi, W. M., Yahaya, N., Aldraiweesh, A. A., Alamri, M. M., Aljarboa, N. A., Alturki, U., & Aljeraiwi, A. A. (2019). Integrating technology acceptance model with innovation diffusion theory: An empirical investigation on students' intention to use E-learning systems. *Ieee Access*, *7*, 26797–26809.

Al-Saedi, K., Al-Emran, M., Ramayah, T., & Abusham, E. (2020). Developing a general extended UTAUT model for M-payment adoption. *Technology in Society*, *62*, 101293.

Anibaldi, R., Rundle-Thiele, S., David, P., & Roemer, C. (2021). Theoretical Underpinnings in Research Investigating Barriers for Implementing Environmentally Sustainable Farming Practices: Insights from a Systematic

Literature Review. *Land*, *10*(4), Article 4. https://doi.org/10.3390/land10040386

Arkorful, V., Barfi, K. A., & Baffour, N. O. (2022). Factors affecting use of massive open online courses by Ghanaian students. *Cogent Education*, *9*(1). Scopus. https://doi.org/10.1080/2331186X.2021.2023281

Arnold, M., & Reynolds, K. (2009). Affect and Retail Shopping Behavior: Understanding the Role of Mood Regulation and Regulatory Focus. *Journal of Retailing - J RETAIL*, *85*, 308–320. https://doi.org/10.1016/j.jretai.2009.05.004

Aryal, J. P., Mehrotra, M. B., Jat, M. L., & Sidhu, H. S. (2015). Impacts of laser land leveling in rice–wheat systems of the north–western indo-gangetic plains of India. *Food Security*, *7*(3), 725–738. https://doi.org/10.1007/s12571-015-0460-y

Ayilara, M. S., Adeleke, B. S., Akinola, S. A., Fayose, C. A., Adeyemi, U. T., Gbadegesin, L. A., Omole, R. K., Johnson, R. M., Uthman, Q. O., & Babalola, O. O. (2023). Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. *Frontiers in Microbiology*, *14*, 1040901. https://doi.org/10.3389/fmicb.2023.1040901

Bacenetti, J., Paleari, L., Tartarini, S., Vesely, F. M., Foi, M., Movedi, E., Ravasi, R. A., Bellopede, V., Durello, S., Ceravolo, C., Amicizia, F., & Confalonieri, R. (2020). May smart technologies reduce the environmental impact of nitrogen fertilization? A case study for paddy rice. *Science of The Total Environment*, *715*, 136956. https://doi.org/10.1016/j.scitotenv.2020.136956

Bakhshandeh, E., Jamali, M., Emadi, M., & Francaviglia, R. (2022). Greenhouse gas emissions and financial analysis of rice paddy production scenarios in northern Iran. *Agricultural Water Management*, *272*, 107863.

Bali Swain, R., & Yang-Wallentin, F. (2020). Achieving sustainable development goals: Predicaments and strategies. *International Journal of Sustainable Development & World Ecology*, *27*(2), 96–106. https://doi.org/10.1080/13504509.2019.1692316

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Basavalingaiah, K., Ramesha, Y. M., Paramesh, V., Rajanna, G. A., Jat, S. L., Dhar Misra, S., Kumar Gaddi, A., Girisha, H. C., Yogesh, G. S., Raveesha, S., Roopa, T. K., Shashidhar, K. S., Kumar, B., El-Ansary, D. O., & Elansary, H. O. (2020). Energy Budgeting, Data Envelopment Analysis and Greenhouse Gas Emission from Rice Production System: A Case Study from Puddled Transplanted Rice and Direct-Seeded Rice System of Karnataka, India. *Sustainability*, *12*(16), Article 16. https://doi.org/10.3390/su12166439

Benitez, J., Henseler, J., Castillo, A., & Schuberth, F. (2020). How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory IS research. *Information & Management*, *57*(2), 103168. https://doi.org/10.1016/j.im.2019.05.003

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–606. https://doi.org/10.1037/0033-2909.88.3.588

Berndt, A. E. (2020). Sampling Methods. *Journal of Human Lactation*, *1*(3). https://doi.org/10.1177/890334420906850

Bhalla, G. S. (1995). *Agricultural growth and industrial development in Punjab* (pp. 67–112). http://www.ifpri.org/sites/default/files/pubs/pubs/books/mellor95/mellor95ch03.pdf

Bhalla, G. S. & others. (1990). *Agricultural growth and structural changes in the Punjab economy: An input-output analysis* (Vol. 82). Intl Food Policy Res Inst.

Biodynamic Association. (2024). *Biodynamic Principles and Practices | Biodynamic Association*. Biodynamics. https://www.biodynamics.com/biodynamic-principles-and-practices

Blesh, J., & Wolf, S. (2014). "Transitions to agroecological farming systems in the Mississippi River Basin: Toward an integrated socioecological analysis. *Agriculture and Human Values*, *31*(4), 621–635. https://doi.org/10.1007/s10460-014-9517-3

Blythe, J., Sulu, R., Harohau, D., Weeks, R., Schwarz, A.-M., Mills, D., & Phillips, M. (2017). Social Dynamics Shaping the Diffusion of Sustainable Aquaculture Innovations in the Solomon Islands. *Sustainability*, *9*(1), 126. https://doi.org/10.3390/su9010126

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal*, *19*(4), 426–432. https://doi.org/10.1108/QMR-06-2016-0053

Borremans, L., Marchand, F., Visser, M., & Wauters, E. (2018). Nurturing agroforestry systems in Flanders: Analysis from an agricultural innovation systems perspective. *Agricultural Systems*, *162*, 205–219. https://doi.org/10.1016/j.agsy.2018.01.004

BRAR, A. S., KAUR, K., SHARMA, R., & SINDHU, V. K. (2021). Performance of rice (Oryza sativa) cultivars as influenced by irrigation regimes and establishment methods. *The Indian Journal of Agricultural Sciences*, *91*(9), 1296–1301. https://doi.org/10.56093/ijas.v91i9.116073

Bray, C. D., Battye, W. H., & Aneja, V. P. (2019). The role of biomass burning agricultural emissions in the Indo-Gangetic Plains on the air quality in New Delhi, India. *Atmospheric Environment*, *218*, 116983.

Brown, B., Nuberg, I., & Llewellyn, R. (2018). Further participatory adaptation is required for community leaders to champion conservation agriculture in Africa. *International Journal of Agricultural Sustainability*, *16*(3), 286–296. https://doi.org/10.1080/14735903.2018.1472410

Budovska, V., Torres Delgado, A., & Øgaard, T. (2020). Pro-environmental behaviour of hotel guests: Application of the Theory of Planned Behaviour and social norms to towel reuse. *Tourism and Hospitality Research*, *20*(1), 105–116.

Busenitz W, Lo., Gomez, C., & Spencer, J. (2000). Country Institutional Profiles: Unlocking Entrepreneurial Phenomenon. *Academy of Management Journal*, *43*(5), 994–1003.

Cammarata, M., Scuderi, A., Timpanaro, G., & Cascone, G. (2024). Factors influencing farmers' intention to participate in the voluntary carbon market:

An extended theory of planned behavior. *Journal of Environmental Management*, *369*. Scopus. https://doi.org/10.1016/j.jenvman.2024.122367

Carrer, M. J., Maia, A. G., Vinholis, M. de M. B., & de Souza Filho, H. M. (2020). Assessing the effectiveness of rural credit policy on the adoption of integrated crop-livestock systems in Brazil. *Land Use Policy*, *92*, 104468.

Chang, J., & Yang, C. (2012). Viable or vital? Evaluation of IM services from patrons' perspectives. *The Electronic Library*, *30*(1), 70–88. https://doi.org/10.1108/02640471211204079

Charmaz, K. (2006). *Constructing grounded theory*. Sage Publications.

Chen, L., Jia, J., Xiao, M., Wu, C., & Zhang, L. (2024). A study on the influence of digital literacy on elderly user's intention to identify social media false information. *Electronic Library*, *42*(5), 701–721. Scopus. https://doi.org/10.1108/EL-10-2023-0257

Chen, M., & Martens, P. (2023). Environmental Concern and Public Attitudes Toward Marine Life in Coastal China. *Anthrozoos*, *36*(1), 117–136. Scopus. https://doi.org/10.1080/08927936.2022.2101247

Cheng, G. (2019). Exploring factors influencing the acceptance of visual programming environment among boys and girls in primary schools. *Computers in Human Behavior*, *92*, 361–372.

Chianu, J. N., Tsujii, H., & Mbanasor, J. (2007). Determinants of the decision to adopt improved maize variety by smallholder farmers in the savannas of northern Nigeria. *Journal of Food, Agriculture & Environment*, *5*(2), 318–324.

Chin, W. W. (1998). The Partial Least Squares Approach to Structural Equation Modelling. In *Modern Methods for Business Research* (First).

Cicerchia, A. (2021). Culture Indicators for Sustainable Development. In P. Demartini, L. Marchegiani, M. Marchiori, & G. Schiuma (Eds.), *Cultural Initiatives for Sustainable Development: Management, Participation and Entrepreneurship in the Cultural and Creative Sector* (pp. 345–372). Springer International Publishing. https://doi.org/10.1007/978-3-030-65687-4_16

Cobelli, N., Chiarini, A., & Giaretta, E. (2021). Enabling factors for adopting sustainable, organic wine production. *The TQM Journal*, *33*(6), 1572–1588.

Cohen, J. (2013). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed). Taylor and Francis.

Corbin, J., & Strauss, A. (1990). Grounded Theory Research: Procedures, Canons and Evaluative Criteria. *Zeitschrift Für Soziologie*.

Creswell, J. W. (2021). *A Concise Introduction to Mixed Methods Research* (Second). Sage Publications.

Curry, N., & Kirwan, J. (2014). The Role of Tacit Knowledge in Developing Networks for Sustainable Agriculture. *Sociologia Ruralis*, *54*(3), 341–361. https://doi.org/10.1111/soru.12048

Directorate of Statistics, Department of Planning, Govt of Punjab, D. (2023). *Statistical Abstract of Punjab 2023*. Govt of Punjab.

Doyle, L., Brady, A.-M., & Byrne, G. (2016). An overview of mixed methods research – revisited. *Journal of Research in Nursing*, *21*(8), 623–635. https://doi.org/10.1177/1744987116674257

Dung, L. T., Ho, D. P., Hiep, N. T. K., & Hoi, P. T. (2018). The Determinants of Rice Farmers Adoption of Sustainable Agricultural Technologies in the Mekong Delta, Vietnam. *Applied Economics Journal*, *25*(2), 55–69.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues*, *56*(3), 425–442. https://doi.org/10.1111/0022-4537.00176

Economics and Statistic Division, G. of I. (2023, April). *Agricultural-Statistics-at-a-Glance-2022.pdf*. Www.Desagri.Gov.In. https://desagri.gov.in/wp-content/uploads/2023/05/Agricultural-Statistics-at-a-Glance-2022.pdf

Eliazer Nelson, A. R. L., Ravichandran, K., & Antony, U. (2019). The impact of the Green Revolution on indigenous crops of India. *Journal of Ethnic Foods*, *6*(1), 8. https://doi.org/10.1186/s42779-019-0011-9

Elkington, J. (1994). Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *California Management Review*, *36*(2), 90–100. https://doi.org/10.2307/41165746

Elkington, J. (2018, June 25). 25 Years Ago I Coined the Phrase "Triple Bottom Line." Here's Why It's Time to Rethink It. *Harvard Business Review*. https://hbr.org/2018/06/25-years-ago-i-coined-the-phrase-triple-bottom-line-heres-why-im-giving-up-on-it

Falk, F. R., & Miller, N. B. (1992). *A Primer for Soft Modelling* (First). The University of Akron.

FAOUN. (2014). *Building a common vision for sustainable food and agriculture Principles and Approaches*.

FAOUN. (2024). *Sustainable Food and Agriculture*. Food and Agriculture Organization of the United Nations. http://www.fao.org/sustainability/background/en/

Faqih, K. M. (2016). An empirical analysis of factors predicting the behavioral intention to adopt Internet shopping technology among non-shoppers in a developing country context: Does gender matter? *Journal of Retailing and Consumer Services*, *30*, 140–164.

Fenibo, E. O., Ijoma, G. N., & Matambo, T. (2022). Biopesticides in Sustainable Agriculture: Current Status and Future Prospects. In S. D. Mandal, G. Ramkumar, S. Karthi, & F. Jin (Eds.), *New and Future Development in Biopesticide Research: Biotechnological Exploration* (pp. 1–53). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-3989-0_1

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving Integration in Mixed Methods Designs—Principles and Practices. *Health Services Research*, *48*(6pt2), 2134–2156. https://doi.org/10.1111/1475-6773.12117

Foguesatto, C. R., Borges, J. A. R., & Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. *Science of The Total Environment*, *729*, 138831. https://doi.org/10.1016/j.scitotenv.2020.138831

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39. https://doi.org/10.2307/3151312

Fountas, S., Espejo-García, B., Kasimati, A., Gemtou, M., Panoutsopoulos, H., & Anastasiou, E. (2024). Agriculture 5.0: Cutting-Edge Technologies, Trends, and Challenges. *IT Professional*, *26*(1), 40–47. https://doi.org/10.1109/MITP.2024.3358972

Gansser, O. A., & Reich, C. S. (2023). Influence of the New Ecological Paradigm (NEP) and environmental concerns on pro-environmental behavioral intention based on the Theory of Planned Behavior (TPB). *Journal of Cleaner Production*, *382*. Scopus. https://doi.org/10.1016/j.jclepro.2022.134629

Garson, G. D. (2016). *Partial Least Squares*.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine Transaction.

Goldberger, J. R., Jones, R. E., Miles, C. A., Wallace, R. W., & Inglis, D. A. (2015). Barriers and bridges to the adoption of biodegradable plastic mulches for US specialty crop production. *Renewable Agriculture and Food Systems*, *30*(2), 143–153. https://doi.org/10.1017/S1742170513000276

Gulati, A., Roy, R., & Hussain, S. (2017). *Getting Punjab Agriculture Back on High Growth Path: Sources, Drivers and Policy Lessons*. ICRIER.

Guo, H., Ye, Y., Lin, Y.-C., Khan, A., Chen, S.-C., & Liou, J.-H. (2024a). Evaluating the determinants on students' switching intentions towards distance learning: An extension of the theory of planned behavior. *Cogent Social Sciences*, *10*(1). Scopus. https://doi.org/10.1080/23311886.2024.2356721

Guo, H., Ye, Y., Lin, Y.-C., Khan, A., Chen, S.-C., & Liou, J.-H. (2024b). Evaluating the determinants on students' switching intentions towards distance learning: An extension of the theory of planned behavior. *Cogent Social Sciences*, *10*(1). Scopus. https://doi.org/10.1080/23311886.2024.2356721

Gursoy, D., Chi, O. H., Lu, L., & Nunkoo, R. (2019). Consumers acceptance of artificially intelligent (AI) device use in service delivery. *International Journal*

of Information Management, *49*, 157–169. Scopus. https://doi.org/10.1016/j.ijinfomgt.2019.03.008

Habibi, E., Niknejad, Y., Fallah, H., Dastan, S., & Tari, D. B. (2019). Life cycle assessment of rice production systems in different paddy field size levels in north of Iran. *Environmental Monitoring and Assessment*, *191*(4), 202.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–152. https://doi.org/10.2753/MTP1069-6679190202

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, *31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Harman, H. H. (1968). *Modern Factor Analysis* (Second). The University of Chicago Press.

Harrison, R. L., Reilly, T. M., & Creswell, J. W. (2020). Methodological Rigor in Mixed Methods: An Application in Management Studies. *Journal of Mixed Methods Research*, *14*(4), 473–495. https://doi.org/10.1177/1558689819900585

Harwood, R. R. (2020). A History of Sustainable Agriculture. In *Sustainable agricultural systems* (1st Edition, pp. 3–19). CRC Press.

He, G., Wang, Z., & Cui, Z. (2020). Managing irrigation water for sustainable rice production in China. *Journal of Cleaner Production*, *245*, 118928.

He, X., Qiao, Y., Liang, L., Knudsen, M. T., & Martin, F. (2018). Environmental life cycle assessment of long-term organic rice production in subtropical China.

Journal of Cleaner Production, *176*, 880–888. https://doi.org/10.1016/j.jclepro.2017.12.045

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Herrero-Crespo, Á., Viejo-Fernández, N., Collado-Agudo, J., & Sanzo, M. J. (2021). Webrooming or showrooming, that is the question: Explaining omnichannel behavioural intention through the technology acceptance model and exploratory behaviour. *Journal of Fashion Marketing and Management: An International Journal*, *ahead-of-print*. https://doi.org/10.1108/JFMM-05-2020-0091

Herzallah, F., & Mukhtar, M. (2016). The Impact of Percieved Usefulness, Ease of Use and Trust on Managers' Acceptance of e-Commerce Services in Small and Medium-Sized Enterprises (SMEs) in Palestine. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(6), 922. https://doi.org/10.18517/ijaseit.6.6.1377

Hill, S. B., & MacRae, R. J. (1996). Conceptual Framework for the Transition from Conventional to Sustainable Agriculture. *Journal of Sustainable Agriculture*, *7*(1), 81–87. https://doi.org/10.1300/J064v07n01_07

Hira, G. S. (2009). Water Management in Northern States and the Food Security of India. *Journal of Crop Improvement*, *23*(2), 136–157. https://doi.org/10.1080/15427520802645432

HLPE. (2019). *HLPE Report #14—Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition.* (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. CFS HLPE Report 14; p. 163). Commitee on World Food Security, FAO. https://openknowledge.fao.org/server/api/core/bitstreams/ff385e60-0693-40fe-9a6b-79bbef05202c/content#page=13.08

Holmgren, D. (2002a). *Permaculture—Principles and Pathways beyond sustainability*. Permanent Publications.

Holmgren, D. (2002b, December). *Permaculture Principles & Pathways Beyond Sustainability.pdf*. Holmgren design Services.

Horrigan, L., Lawrence, R. S., & Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives*, *110*(5), 445–456. https://doi.org/10.1289/ehp.02110445

Hsu, C.-L., & Lin, J. C.-C. (2008). Acceptance of blog usage: The roles of technology acceptance, social influence and knowledge sharing motivation. *Information & Management*, *45*(1), 65–74. https://doi.org/10.1016/j.im.2007.11.001

Hu, L., & Bentler, P. M. (1998). Fit Indices in Covariance Structure Modeling: Sensitivity to Underparameterized Model Misspecification. *Psychological Methods*, *3*(4), 424–453.

Huat, L., Sidin, J., & Sondoh Jr, S. (2017). Did RSPO Overlook the Unwelcome Thoughts Amongst Growers and Millers? *Jurnal Pengurusan*, *49*, 13–24. https://doi.org/10.17576/pengurusan-2017-49-02

Husin, J., Cordelia, S., Christophilus, V. D., & Limantara, N. (2023). *Analysis of Factors Influencing The Use of QRIS Through Mobile Banking in Jakarta and Tangerang*. 2023 6th International Conference on Information Systems and Computer Networks, ISCON 2023. Scopus. https://doi.org/10.1109/ISCON57294.2023.10111978

IFOAM Organics International. (2024). *The Four Principles of Organic Agriculture | IFOAM*. https://www.ifoam.bio/why-organic/shaping-agriculture/four-principles-organic

IFOAM-Organics International. (2008). *Definition of Organic Agriculture | IFOAM*. https://www.ifoam.bio/why-organic/organic-landmarks/definition-organic

IFOAM-Organics International. (2021). *IFOAM-Organic International 2021 Annual Report*. IFOAM-Organics International. https://www.ifoam.bio/about-us/annual-reports

Irani, Z., Dwivedi, Y. K., & Williams, M. D. (2009). Understanding consumer adoption of broadband: An extension of the technology acceptance model. *Journal of the Operational Research Society*, *60*(10), 1322–1334.

Ishaq, M. I., Sarwar, H., Aftab, J., Franzoni, S., & Raza, A. (2024). Accomplishing sustainable performance through leaders' competencies, green entrepreneurial orientation, and innovation in an emerging economy: Moderating role of institutional support. *Business Strategy and the Environment*, *33*(2), 1515–1532. Scopus. https://doi.org/10.1002/bse.3557

Jat, H. S., Datta, A., Choudhary, M., Yadav, A. K., Choudhary, V., Sharma, P. C., Gathala, M. K., Jat, M. L., & McDonald, A. (2019). Effects of tillage, crop establishment and diversification on soil organic carbon, aggregation,

aggregate associated carbon and productivity in cereal systems of semi-arid Northwest India. *Soil and Tillage Research*, *190*, 128–138. https://doi.org/10.1016/j.still.2019.03.005

Jeong, E., Lee, T., Brown, A. D., Choi, S., & Son, M. (2021). Does a National Park Enhance the Environment-Friendliness of Tourists as an Ecotourism Destination? *International Journal of Environmental Research and Public Health*, *18*(16), 8321. https://doi.org/10.3390/ijerph18168321

Jha, C. K., & Gupta, V. (2021). Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India. *Environmental and Sustainability Indicators*, *10*, 100112. https://doi.org/10.1016/j.indic.2021.100112

John, D. A., & Babu, G. R. (2021). Lessons From the Aftermaths of Green Revolution on Food System and Health. *Frontiers in Sustainable Food Systems*, *5*, 644559. https://doi.org/10.3389/fsufs.2021.644559

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, *33*(7), 14–26.

K., S. S., T.P., T., & M.V.N., S. K. (2022). Implementing construction waste management in India: An extended theory of planned behaviour approach. *Environmental Technology and Innovation*, *27*. Scopus. https://doi.org/10.1016/j.eti.2022.102401

Kammerer, M., & Namhata, C. (2018). What drives the adoption of climate change mitigation policy? A dynamic network approach to policy diffusion. *Policy Sciences*, *51*(4), 477–513. Scopus. https://doi.org/10.1007/s11077-018-9332-6

Kaur, M., Dheri, G. S., Brar, A. S., & Kalia, A. (2024). Methane and nitrous oxide emissions in rice fields influenced with duration of cultivars and irrigation regimes. *Agriculture, Ecosystems & Environment*, *365*, 108923. https://doi.org/10.1016/j.agee.2024.108923

Keeble, B. R. (1988). The Brundtland report: 'Our common future.' *Medicine and War*, *4*(1), 17–25. https://doi.org/10.1080/07488008808408783

Kena, D., Golicha, D., Jemal, E., Kanu, B., & Gayo, G. (2022). Smallholder dairy producers' participation in dairy marketing in Southern Omo Zone, Ethiopia. *Pastoralism*, *12*(1), 48.

Kim, K. K., Shin, H. K., & Kim, B. (2011). The role of psychological traits and social factors in using new mobile communication services. *Electronic Commerce Research and Applications*, *10*(4), 408–417.

Kimberlin, C. L., & Winterstein, A. G. (2008). Validity and reliability of measurement instruments used in research. *American Journal of Health-System Pharmacy*, *65*(23), 2276–2284. https://doi.org/10.2146/ajhp070364

Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, *6*(5), 26. https://doi.org/10.5430/ijhe.v6n5p26

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour—A meta-analysis. *Global Environmental Change*, *23*(5), 1028–1038. https://doi.org/10.1016/j.gloenvcha.2013.05.014

Kock, N. (2015). PLS-based SEM Algorithms: The Good Neighbor Assumption, Collinearity, and Nonlinearity. *Information Management and Business Review*, *7*(2), 113–130. https://doi.org/10.22610/imbr.v7i2.1146

Kuhlman, T., & Farrington, J. (2010). What is Sustainability? *Sustainability*, *2*(11), 3436–3448. https://doi.org/10.3390/su2113436

Kumar, J., Ramlal, A., Mallick, D., & Mishra, V. (2021). An Overview of Some Biopesticides and Their Importance in Plant Protection for Commercial Acceptance. *Plants*, *10*(6), 1185. https://doi.org/10.3390/plants10061185

Lau, J. L., & Hashim, A. H. (2019). Mediation analysis of the relationship between environmental concern and intention to adopt green concepts. *Smart and Sustainable Built Environment*, *9*(4), 539–556. https://doi.org/10.1108/SASBE-09-2018-0046

Lavidas, K., Komis, V., & Achriani, A. (2022). Explaining faculty members' behavioral intention to use learning management systems. *Journal of Computers in Education*, *9*(4), 707–725.

Lee, Y.-C. (2008). The role of perceived resources in online learning adoption. *Computers & Education*, *50*(4), 1423–1438.

Lim, W. M. (2024). A typology of validity: Content, face, convergent, discriminant, nomological and predictive validity. *Journal of Trade Science*, *12*(3), 155–179. https://doi.org/10.1108/JTS-03-2024-0016

Liu, J., Kamarudin, K. M., Liu, Y., Zou, J., & Zhang, J. (2022). Developing a Behavior Change Framework for Pandemic Prevention and Control in Public Spaces in China. *Sustainability (Switzerland)*, *14*(4). Scopus. https://doi.org/10.3390/su14042452

Liu, S., & Wang, L. (2016). Influence of managerial control on performance in medical information system projects: The moderating role of organizational

environment and team risks. *International Journal of Project Management*, *34*(1), 102–116. https://doi.org/10.1016/j.ijproman.2015.10.003

LokSabha. (2022). Adverse Effects of Chemicals and Fertilizers. *GOVERNMENT OF INDIA MINISTRY OF AGRICULTURE AND FARMERS WELFARE DEPARTMENT OF AGRICULTURE AND FARMERS WELFARE*, *1*. https://sansad.in/getFile/loksabhaquestions/annex/1710/AU1069.pdf?source=pqals#page=6.00

Ma, W., Rahut, D. B., Sonobe, T., & Gong, B. (2024). Linking farmers to markets: Barriers, solutions, and policy options. *Economic Analysis and Policy*, *82*, 1102–1112. https://doi.org/10.1016/j.eap.2024.05.005

Makanyeza, C. (2017). Determinants of consumers' intention to adopt mobile banking services in Zimbabwe. *International Journal of Bank Marketing*, *35*(6), 997–1017.

Malterurd, K., Siersma, V. D., & Guassora, A. D. (2016). Sample Size in Qualitative Interview Studies: Guided by Information Power. *SAGE Publications*, *26*(13), 1753–1760. https://doi.org/10.1177/1049732315617444

Manda, J., Alene, A., Gardebroek, C., Berresaw, M., & Tembo, G. (2015). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. *Journal of Agricultural Economics*, *67*. https://doi.org/10.1111/1477-9552.12127

Maraseni, T. N., Deo, R. C., Qu, J., Gentle, P., & Neupane, P. R. (2018). An international comparison of rice consumption behaviours and greenhouse gas emissions from rice production. *Journal of Cleaner Production*, *172*, 2288–2300.

Mariyono, J. (2019). Stepping up from subsistence to commercial intensive farming to enhance welfare of farmer households in Indonesia. *Asia & the Pacific Policy Studies*, *6*(2), 246–265.

Márquez-García, M., Jacobson, S. K., & Barbosa, O. (2019). Wine with a Bouquet of Biodiversity: Assessing Agricultural Adoption of Conservation Practices in Chile. *Environmental Conservation*, *46*(1), 34–42. https://doi.org/10.1017/S0376892918000206

Martin, S., Rieple, A., Chang, J., Boniface, B., & Ahmed, A. (2015). Small farmers and sustainability: Institutional barriers to investment and innovation in the Malaysian palm oil industry in Sabah. *Journal of Rural Studies*, *40*, 46–58. https://doi.org/10.1016/j.jrurstud.2015.06.002

Meng, H. (2011). Rural teachers' acceptance of interactive white board-based ICT in Taiwan. *Global Journal of Engineering Education*.

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1), 1653531. https://doi.org/10.1080/23311886.2019.1653531

Mishra, A. K., Kumar, A., Joshi, P. K., D'Souza, A., & Tripathi, G. (2018). How can organic rice be a boon to smallholders? Evidence from contract farming in India. *Food Policy*, *75*, 147–157. https://doi.org/10.1016/j.foodpol.2018.01.007

Moghimehfar, F., Halpenny, E. A., & Harshaw, H. (2020). Ecological worldview, attitudes, and visitors' behaviour: A study of front-country campers. *Journal of Ecotourism*, *19*(2), 176–184.

Mohamed, M., Higgins, C., Ferguson, M., & Kanaroglou, P. (2016). Identifying and characterizing potential electric vehicle adopters in Canada: A two-stage modelling approach. *Transport Policy*, *52*, 100–112. https://doi.org/10.1016/j.tranpol.2016.07.006

Muktesh, C., Shiwani, S., & Bhawana, M. (2022). Green nanotechnology: A paradigm, panacea and new perspective for sustainable agriculture. In *New and Future Developments in Microbial Biotechnology and Bioengineering* (pp. 45–81). Elsevier.

Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, *1324*(1), 7–14. https://doi.org/10.1111/nyas.12540

Myeni, L., Moeletsi, M., Thavhana, M., Randela, M., & Mokoena, L. (2019). Barriers affecting sustainable agricultural productivity of smallholder farmers in the eastern free state of South Africa. *Sustainability (Switzerland)*, *11*(11). Scopus. https://doi.org/10.3390/su11113003

National Remote Sensing Centre, I. (2023, October). *Assessment of paddy stubble burnt area progression over Punjab and Haryana.* ISRO, Govt of India. https://www.nrsc.gov.in/sites/default/files/ScienceStory/Science_Story_Stubble_burning_Pun_Har_2023.pdf#page=3.07

Ndah, H. T., Schuler, J., Uthes, S., Zander, P., Triomphe, B., Mkomwa, S., & Corbeels, M. (2015). Adoption Potential for Conservation Agriculture in Africa: A Newly Developed Assessment Approach (QAToCA) Applied in

Kenya and Tanzania. *Land Degradation & Development*, *26*(2), 133–141. https://doi.org/10.1002/ldr.2191

Nguyen-Van-Hung, Balingbing, C., Sandro, J., Khandai, S., Chea, H., Songmethakrit, T., Meas, P., Hitzler, G., Zwick, W., Viriyangkura, L., Bautista, E., & Gummert, M. (2022). Precision land leveling for sustainable rice production: Case studies in Cambodia, Thailand, Philippines, Vietnam, and India. *Precision Agriculture*, *23*(5), 1633–1652. https://doi.org/10.1007/s11119-022-09900-8

Nikou, S. A., & Economides, A. A. (2019). Factors that influence behavioral intention to use mobile-based assessment: A STEM teachers' perspective. *British Journal of Educational Technology*, *50*(2), 587–600.

Norton, G. W., & Alwang, J. (2020). Changes in Agricultural Extension and Implications for Farmer Adoption of New Practices. *Applied Economic Perspectives and Policy*, *42*(1), 8–20. Scopus. https://doi.org/10.1002/aepp.13008

Nugraha, R., Wahib Muhaimin, A., Maulidah, S., Widya Putri, R., & Maulidah, D. L. (2024). *Fostering Food Security through Farmers' Intentions to Embrace Climate-Smart Agriculture: Unraveling the Impact of Attitude, Subjective Norms, and Behavioral Control*. *1323*(1). Scopus. https://doi.org/10.1088/1755-1315/1323/1/012018

Nunnally, J. C., & Bernstein, I. H. (1994). *Jum Nunnally, Ira Bernstein—Psychometric Theory-McGraw-Hill, Inc (1994).pdf* (Third). McGraw-Hill Inc.

Ogbeibu, S., Senadjki, A., & Gaskin, J. (2018). The moderating effect of benevolence on the impact of organisational culture on employee creativity. *Journal of Business Research*, *90*, 334–346. https://doi.org/10.1016/j.jbusres.2018.05.032

Oluwadamilola Olufemi Rotimi, E., Kalantari Daronkola, H., Topple, C., & Johnson, L. (2024). Behavioural determinants of consumers' intention to reuse end-of-life garments in Australia. *Cleaner Logistics and Supply Chain*, *10*. Scopus. https://doi.org/10.1016/j.clscn.2023.100138

Oluwajana, D., Nat, M., Idowu, A., Vanduhe, V., & Fadiya, S. (2019). The Adoption of Students' Hedonic Motivation System Model to Gamified Learning Environment. *Journal of Theoretical and Applied Electronic Commerce Research*, *14*(3), 156–167. https://doi.org/10.4067/S0718-18762019000300109

Omulo, G., Daum, T., Köller, K., & Birner, R. (2024). Unpacking the behavioral intentions of 'emergent farmers' towards mechanized conservation agriculture in Zambia. *Land Use Policy*, *136*. Scopus. https://doi.org/10.1016/j.landusepol.2023.106979

Onwuegbuzie, A. J., Bustamante, R. M., & Nelson, J. A. (2010). Mixed Research as a Tool for Developing Quantitative Instruments. *Journal of Mixed Methods Research*, *4*(1), 56–78. https://doi.org/10.1177/1558689809355805

Paco. (2023, December 22). The Definition of Regenerative Agriculture. *Regeneration International*. https://regenerationinternational.org/2023/12/22/the-definition-of-regenerative-agriculture/

Pett, M. A., Lackey, N. R., & Sullivan, J. J. (2006). *Making sense of factor analysis: The use of factor analysis for instrument development in health care research* (Nachdr.). Sage.

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, *3*(10), 809–820. https://doi.org/10.1038/s41893-020-00617-y

Pingali, P. L. (2012). Green Revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, *109*(31), 12302–12308. https://doi.org/10.1073/pnas.0912953109

Pliatsikas, P., & Economides, A. A. (2022). Factors Influencing Intention of Greek Consumers to Use Smart Home Technology. *Applied System Innovation*, *5*(1). Scopus. https://doi.org/10.3390/asi5010026

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health*, *30*(4), 459–467. https://doi.org/10.1002/nur.20199

Pratibha, G., Srinivas, I., Raju, B., Suvana, S., Rao, K., Rao, M. S., Jha, A., Anna, S., Prabhakar, M., Singh, V., & others. (2024). Do rainfed production systems have lower environmental impact over irrigated production systems?: On-farm mitigation strategies. *Science of The Total Environment*, *917*, 170190.

Pretty, J. N. (1994). Alternative Systems of Inquiry for a Sustainable Agriculture. *IDS Bulletin*, *25*(2), 37–49. https://doi.org/10.1111/j.1759-5436.1994.mp25002004.x

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, *23*(8), 1247–1263. https://doi.org/10.1016/0305-750X(95)00046-F

Puah, S., Bin Mohmad Khalid, M. I. S., Looi, C. K., & Khor, E. T. (2022). Investigating working adults' intentions to participate in microlearning using the decomposed theory of planned behaviour. *British Journal of Educational Technology*, *53*(2), 367–390. Scopus. https://doi.org/10.1111/bjet.13170

Punjab State Council for Science and Technology, Chandigarh. (2020, June). *EIACP Centre Punjab, Status of Environment and related Issues*. Www.Punenvis.Nic.In. https://punenvis.nic.in//index2.aspx?slid=5619&sublinkid=936&langid=1&mid=1

Punjab State Council for Science and Technology, Chandigarh. (2024, March). *EIACP Centre Punjab, Status of Environment and related Issues*. Http://Punenvis.Nic.In/. https://punenvis.nic.in//index1.aspx?lid=5617&mid=1&langid=1&linkid=1257

Punjab State Council for Science and Technology, Chandigarh. (June 20). *EIACP Centre Punjab, Status of Environment and related Issues*. Www.Punenvis.Nic.In. https://punenvis.nic.in//index2.aspx?slid=5618&mid=1&langid=1&sublinkid=935

Quirós-Vargas, J., Romanelli, T. L., Rascher, U., & Agüero, J. (2020). Sustainability Performance through Technology Adoption: A Case Study of Land Leveling in

a Paddy Field. *Agronomy*, *10*(11), 1681. https://doi.org/10.3390/agronomy10111681

Raj, N., Swamy, M., Purushotham, B., & Sukrutha, S. (2021). Applications of microbe-based nanoparticles in agriculture: Present state and future challenges. *Microbial Nanobiotechnology: Principles and Applications*, 343–382.

Rajya Sabha. (2021). Soil Erosion and Land Degradation. *GOVERNMENT OF INDIA MINISTRY OF AGRICULTURE AND FARMERS WELFARE DEPARTMENT OF AGRICULTURE, COOPERATION AND FARMERS WELFARE*. https://sansad.in/getFile/annex/253/AU2729.pdf?source=pqars

RajyaSabha, R. (2024). GOVERNMENT OF INDIA MINISTRY OF CHEMICALS AND FERTILIZERS DEPARTMENT OF FERTILIZERS. *PIB, Govt of India*. https://sansad.in/getFile/annex/265/AU1612_hTL1QP.pdf?source=pqars

Ravisankar, N., Singh, R., Panwar, A. S., Shamim, M., & Prusty, A. K. (2020). *Comparative Performance of Different Production Systems with Respect to Yield, Income and Sustainability*.

Redclift, M. (2005). Sustainable development (1987–2005): An oxymoron comes of age. *Sustainable Development*, *13*(4), 212–227. https://doi.org/10.1002/sd.281

regenagri. (2024). *What is regenerative agriculture?* Regenagri. https://regenagri.org/our-initiative/regenerative-agriculture/

Regeneration International. (2023). Why Regenerative Agriculture? *Regeneration International*. https://regenerationinternational.org/why-regenerative-agriculture/

Ringle, C. M., Wende, S., & Becker, J.-M. (2024). SmartPLS 4. In *Https://www.smartpls.com/documentation/algorithms-and-techniques/model-fit*. {https://www.smartpls.com/}

Ritchie, H., & Roser, M. (2024). Sector by sector: Where do global greenhouse gas emissions come from? *Our World in Data*. https://ourworldindata.org/ghg-emissions-by-sector

Robinson, G. M. (2009). Towards Sustainable Agriculture: Current Debates. *Geography Compass*, *3*(5), 1757–1773. https://doi.org/10.1111/j.1749-8198.2009.00268.x

Rogers, E. M. (1995). *Diffusion of Innovations* (Fourth). The Free Press, New York.

Rosa, L., & Gabrielli, P. (2023). Achieving net-zero emissions in agriculture: A review. *Environmental Research Letters*, *18*(6), 063002.

Ruslim, T. S., & Herwindiati, D. E. (2024). Adoption of e-wallet in the post-pandemic era: A study on Generation X's intention to use e-wallet. *Innovative Marketing*, *20*(2), 267–280. Scopus. https://doi.org/10.21511/im.20(2).2024.22

Saber, Z., van Zelm, R., Pirdashti, H., Schipper, A. M., Esmaeili, M., Motevali, A., Nabavi-Pelesaraei, A., & Huijbregts, M. A. J. (2021). Understanding farm-level differences in environmental impact and eco-efficiency: The case of rice production in Iran. *Sustainable Production and Consumption*, *27*, 1021–1029. https://doi.org/10.1016/j.spc.2021.02.033

Sachin, Raj, R., Dhiman, S., & Shakya, L. (2022). Nanotechnological interventions in sustainable agriculture. *Indian Journal of Biochemistry and Biophysics*. https://doi.org/10.56042/ijbb.v59i12.67308

Schmidthuber, L., Maresch, D., & Ginner, M. (2020). Disruptive technologies and abundance in the service sector-toward a refined technology acceptance model. *Technological Forecasting and Social Change*, *155*, 119328.

Sebby, K. (2010). *The Green Revolution of the 1960's and Its Impact on Small Farmers in India*.

Sener, H. (2023, June 9). *Biodynamic Farming: A Comprehensive Overview*. Permalogica. https://www.permalogica.com/post/biodynamic-farming-a-comprehensive-overview

Shaik, D. S., Kant, Y., Mitra, D., Singh, A., Chandola, H., Sateesh, M., Babu, S. S., & Chauhan, P. (2019). Impact of biomass burning on regional aerosol optical properties: A case study over northern India. *Journal of Environmental Management*, *244*, 328–343.

Shao, Y., Wang, Z., Zhou, Z., Chen, H., Cui, Y., & Zhou, Z. (2022a). Determinants Affecting Public Intention to Use Micro-Vertical Farming: A Survey Investigation. *Sustainability (Switzerland)*, *14*(15). Scopus. https://doi.org/10.3390/su14159114

Shao, Y., Wang, Z., Zhou, Z., Chen, H., Cui, Y., & Zhou, Z. (2022b). Determinants Affecting Public Intention to Use Micro-Vertical Farming: A Survey Investigation. *Sustainability (Switzerland)*, *14*(15). Scopus. https://doi.org/10.3390/su14159114

Sharifzadeh, M. S., Damalas, C., Abdollahzadeh, G., & Ahmadi-Gorgi, H. (2017). Predicting adoption of biological control among Iranian rice farmers: An application of the extended technology acceptance model (TAM2). *Crop Protection*, *96*, 88–96. https://doi.org/10.1016/j.cropro.2017.01.014

Sharma, N., & Singh, S. P. (2013). AGRICULTURAL DIVERSIFICATION AND CONTRACT FARMING IN PUNJAB. *Journal of Economic & Social Development*, *IX*(1).

Sharma, V., Giri, S., & Shankar Rai, S. (2013). Supply Chain Management Of Rice In India: A Rice Processing Company's Perspective. *International Journal of Managing Value and Supply Chains*, *4*(1), 25–36. https://doi.org/10.5121/ijmvsc.2013.4103

Shigemochi, H. (1978). *The structure of disparity in developing agriculture.*

Shroff, R. H., Deneen, C. C., & Ng, E. M. W. (2011). Analysis of the technology acceptance model in examining students' behavioural intention to use an e-portfolio system. *Australasian Journal of Educational Technology*, *27*(4). https://doi.org/10.14742/ajet.940

Sidhu, H. (2005). Production conditions in contemporary Punjab agriculture. *Journal of Punjab Studies*, *12*(2), 197–217.

Sim, J., & Lewis, M. (2012). The size of a pilot study for a clinical trial should be calculated in relation to considerations of precision and efficiency. *Journal of Clinical Epidemiology*, *65*(3), 301–308. https://doi.org/10.1016/j.jclinepi.2011.07.011

Singla, C., Aggarwal, R., & Kaur, S. (2022). Groundwater decline in Central Punjab—Is it a warning? *Groundwater for Sustainable Development*, *16*, 100718. https://doi.org/10.1016/j.gsd.2021.100718

Singla, C., Aggarwal, R., & Kaur, S. (2024). Agricultural policies for mitigating groundwater depletion in central Punjab. *Groundwater for Sustainable Development*, *25*, 101117. https://doi.org/10.1016/j.gsd.2024.101117

Sinha, N., & Verma, P. (2020). Adoption of ICT enabled Agricultural Extension Services through Perceived Economic wellbeing: ICT and PEwB. *International Journal of Information and Communication Technology Education*, *16*(3), 30–41. Scopus. https://doi.org/10.4018/IJICTE.2020070103

Spralls, S. A., Hunt, S. D., & Wilcox, J. B. (2011). Extranet Use and Building Relationship Capital in Interfirm Distribution Networks: The Role of Extranet Capability. *Journal of Retailing*, *87*(1), 59–74. https://doi.org/10.1016/j.jretai.2010.09.001

SRP. (2023). *Sustainable Rice Platform Standard for Sustainable Rice Cultivation (Version 2.2)* (NO-202308-ST-EN; Version 2.2). https://sustainablerice.org/wp-content/uploads/2022/12/NO-202308-ST-EN-SRP-Standard-for-Rice-Cultivation-V2.2.pdf

Stern, P. C., Dietz, T., & Guagnano, G. A. (1995). The new ecological paradigm in social-psychological context. *Environment and Behavior*, *27*(6), 723–743.

Syan, A. S., Kumar, V., Sandhu, V., & Hundal, B. S. (2019). Empirical Analysis of Farmers Intention to Adopt Sustainable Agricultural Practices. *Asia-Pacific Journal of Management*, *15*((1-2)), 39–52. https://doi.org/10.1177/2319510X19848857

Taherdoost, H. (2016). Sampling method in Research Methodology. *International Journal of Academic Research in Management*, *1,*(2), 18–27. https://doi.org/hal-02546796

Taherpour, M., Mirzaei-Alavijeh, M., Khazaie, H., Hosseini, S. N., Fattahi, M., Karimi, N., & Jalilian, F. (2022). Socio-cognitive Determinants of Healthy Sleep Behaviors Among Iranian Elderly: Application of the Theory of Planned

Behavior. *Journal of Education and Community Health*, *9*(2), 80–85. Scopus. https://doi.org/10.34172/jech.2022.12

Tajeri Moghadam, M., Raheli, H., Zarifian, S., & Yazdanpanah, M. (2020). The power of the health belief model (HBM) to predict water demand management: A case study of farmers' water conservation in Iran. *Journal of Environmental Management*, *263*, 110388. https://doi.org/10.1016/j.jenvman.2020.110388

Tama, R. A. Z., Ying, L., Yu, M., Hoque, M. M., Adnan, K. M., & Sarker, S. A. (2021). Assessing farmers' intention towards conservation agriculture by using the Extended Theory of Planned Behavior. *Journal of Environmental Management*, *280*. Scopus. https://doi.org/10.1016/j.jenvman.2020.111654

Taneja, G., Rawat, S., & Vatta, K. (2018). Towards Unsustainable Resource use in Punjab Agriculture. *Indian Journal of Ecology*, *45*(2), 342–346.

Tapuswan, S., Alcon, F., & Hunink, J. (2014). Assessing the Design of A Model-Based Irrigation Advisory Bulletin: The Importance of End-User Participation. *Irrigation and Drainage*, *64*(2). http://dx.doi.org/10.1002/ird.1887

Tarhini, A., Deh, R. M., Al-Busaidi, K. A., Mohammed, A. B., & Maqableh, M. (2017). Factors influencing students' adoption of e-learning: A structural equation modeling approach. *Journal of International Education in Business*, *10*(2), 164–182. Scopus. https://doi.org/10.1108/JIEB-09-2016-0032

Taylor, S., & Todd, P. (1995). Decomposition and crossover effects in the theory of planned behavior: A study of consumer adoption intentions. *International Journal of Research in Marketing*, *12*(2), 137–155. https://doi.org/10.1016/0167-8116(94)00019-K

Tian, Z., Fan, Y., Wang, K., Zhong, H., Sun, L., Fan, D., Tubiello, F. N., & Liu, J. (2021). Searching for "Win-Win" solutions for food-water-GHG emissions tradeoffs across irrigation regimes of paddy rice in China. *Resources, Conservation and Recycling*, *166*, 105360. https://doi.org/10.1016/j.resconrec.2020.105360

Timpanaro, G., Chinnici, G., Selvaggi, R., Cascone, G., Foti, V. T., & Scuderi, A. (2023). Farmer's adoption of agricultural insurance for Mediterranean crops as an innovative behavior. *Economia Agro-Alimentare*, *25*(2), 155–188. Scopus. https://doi.org/10.3280/ecag2023oa14966

T'ing, L. C., Moorthy, K., Mei, C. Y., Yin, F. P., Ying, W. Z., Khong, C. W., Chern, G. Z., & Lin, T. Z. (2020). Determinants of 3Rs behaviour in plastic usage: A study among Malaysians. *Heliyon*, *6*(12).

Umrani, F., & Ghadially, R. (2003). Empowering women through ICT education: Facilitating computer adoption. *Gender, Technology and Development*, *7*(3), 359–377.

United Nations, D. of E. and S. W. (2023). *Goal 2 | Department of Economic and Social Affairs*. https://sdgs.un.org/goals/goal2#overview

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What is sustainable agriculture? A systematic review. *Sustainability*, *7*(6), 7833–7865.

Venkatesh, V., & Davis, F. (2000). *A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies* (SSRN Scholarly Paper 4062393). https://papers.ssrn.com/abstract=4062393

Vidogbéna, F., Adégbidi, A., Tossou, R., Assogba-Komlan, F., Martin, T., Ngouajio, M., Simon, S., Parrot, L., Garnett, S. T., & Zander, K. K. (2016). Exploring

factors that shape small-scale farmers' opinions on the adoption of eco-friendly nets for vegetable production. *Environment, Development and Sustainability*, *18*(6), 1749–1770. https://doi.org/10.1007/s10668-015-9717-z

Wang, C., Zhang, J., Cao, J., Hu, H., & Yu, P. (2019). The influence of environmental background on tourists' environmentally responsible behaviour. *Journal of Environmental Management*, *231*, 804–810.

Wang, Y.-M., Wei, C.-L., & Wang, M.-W. (2023). Factors influencing students' adoption intention of brain–computer interfaces in a game-learning context. *Library Hi Tech*, *41*(5), 1594–1620. Scopus. https://doi.org/10.1108/LHT-12-2021-0506

Wezel, A., Casagrande, M., Celette, F., Vian, J.-F., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development*, *34*(1), 1–20. https://doi.org/10.1007/s13593-013-0180-7

Win, E. P., Win, K. K., Bellingrath-Kimura, S. D., & Oo, A. Z. (2021). Influence of rice varieties, organic manure and water management on greenhouse gas emissions from paddy rice soils. *PloS One*, *16*(6), e0253755. https://doi.org/10.1371/journal.pone.0253755

Yazdanpanah, M., & Fourozani, M. (2015). Application of the Theory of Planned Behaviour to predict Iranian students' intention to purchase organic food. *Journal of Cleaner Production*, *107*. https://doi.org/10.1016/j.jclepro.2015.02.071

Yuhua, C., Mustafa, H., Ziqin, F., & Senik, R. (2022). *The Role of Block Chain Technology Adoption on the Budget Performance Management: Moderating Role of Institutional Support*.

Zahid, H., Ali, S., Abu-Shanab, E., & Muhammad Usama Javed, H. (2022a). Determinants of intention to use e-government services: An integrated marketing relation view. *Telematics and Informatics*, *68*. Scopus. https://doi.org/10.1016/j.tele.2022.101778

Zahid, H., Ali, S., Abu-Shanab, E., & Muhammad Usama Javed, H. (2022b). Determinants of intention to use e-government services: An integrated marketing relation view. *Telematics and Informatics*, *68*. Scopus. https://doi.org/10.1016/j.tele.2022.101778

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., & Speelman, S. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *Journal of Environmental Management*, *187*, 71–81. https://doi.org/10.1016/j.jenvman.2016.11.014

Appendices

Appendix A – Qualitative research instruments: Interview Schedule

Dear Sir / Madam,
Greetings.

I am Bhiravi, pursuing research (PhD) at Mittal School of Business, Lovely Professional University, Phagwara. As part of my study, I seek your responses to understand the challenges faced in growing rice using sustainable agricultural practices. In addition to that would like to know about your processing and marketing constraints and your insights on what could be done to have wide adoption of sustainable farming technologies in rice cultivation . The interview will require approximately 20 to 30 minutes and with your consent will be recorded. Your responses will be kept confidential and shall be used exclusively for PhD research purpose. Kindly note that I value the different opinions expressed about the issues addressed in this questionnaire, and there are no right or wrong answers. If you have any questions about this interviews, please feel free to contact me on my Email Id: Bhiravi.41900164@lpu.co.in Thank you.

Interview Schedule:

Date - …….. Time ……

Agro-climatic Zone …… Village (Distt.)……..

1. Could you please share something about your profile, land-holding and how long have you been farming?
2. Is farming your full time occupation? If no, what is other employment?
3. Do you use sustainable agricultural practices for rice cultivation? If so what were your reasons to do that?
4. What was the ground water level when you started farming and what is its current status?

5. Which variety do you use for rice-cultivation and what are the kind of sustainable methods/practices do you use?
6. What is your opinion regarding major challenges in adoption of sustainable rice cultivation in Punjab?
7. What kind of support do you think is needed for sustainable rice cultivation?
8. What can be done for mass adoption of sustainable rice cultivation?

Demographic Information :

1. Respondent No.
2. Mobile No: ……
3. Age …….
4. Gender ……..
5. Education Level ……
6. Land Ownership …….
7. Land on Lease……..
8. Area under SAP (if applicable)……

Appendix B – Quantitative research instruments: Survey Questionnaire

Dear Sir / Madam,

Greetings.

I am Bhiravi, pursuing research (PhD) at Mittal School of Business, Lovely Professional University, Phagwara. As part of my study, I seek your responses to carry out a yield comparison in rice crop using conventional methods and sustainable agricultural technologies. Also, would like to gather your perception on adoption of sustainable agricultural technologies along with your demographic details. The survey will require approximately 15 minutes. Your responses will be kept confidential and shall be used exclusively for PhD research purpose. Kindly note that I value the different opinions expressed about the issues addressed in this questionnaire, and there are no right or wrong answers. If you have any questions about this survey, please feel free to contact me on my Email Id: Bhiravi.41900164@lpu.co.in

Thank you.

Please give your agreement on five-point scale for the following statements related to rice cultivation using Sustainable Agricultural Practices :

(Strongly Disagree 1, Disagree 2, Neither Disagree Nor Agree 3, Agree 4, Strongly Agree 5)

S No	Item	SD 1	D 2	ND NA 3	A 4	SA 5
AW1	I am aware that using a Land Leveller helps in water and soil conservation.					
FOU1	I use land leveller in my field every year or alternate year.					
AW2	I know that applying Farmyard manure in farm enriches soil fertility.					
FOU2	I use farm-yard manure in my farm every year.					
AW3	I think compost is best way to manage waste and enhance health of farm soil.					
AW4	I think reduced tillage helps in maintaining productivity of farm soil.					
FOU3	I do minimum of four times or more tilling in my rice field.					
AW5	I am aware that excessive usage of Urea deteriorates the quality of soil nutrients and leaches to water bodies and contaminate them.					
FOU4	I broadcast Urea more than 3 times in my rice farms					
AW6	I know that green manure like Jantar/Legumes can help in Nitrogen fixation and lead to lesser need of urea broadcast.					
FOU5	I grow Jantar/Moong in field before rice crop.					
AW7	I think that Basmati cultivation could help to prevent decline of ground water in Punjab.					
FOU6	I grow Basmati every year.					

AW8	I think that direct seeding of rice can help in saving water and labour cost.					
FOU7	I grow rice with direct seeding method.					
AW9	I feel that delayed transplantation helps in saving ground water by making good use of monsoon water.					
FOU8	I always grow rice as per the recommended date of transplantation.					
AW10	I am aware that crop residue acts as natural nutrient for soil and following crop.					
FOU9	I burn the paddy crop residue after harvest.					
FOU10	I use seed variety which gives maximum yield.					
FOU11	I use biological pesticides in my rice farm.					
FOU12	I grow wheat using direct method/happy-seeder.					
PU	**PERCEIVED USEFULNESS**	SD 1	D 2	NDNA 3	A 4	SA 5
PU01	I feel that rice cultivation using SAP helps in increase in the ground water table.					
PU02	I think rice cultivation using SAP saves my cost by not spending on expensive agrochemicals.					
PU03	I think the advantages of rice cultivation using SAP are more than the disadvantages.)					
PE	**PERCEIVED EASE OF USE**	SD 1	D 2	NDNA 3	A 4	SA 5
PE01	I feel it will be hard to do rice cultivation using SAP.					
PE02	I feel it will be difficult to do weeding in rice cultivation using SAP					

PE03	I feel it will be tough to learn to do rice cultivation through SAP.					
PC	**PERCEIVED COMPATIBILITY**	SD 1	D 2	NDNA 3	A 4	SA 5
PC01	I can do Rice cultivation through SAP along with conventional farming.					
PC02	I require additional tools or machinery for SRC.					
PC03	I need more knowledge about pest management and disease control in SAP.					
PC04	I need separate storage system for pesticide free rice produce.					
NEP	**NEW ECOLOGICAL PARADIGM**	SD 1	D 2	NDNA 3	A 4	SA 5
NEP01	We are approaching the limit of the number of people the earth can support.					
NEP02	When humans interfere with nature it often produces disastrous consequences.					
NEP03	Human ingenuity will ensure that we do NOT make the earth unliveable.					
NEP04	The earth has plenty of natural resources if we just learn how to develop them.					
PEF	**PERSONAL EFFICACY**	SD 1	D 2	NDNA 3	A 4	SA 5
PEF01	I am confident that If I wish, I can do Sustainable Rice Cultivation.					
PEF02	I am confident that I can collect desired information and knowledge for SRC.					
PEF03	I feel it should be easy for me to learn this new method of rice farming with SAP.					

PEF04	I believe I can succeed at growing rice sustainably and making profit.					
PR	**PERSONAL RESOURCES**	SD 1	D 2	NDNA 3	A 4	SA 5
PR01	I have land to experiment with SRC methods.					
PR02	I can avail technical knowledge through seminars organised in my area.					
PR03	I am benefitted from extension service team regarding information and knowledge.					
PR04	I have most of the SAP inputs readily available at home.					
SI	**SOCIAL INFLUENCE**	SD 1	D 2	NDNA 3	A 4	SA 5
SI01	I will adopt SAP in rice cultivation if other farmers in the village/block adopt it.					
SI02	I would be interested to cultivate rice using SAP if there are more successful farmers doing so.					
SI03	I have often adopted new farming practices by observing other farmers.					
SI04	I will have to use SAP in rice cultivation if the traders insist on sustainable rice.					
ES	**EXTENTION SERVICES**	SD 1	D 2	NDNA 3	A 4	SA 5
ES01	I think extension services can influence me in adopting sustainable methods in rice cultivation.					
ES02	I have more trust on extension officials than private company representatives.					
ES03	I have the opportunity available to regularly attend training/workshop/seminar/webinar to get					

	information and knowledge about SAP in rice cultivation.					
ES04	I can conveniently reach out to extn office in my region and avail various products and services.					
AT	**ATTITUDE**	SD 1	D 2	NDNA 3	A 4	SA 5
AT1	I like the idea of adopting SAP in rice cultivation.					
AT2	I think adopting SAP in rice cultivation is a wise decision.					
AT3	I think adopting SAP in rice cultivation is a great idea.					
AT4	I think adopting SAP in rice cultivation is a good step to save nature.					
PBC	**PERCEIVED BEHAVIOUR CONTROL**	SD 1	D 2	NDNA 3	A 4	SA 5
PBC01	I have the resources and ability to afford SAP in rice cultivation.					
PBC02	I have the resources and ability to implement SAP in rice cultivation.					
PBC03	I would be able to afford SAP in rice cultivation.					
PBC04	I would be able to implement SAP in rice cultivation.					
SN	**SUBJECTIVE NORMS**	SD 1	D 2	NDNA 3	A 4	SA 5
SN01	I think I would adopt SAP in rice cultivation because there are successful farmers who expect me to do so.					
SN02	I think I would adopt SAP in rice cultivation because my family members want me to do so.					

SN03	I think I would adopt SAP in rice cultivation because extension service officers expect me to do so.					
SN04	I think I would adopt SAP in rice cultivation because the traders and exporters expect me to do so.					
IS	**INSTITUTIONAL SUPPORT**	SD 1	D 2	NDNA 3	A 4	SA 5
IS01	I know that govt is making many efforts for promoting Sustainable/Organic Agriculture by subsidies and other certification support.					
IS02	It is easy for me to avail services related to promotion of SAP in rice cultivation.					
IS03	I think govt should provide for the conversion/adoption cost. In the beginning years. (eg labour from MNREGA, or free bio-pesticides)					
MI	**MARKET INFRASTRUCTURE**	SD 1	D 2	NDNA 3	A 4	SA 5
MI01	I think the rice grower has no advantage for his pesticide free produce.					
MI02	I find that there are no quality standards for sustainable produce of rice and hence no price premium.					
MI03	I think that govt should develop infra structure for sustainable rice or/and Basmati.					
MI04	I could adopt rice cultivation with SAP If there are export oriented infrastructure.					
MI05	I find that there are many NGOs engaged in sustainable practices in my area.					
BI	**BEHAVIOURAL INTENTION**	SD 1	D 2	NDNA 3	A 4	SA 5
BI01	I intend to use SAP in rice cultivation.					

BI02	I have plans to move to SAP in coming few years.					
BI03	I intend to adopt diversification even if there is no MSP					

Demographic Information

Agroclimatic Zone _____

Distt _____

Village _____

1. Respondent No….
2. Mobile No: ……
3. Age …….
4. Gender ……..
5. Area of farmland ……
6. Ownership …….
7. Tenet/Lease……..
8. Farming experience in years ……
9. Marital Status Single …… Married ……..
10. Education ……
11. Area under Rice cultivation _____ acres.
12. Basmati _____ acre, Non-Basmati _____acres.
13. Yield per acre from Basmati _____ Non-Basmati _____

Appendix C – Published research paper

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A QUALITATIVE ANALYSIS ON FARMER PERCEPTION REGARDING SUSTAINABLE RICE CULTIVATION IN PUNJAB

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ABSTRACT

The farmers of Punjab have consistently achieved the maximum yield in rice production in the nation by implementing Green Revolution (GR) practices. Nevertheless, the ecosystem has suffered a significant decline because of the excessive use of resources and groundwater for irrigation. Despite the persistent demands for diversification, the farmers continue to adhere to traditional GR methods of rice cultivation. The objective of the current study is to investigate the farmers' perspectives regarding the sustainable cultivation of rice in Punjab. Additionally, the research facilitates the understanding of the elements that are responsible for a smooth transition to sustainable rice cultivation. The study employed Qualitative research design. The data was collected in the Moga district of Punjab using the purposive sampling technique, which included semi-structured interviews. Using MAXQDA 2022, the data analysis employs the grounded theory approach of thematic analysis. The findings suggest that producers are aware of the unsustainable nature of their current practices. Nevertheless, the primary obstacles to adoption are the absence of a specific market for sustainable produce and the lack of relevant knowledge on sustainability. The study demonstrates the farmers' expectations for environmentally responsible agricultural production, including well-designed policies, guaranteed markets, and prices.

KEYWORDS:

Sustainability, Sustainable Rice Cultivation (SRC), Adoption, Perception, MAXQDA

1. INTRODUCTION

Asia dominates global rice production, with nations such as China, India, Vietnam, Thailand, the Philippines, Myanmar, Bangladesh, Indonesia, Japan, Cambodia, the Republic of Korea, Nepal, and Sri Lanka accounting for nearly 90% of total output, while India and China consume approximately 50% of this production (Muthayya et al., 2014). Rice cultivation employs nearly 25% of the global agricultural workforce, underscoring its significant social and economic influence. The ecological impact of rice agriculture has emerged as a significant sustainability concern. The demands for substantial irrigation and pest management in rice farming create a considerable environmental impact, adversely affecting the health and safety of farmers. Moreover, rice agriculture accounts for 10% of global greenhouse gas emissions (Maraseni et al., 2018; Ritchie, 2019; Basavalingaiah et al., 2020).

As we analyse Punjab's historical agricultural contributions and contemporary rice cultivation status, there are significant concerns regarding its future. Since the Green Revolution, rice, a non-indigenous crop in Punjab, has experienced substantial expansion throughout the state. The dismal situation in Punjab has been the result of the shift in cropping patterns. The area under rice cultivation has experienced a remarkable increase, rising from 285 thousand

hectares (6.82%) in 1966-67 to 2894 thousand hectares (40.76%) in 2014-15. In contrast, other crops that contributed 54.54% in 1966-67 have considerably decreased to only 9.87% in 2014-15, while wheat and rice together accounted for 76.9% of the total crop production, covering approximately 90.1% of the cultivated land (Mann, 2017; Vatta & Budhiraja, 2020). The sustainability of agricultural production in Punjab is significantly threatened by the decrease in crop diversification. This matter has a broad-based impact and numerous implications (Dutta & Dhillon, 2020). According to the Punjab Envis Centre, the state has attained an irrigation level of 99.9%. Rice is the primary crop that consumes this irrigation, which has a dangerous impact on the groundwater table (ENVIS Centre: Punjab Status of Environment, 2020). The rate of groundwater table decline exceeds that of its replenishment (A. Singh et al., 2015; Khush, 2015; Gulati et al., 2021). In addition, the overuse of agrochemicals presents a big challenge as a result of soil depletion, food contamination, and adverse effects on food quality and safety. Several studies have emphasized this issue (Pandher et al., 2021; Sharma et al., 2021; Daulta et al., 2022). Furthermore, the agricultural development has declined, while production has remained constant. In 1985-86, the agricultural growth rate was twice the national average, at 5.7%. However, it has since declined to 1.6%, which is one-half the national average in 2014-15 (Dutta, 2012; Gulati et al., 2017, 2021).

Certain groups maintain the conviction that the Green Revolution has failed in its pursuit of sustainability and its overall approach to well-being (Benbi, 2018; Hurt, 2020; John & Babu, 2021). The Green Revolution's production-oriented approach has resulted in a substantial depletion of environmental resources, while the economic benefits have reached a state of stagnation. Disillusioned young individuals who are contending with the real world and widespread emigration to other countries are the resulting effects on social structure (Kaur et al., 2021; Nanda et al., 2021; Ohno et al., 2021). Benbi (2018), Hurt (2020), and John and Babu (2021) are among the organizations that maintain the belief that the Green Revolution has failed in its pursuit of sustainability and its overall approach to well-being. The Green Revolution's production-oriented approach has led to a significant depletion of environmental resources, while the economic benefits have reached a state of stagnation. The resulting effects on social structure include disillusioned young individuals who are coping with the real world and pervasive emigration to other countries (Kaur et al., 2021; Nanda et al., 2021; Ohno et al.,2021).

Consequently, it is crucial to ascertain the reasons why the agricultural community in Punjab, which is usually diligent and enthusiastic, is disregarding the severe consequences of extensive rice cultivation. What are the causes for the lack of adoption of sustainable rice cultivation methods? The objective of this study is to examine the feasibility of implementing sustainable rice production practices in Punjab. This investigation is divided into five sections. The literature review is the primary focus of the subsequent section. The objectives of the study are delineated in Section 3, which is followed by a detailed explanation of the research methodology in Section 4. The data analysis and discussion are presented in Section 5, which is followed by the conclusion and implications of the study.

2. LITERATURE REVIEW

The literature review section investigates the concept of sustainable agriculture, its strategy, and the methods used to achieve the intended objectives. Furthermore, it looks at the factors that contribute to the adoption of sustainable practices. The concept of sustainability is intricate and holds significant importance in all facets of human existence. Pretty (1994) has expressed her disapproval of the positivist approach, which aims to establish an absolute definition and prescribed course of action for sustainability. In contrast, Pretty contends that

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sustainable agriculture requires a system-oriented approach. Pretty (1995) contends in a distinct study that the concept of sustainability is too complex to be adequately captured by a single definitive explanation. In contrast, Pretty underscores the importance of implementing a participatory methodology. As a result, the term "sustainability" is subject to a variety of interpretations, which presents a challenge when applied to agriculture. Depending on the unique factors of a specific location, the concept of "Sustainable Agriculture" can have a variety of interpretations and implications. Consequently, the authors have chosen to implement an interpretive methodology for this investigation.

It is difficult to ascertain the precise definition of sustainable agriculture due to the conflicting interpretations of sustainability. In order to resolve this matter, it is imperative to establish an outline that will serve as the basis for the current investigation. Velten et al. (2015) have developed a framework that is the foundation of the current research problem. This framework is founded on the goals, strategies, and fields of action that have been selected to achieve the economic, social, and environmental objectives identified in a systematic literature review (Table 1). Production-specific and non-production-specific environmental objectives are distinguished. The non-production specific objectives are centered on the preservation of nature for its intrinsic value, rather than for human-centered purposes. This framework is exceedingly advantageous for comprehending the notion's interpretation within academia. Nevertheless, the genuine deficiency is the lack of comprehension of the complexities of sustainable agriculture by individuals at the grassroots level, specifically producers, within their own environmental context. It is essential to comprehend the rationale behind this perception.

Table 1- Themes and categories making up the goals of sustainable agriculture. Source - (Velten et al., 2015).

Goals	**Theme**	
	General	*Specific*
Overarching Goals		• ethics
		• multifunctionality
		• safety
		• stability & resilience
Environment Goals; Production Specific	ecological soundness	• ecosystem function conservation
		• natural resource conservation
		• providing capacity
Environmental Goals; Non-Production Specific		• animal well-being
		• environment conservation & improvement
		• harmony with nature
Social Goals	social responsibility	• acceptability
		• cultural preservation
		• equity, justice, fairness
		• fulfilment of human needs
		• good working conditions
		• human health
		• nourishment
		• quality of life
		• strong communities
Economic Goals	economic	• development

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	viability	• livelihood
		• provision of products
		• thriving economy

The perspectives of scientists from various disciplines in the pursuit of sustainable agriculture can be essentially categorized into two groups: Agroecological-Ruralist and Techno-Economic (Velten et al., 2015). The concept of "Precision Agriculture (PA)" has given rise to the era of Agriculture 5.0, which encompasses the use of Artificial Intelligence (AI), the Internet of Things (IoT), and Machine Learning (ML). Nevertheless, developing countries have not yet adequately prepared for this development. Altieri (2018) had introduced the concept of an agroecological approach as a method of achieving sustainability. Traditional indigenous knowledge is the foundation of agroecology, a variegated ecosystem that is unique to a specific location. It can sustain itself by managing natural resources and encompasses the aspect of ethnoecology. Wezel et al. (2014) have provided an exhaustive description of the numerous agroecological techniques and the methods by which they can be implemented at various levels, such as the field, cropping system, or landscape. This enables the enhancement of efficacy in the entire food system, a farm, or a crop. The robustness and adaptability of agroecological techniques are illustrated by this. These solutions are not only cost-effective and environmentally friendly, but they also have the capacity to be progressively expanded.

The farmer's financial capacity and the broader environment in which he operates are both factors that influence the selection of sustainable practices. It is crucial to take into account the policy framework and the perspective of the farmers in the predominantly agricultural economy of Punjab in order to gain a comprehensive understanding of the success and impact of the Green Revolution. The Green Revolution's extraordinary success is largely attributed to the innovative cultivators of Punjab; however, it is equally crucial to recognize the diligent efforts of the policy makers (Hurt, 2020). A comprehensive and resilient support system was implemented with immense efficiency, spanning from production to post-harvest sales. The production was considerably increased by the implementation of government purchase at licensed mandis, which included a guarantee of Minimum Support Price (MSP). Consequently, it was logical for farmers to adopt a mono-cropping system and employ modern agrochemicals, such as pesticides and fertilizers, to facilitate their economic and social development. Demographic, socio-economic, and personal value belief systems are among the factors that influence the adoption of sustainable practices. Education, farming experience, perceived usefulness, perceived simplicity of use, environmental concern, small land holding, and lower cost per hectare are all positive factors that influence adoption (Ashari et al., 2019; Suwanmaneepong et al., 2020). Furthermore, adoption is influenced by the knowledge, talent, and competency of the farmer (Roy & Chan, 2015). Digal and Placencia (2019) and Mahdavi et al. (2020) have emphasized the critical role of government institutions and extension teams in the development of policies and the implementation of activities. The adoption of this technology was impeded by financial considerations, limited productivity, the absence of viable markets, and profitability concerns (Singh et al., 2023). The psychological factors, such as the farmer perspective, have not been adequately considered when examining the reasons for the adoption of sustainable practices, despite the fact that the socio-economic aspects have been taken into account (Foguesatto et al., 2020). The significance of crop diversification is extensively supported by the existing literature. Nevertheless, there is still space for additional investigation into the potential for fostering sustainable rice farming in the region. The following specific concerns are the focus of this

study that how does the average farmer perceive the cultivation of rice using sustainable methods? And in addition , what are the fundamental factors that drive this perception?

3. OBJECTIVE

The majority of the research conducted on the designated subject and region is conducted using quantitative methods, with a primary emphasis on the broader scope of agriculture. Nevertheless, there is a scarcity of specific analysis and comprehension regarding the sustainable cultivation of rice. The current research endeavour aims to rectify this deficiency by examining the perception of cultivators that is influencing the cultivation of rice in Punjab. The contextual aspects are taken into account while employing a qualitative approach. By conducting qualitative interviews with farmers from the Moga district of Punjab, the research intends to investigate the perception of sustainable rice cultivation in Punjab. The objective of this research is to identify the most effective methods and ways to enhance the adoption of sustainable rice cultivation.

4. RESEARCH METHODOLOGY

Qualitative research facilitates comprehension of the sentiments and perspectives of individuals, thereby enabling an understanding of the importance that individuals attach to a particular subject. Furthermore, it is advantageous to refrain from extrapolating the results to a broader demographic (Sutton & Austin, 2015). The analysis was conducted using the grounded theory approach of theme analysis, and the research methodology employed was qualitative. Semi-structured scheduled interviews are conducted with 20 rice producers who reside in the Moga district of Punjab to collect data. A purposive sampling technique was employed to ensure that all farmer categories in Punjab were represented in the sample. The inclusion criteria guaranteed that the farmers interviewed were proprietors and had been involved in rice cultivation for a minimum of five years. Furthermore, they exhibited an inclusive and receptive demeanour that facilitated a comprehensive dialogue. In order to facilitate a comfortable and seamless interaction with the research participants, the discussions were conducted in an informal manner and in the local language. The interviews lasted an average of 25 minutes. Notes were taken during the interviews, and the interviewees' surroundings and body language were observed. The principle of data saturation, as outlined by Boddy (2016), was employed to determine the sample size. The data appeared to be inundated by the eleventh interview. Nine additional interviews were incorporated into the pool to mitigate the risk of missing information. The coding was done with a deductive after the verbal transcripts were translated and uploaded as a project in the MAXQDA 22 software.

5. RESULT AND DISCUSSION

Demographics

With an average of five family members, all respondents are married males who primarily adhere to a joint family system. The family's size is decreasing, and there are only a handful of family members who provide assistance with farm labor. The cohort is characterized by a predominance of the middle age group, as the younger generation is becoming increasingly disengaged from agricultural activities. The sample is composed of farmers from a variety of land ownership categories, including those with operational land holdings of less than or equal to 5 acres and those with more than 25 acres. The complete farm is dedicated to the cultivation of rice. The distribution of rice varieties is the most noticeable. The farmer primarily relies on non-Basmati varieties for cultivation, with only three farmers from the sample set engaging in Basmati growing on a minor portion of their field. The Basmati

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variety is a rice of exceptional quality, distinguished by its long grains, delicate flavor, and aromatic fragrance. Punjab accounts for approximately 45% of the total export share, with India being the primary source of exports. A prime example is the "GI Tagging" of Basmati from Punjab (APEDA, 2016). Basmati is a type of rice that has a brief development period. The capacity to sow Basmati rice later in the season, which allows for irrigation with monsoon water, is one of the advantages of cultivating it. Additionally, it is known for its early harvest and commands higher market prices than non-Basmati varieties. However, it is perceived as a hazardous proposition as a result of the absence of institutional support in the form of procurement or Minimum Support Price (MSP). Conversely, the non-Basmati variety offers a guaranteed return and instills a sense of security in the cultivator. It is important to note that farmers do not engage in sustainable or organic rice cultivation. However, they do implement sustainable methods in their domestic gardens and wheat farms, which are intended for self-consumption. This is evidently a result of rice's non-native status and its absence as a staple cuisine on their menu. Additionally, the absence of government procurement renders it devoid of any business advantages.

Thematic Analysis

'Profitability' is the primary code and a significant issue for the farmer, as evidenced by a word cloud of the top 25 codes that were utilized a minimum of 10 times across the scripts (Fig. 1). Furthermore, the "additional effort required" in the implementation of sustainable rice cultivation, the "lack of exclusive market," the expectation of "institutional support" in the form of policy or subsidy, the "dislike for chemicals" and the "willingness to learn new farming methods" are all highlighted. Fig. 2 illustrates the frequency distribution of the nine emergent themes from the study.

Figure 1- A word cloud of top 25 codes with minimum frequency 10

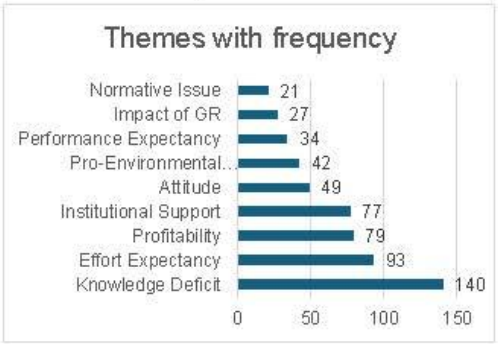

Figure 2 - A graphical representation of emergent themes with frequencies

Knowledge Deficit

The recurrent response to the question about Sustainable Agriculture was that it was like natural farming, which uses no chemicals and relies on nature. Some said their elders farmed this way, and they hate agrochemicals and automated methods, which disengages them more. Data analysis shows basic sustainable practices use. However, they have the tenacity to deliberately perform a practice when they see its benefits. Rice farmers use computer-assisted land-levellers to conserve irrigation water. Precision farming was unknown to all farmers save one. They consistently claim that farming without agrochemicals is impossible, demonstrating their ignorance. They also use the term "zehran" (toxins) to criticize the latter.

Effort Expectancy

The second important issue is effort expectancy. The consensus is that sustainable farming would need pesticide elimination, making farming physically and time-consuming. Farm labor from relatives is insufficient. These approaches are labor-intensive, but using locally sourced resources like compost or Jeevamrit (an insect control cure made from Neem, Cow-dung, and buttermilk) can be sustainable. Additionally, the typical rice growing method has become so ingrained that it requires no conscious effort. Given their habit, farmers are likely to resist change and lack enthusiasm for sustainable methods in the now and future.

Profitability

Due to yield loss, the lack of a price premium, the increased cost of labor and training, and the lack of a sustainable produce advantage, Sustainable Agricultural Practices (SAP) are linked to profit. Furthermore, contractual land charges are excessive. Entrepreneurship is also low among farmers. Additionally, dairy is unprofitable. Farmers know environmental threats are coming, but they prioritize economic concerns. Farmers argue, "Why would I cultivate crops that do not generate revenue and profit?" & "If we fail to maintain our soil, it will be destroyed; however, I have immediate economic needs, which is also a harsh reality."

Institutional Support

Farmers deplore the lack of sustainable rice policy. Sustainable produce will be priced the same as conventional crops since there is no Minimum Support Price. No exclusive markets, storage, or extension support exist. Basmati has promising economic and environmental sustainability, but export-focused policies are lacking. The government's supportive policy framework during the Green Revolution increased agricultural production and profitability. By guaranteeing high-quality hybrid seeds, providing free bags of urea for trial, actively engaging the extension team with farmers at the field level to provide guidance and support, and establishing cooperative societies to help farmers with credit, every aspect of increasing production was addressed. This increased producers' profits and social progress.

6. CONCLUSION

The attitude of cultivators in Punjab toward the sustainable farming of rice was examined in this study through the use of an interpretive methodology. The farmer is oblivious of the potential options to preserve his natural environment and lacks a comprehensive understanding of sustainable agriculture, as indicated by the analysis of semi-structured interviews conducted using MAXQDA 2022. His view of sustainability is restricted to the reduction of agrochemical use, which he deems unfeasible due to the necessity of safeguarding his production and profits. He does not discern any distinction between terms such as "Organic Farming" and "Natural Farming." He regards these terms as

interchangeable. His comprehension of the Techno-Economic approach to sustained rice cultivation is restricted to antiquated machinery, including tractors and land-levelers. He is unaware of the most sophisticated agricultural techniques, including Precision Agriculture, the Internet of Things (IoT), and big data. His sustainable practices, which are based on the Agroecological Ruralist approach, involve the consistent application of micronutrients without the need for soil tests, periodic seeding of green manure, and the use of farmyard manure. The full potential of green chemicals and biologicals, which will unquestionably play a crucial role in the future of sustainable farming, is not yet known to him. The coded segments from the verbal scripts of farmers reveal nine significant factors: Knowledge deficit, Effort Expectancy, Profitability, Institutional Support, Attitude, Pro-environmental disposition, Performance expectancy, Impact of green revolution, and Normative issue. If these variables are effectively managed, they can guide producers toward sustainable rice agriculture and halt the ongoing degradation of Punjab's soil and water resources. The primary objective of a farmer is to optimize the profitability of their agricultural enterprise, as their social status is closely associated with financial gains. The debate surrounding the three pillars of sustainability is enhanced by the comprehension and insight that this research has provided.

It is evident that economic benefits are prioritized. We must also be cognizant of the fact that we are not interacting with individuals who are experiencing financial hardship and lack resources, knowledge, or training in Punjab. They exhibit remarkable skill, a strong entrepreneurial spirit, boundless vitality, and exceptional intelligence. They have the capacity and opportunity to lead the way in the next transformation as the first to introduce an agricultural revolution in the country. A Punjabi farmer has the capacity to seamlessly transition from a symbol of the green revolution to a symbol of sustainable rice agriculture.

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REFERNCES

1. Altieri, M. A. (2018). Agroecology: the science of sustainable agriculture. CRC Press.
2. APEDA. (2016). GI Tagging of Punjab Basmati Rice. Agricultural and Processed Food Products Export Development Authority. https://apeda.gov.in/apedawebsite/about_apeda/Punjab.htm
3. Ashari, Sharifuddin, J., Mohammed, Z., & Terano, R. (2019). Paddy farmer's perception and factors influencing attitude and intention on adoption of organic rice farming. International Food Research Journal, 26(1), 135–145.
4. Basavalingaiah, K., Ramesha, Y. M., Paramesh, V., Rajanna, G. A., Lal Jat, S., Misra, S. D., Gaddi, A. K., Girisha, H. C., Yogesh, G. S., Raveesha, S., Roopa, T. K., Shashidhar, K. S., Kumar, B., El-Ansary, D. O., & Elansary, H. O. (2020). Energy budgeting, data envelopment analysis and greenhouse gas emission from rice production system: A case study from puddled transplanted rice and direct-seeded rice system of Karnataka, India. Sustainability (Switzerland), 12(16). https://doi.org/10.3390/SU12166439
5. Benbi, D. K. (2018). Carbon footprint and agricultural sustainability nexus in an intensively cultivated region of Indo-Gangetic Plains. Science of the Total Environment, 644, 611–623. https://doi.org/10.1016/j.scitotenv.2018.07.018

6. Boddy, C. R. (2016). Sample size for qualitative research. Qualitative Market Research, 19(4), 426–432. https://doi.org/10.1108/QMR-06-2016-0053
7. Daulta, R., Prakash, M., & Goyal, S. (2022). Metal content in soils of Northern India and crop response: a review. International Journal of Environmental Science and Technology. https://doi.org/10.1007/s13762-022-03953-y
8. Digal, L. N., & Placencia, S. G. P. (2019). Factors affecting the adoption of organic rice farming: the case of farmers in M'lang, North Cotabato, Philippines. Organic Agriculture, 9(2), 199–210. https://doi.org/10.1007/s13165-018-0222-1
9. Dutta, S. (2012). Green Revolution Revisited: The Contemporary Agrarian Situation in Punjab, India. Social Change, 42(2), 229–247. https://doi.org/10.1177/004908571204200205
10. Dutta, S., & Dhillon, S. S. (2020). Structural Transformation of Punjab Agriculture and its Environmental Implications. Indian Journal of Economics and Development, 533–546. https://doi.org/10.35716/IJED/20036
11. ENVIS Centre: Punjab Status of Environment, W. R. (2020). ENVIS Centre: Punjab Status of Environment.
12. Foguesatto, C. R., Borges, J. A. R., & Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. Science of The Total Environment, 729, 138831. https://doi.org/10.1016/j.scitotenv.2020.138831
13. Gulati, A., Roy, R., & Hussain, S. (2017). Getting Punjab Agriculture Back on High Growth Path: Sources, Drivers, and Policy Lessons.
14. Gulati, A., Roy, R., & Saini, S. (2021). India Studies in Business and Economics: Revitalizing Indian Agriculture and Boosting Farmer Incomes. https://doi.org/https://doi.org/10.1007/978-981-15-9335-2
15. Hurt, R. D. (2020). The green revolution in the global south: science, politics, and unintended consequences. University Alabama Press.
16. John, D. A., & Babu, G. R. (2021). Lessons From the Aftermaths of Green Revolution on Food System and Health. In Frontiers in Sustainable Food Systems (Vol. 5). Frontiers Media S.A. https://doi.org/10.3389/fsufs.2021.644559
17. Kaur, G., Singh, G., Dharampal, R., Kaur, R., Kaur, S., & Jyoti. (2021). Socio-economic and Demographic Analysis of International Migration from Rural Punjab: A Case Study of Patiala District. Indian Journal of Economics and Development, 55–67. https://doi.org/10.35716/IJED/20083
18. Khush, G. S. (2015). Punjab's water woes and India's food security. Journal of Crop Improvement, 29(1). https://doi.org/10.1080/15427528.2015.997655
19. Mahdavi, H., Allahyari, M. S., Damalas, C. A., & Dunn, E. S. (2020). Drivers and barriers for organic rice (Oryza sativa L.) production in northern Iran: experts' consensus using the Delphi method. Biological Agriculture & Horticulture, 36(2), 96–106. https://doi.org/10.1080/01448765.2019.1698464
20. Mann, R. S. (2017). Cropping pattern in Punjab (1966-67 to 2014-15). 52, 30–33.

21. Maraseni, T. N., Deo, R. C., Qu, J., Gentle, P., & Neupane, P. R. (2018). An international comparison of rice consumption behaviours and greenhouse gas emissions from rice production. Journal of Cleaner Production, 172, 2288–2300. https://doi.org/10.1016/j.jclepro.2017.11.182

22. Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. Annals of the New York Academy of Sciences, 1324(1), 7–14. https://doi.org/10.1111/nyas.12540

23. Nanda, A. K., Véron, J., & Rajan, S. I. (2021). Passages of Fortune? Routledge India. https://doi.org/10.4324/9780429321306

24. Ohno, A., Fujita, K., & Vatta, K. (2021). Agrarian Structure of Punjab in the Post-green Revolution Era Household Strategies for Distress Coping. Economic and Political Weekly, 56–64.

25. Pandher, S., Singh, S., Singh, H., Singh, A., & Rathore, P. (2021). Pesticide use ethics: disseminating environmental safety values among farmers of Punjab (India) through sensitization programmes. Agricultural Research Journal, 58(5), 814–820. https://doi.org/10.5958/2395-146X.2021.00116.2

26. Pretty, J. N. (1994). Alternative Systems of Inquiry for a Sustainable Agriculture. IDS Bulletin, 25(2), 37–49. https://doi.org/10.1111/j.1759-5436.1994.mp25002004.x

27. Pretty, J. N. (1995). Participatory learning for sustainable agriculture. World Development, 23(8), 1247–1263. https://doi.org/10.1016/0305-750X(95)00046-F

28. Roy, R., & Chan, N. W. (2015). Determinants of Sustainable Irrigated and Rainfed Rice Farming in Bangladesh. In J. Agr. Sci. Tech (Vol. 17).

29. Sharma, T., Litoria, P. K., Bajwa, B. S., & Kaur, I. (2021). Appraisal of groundwater quality and associated risks in Mansa district (Punjab, India). Environmental Monitoring and Assessment, 193(4), 159. https://doi.org/10.1007/s10661-021-08892-8

30. Singh, A., Sharma, C. S., Jeyaseelan, A. T., & Chowdary, V. M. (2015). Spatio–temporal analysis of groundwater resources in Jalandhar district of Punjab state, India. Sustainable Water Resources Management, 1(3). https://doi.org/10.1007/s40899-015-0022-7

31. Singh, S. P., Priya, & Sajwan, K. (2023). Factors influencing the adoption of organic farming: a case of Middle Ganga River basin, India. Organic Agriculture, 13(2), 193–203. https://doi.org/10.1007/s13165-022-00421-2

32. Sutton, J., & Austin, Z. (2015). Qualitative Research: Data Collection, Analysis, and Management. The Canadian Journal of Hospital Pharmacy, 68(3). https://doi.org/10.4212/cjhp.v68i3.1456

33. Suwanmaneepong, S., Kerdsriserm, C., Iyapunya, K., & Wongtragoon, U. (2020). Farmers' Adoption of Organic Rice Production in Chachoengsao Province, Thailand. Journal of Agricultural Extension, 24(2), 71–79. https://doi.org/10.4314/jae.v24i2.8

34. Vatta, K., & Budhiraja, P. (2020). Challenges of growth and sustainability. In Sustainable Development in India (pp. 160–183). Routledge. https://doi.org/10.4324/9781003036074-10

ISSN: 0970-9045 (Print)

35. Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What is sustainable agriculture? A systematic review. In Sustainability (Switzerland) (Vol. 7, Issue 6, pp. 7833–7865). MDPI. https://doi.org/10.3390/su7067833

36. Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. In Agronomy for Sustainable Development (Vol. 34, Issue 1, pp. 1–20). EDP Sciences. https://doi.org/10.1007/s13593-013-0180-7