High-Value Agriculture:

Potential in Punjab Through Use of Climate Smart Technology

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Abstract

This study explores the potential of high-value agriculture (HVA) in Punjab, Pakistan, specifically focusing on its development through climate-smart technology. The research aims to assess the adoption of climate-smart agriculture practices among farmers and investigate the impact of climate change on crop yields, with specific emphasis on high-value agriculture. Interviews with 49 farmers provide valuable insights into demographics, farming specifics, cropping patterns, and observed effects of climate change. The results show that middle-aged farmers having land ownership and significant experience are more convinced to adopt climate-smart practices. The agricultural landscape of Punjab is predominantly comprised of field crops like sugarcane, rice, and wheat. However, climate change events, like erratic rainfalls and heat waves, pose significant challenges for agriculture in general and for high-value agriculture in particular. This situation has resulted in reduced yields due to increased pest attacks. Similarly, compromised water availability has also posed threats to the livelihood of the farming community.

This study draws attention towards the importance of implementing climate-smart practices for addressal of these challenges in Punjab's agriculture sector. This includes improved irrigation techniques like drip irrigation and precision water management which can optimize water use efficiency. Additionally, development and promotion of resilient crop varieties that can better withstand climate stressors and ensure sustainable agriculture in the face of changing climatic conditions. Moreover, the study emphasizes the dire need to enhance the intellectual capacity of farmers'

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knowledge through training programs and specialized extension services. The farmers need to be provided with access to real-time climate information and early warning systems which can help them in making informed decisions regarding crop selection, adjusted sowing times and better input management. The results accentuate the importance of policy frameworks and investment in climate-smart agriculture initiatives. Government interventions play a crucial role in promoting the adoption of climate-smart technologies by providing subsidies, easy access to credit, crop insurance and supportive infrastructure. Collective efforts by all stakeholders including policymakers, researchers, agricultural extension agencies and farming community are essential to enhance the adoption of climate-smart practices across Punjab.

In conclusion, this study emphasizes the vital role of adopting climate-smart technologies to mitigate the adverse effects of climate change on Punjab's agriculture, particularly in the high-value agriculture sector. By implementing resilient crop varieties, improving irrigation practices, and enhancing farmers' knowledge, Punjab can enhance agricultural productivity, strengthen farmers' resilience, and foster sustainable development in the HVA sector.

Keywords: *Climate Smart Agriculture, Gross Domestic Product, Food and Agriculture Organization, Global Climate Risk Index, World Trade Organization.*

1. Introduction

Climate change is one of the most threatening global issues of this century. The 2020 Global Risks Report of the World Economic Forum has unequivocally considered climate-related disasters as the most threatening global risk. From the bushfire incident in Australia to water shortage issues in Asia and Africa, virtually every event is linked with climate change, hence, almost every part of the world is facing significant socio-economic damages due to climate change.

In Pakistan, Agriculture is the mainstay of national economy as it holds 19% share of the GDP and is providing employment to 48% of the population. Furthermore, this sector significantly contributes in provision of raw materials to major industries like rice processing, sugar, textile, edible oil and various food processing industries. Overall, Agriculture Sector is contributing three fourth share in Pakistan's total export, out of which 60% is being provided by Punjab.

High Value Agriculture (HVA) refers to the cultivation of crops that have a higher market value, such as fruits, vegetables, horticultural products, and non-traditional agricultural commodities. Punjab is the major contributor of National HVA Production with average share of 64-66% in most of the

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horticulture product categories. During 2021, Punjab's total horticultural production was 10 million tons. Citrus and mango are the two main contributors in Punjab's total fruit production. Punjab's share in national vegetable production (excluding potatoes) pitched at 70.7% (MNFS&R, 2023). Hence Punjab is playing lead role in producing High Value Crops in Pakistan. Even though HVA give good returns in market these crops are more vulnerable to adverse effects of climate change as compared to other traditional crops.

Punjab Agriculture Department is the biggest stakeholder of Agriculture Sector after farming community. It consists of 20 attached departments including 06 Directorate Generals (Extension, Research, Water Management, Mechanization, Pest Waring and Soil Survey), academia (03 agricultural universities). Hence Punjab Agriculture Department is a complete department having an organizational structure which supports the exploration and development of new technologies along with promotion of these developments in farming community through subsidies and other incentives. Moreover, Agriculture Department has capacity to expand the canvas of provincial agriculture through horizontal (Area Expansion) and vertical (Productivity Enhancement) approaches.

During last 10 years there has been observed significant allocation of resources by Punjab Government through Agriculture Department in the areas of Climate Smart Agriculture for improvement and promotion of High Value Agriculture in Punjab. It is pertinent to mention here that Climate-smart agriculture (CSA) refers to a set of practices, technologies, and approaches in the field of agriculture that aim to sustainably increase productivity and resilience while reducing greenhouse gas emissions and adapting to the impacts of climate change. The concept of climate-smart agriculture emerged as a response to the challenges posed by climate change on agricultural systems and the need to ensure food security in the face of changing climatic conditions. The major areas of investment were enhancement of water use efficiency, subsidized high efficiency irrigation systems, laser land leveling, reduction in post-harvest losses, promotion of high value crops like Sesame, Sunflower, vegetables, pulses, dates, citrus and olives etc, development of climate resilient crop varieties and diversification of cropping patterns.

Table 1.
Total Investment in Climate Smart HVA by the Provincial Agriculture department

Year	Total Funds allocation for Agriculture development (billion)	Funds allocated for CSA- HVA (billion)	%age share
2013-14	5.27	4.93	93%
2014-15	6.41	4.95	77%

| Year	Total Funds allocation for Agriculture development (billion)	Funds allocated for CSA- HVA (billion)	%age share
2015-16	6.53	4.89	75%
2016-17	9.29	6.60	71%
2017-18	7.97	5.23	66%
2018-19	9.43	8.39	89%
2019-20	10.25	7.95	78%
2020-21	15.00	11.30	75%
2021-22	25.20	17.46	69%
2022-23	14.70	10.00	68%
Total	**110.05**	**81.69**	**74%**

*Source: Punjab Agriculture Department*

Figure 1.

Year-wise area under High Value Agriculture in Punjab
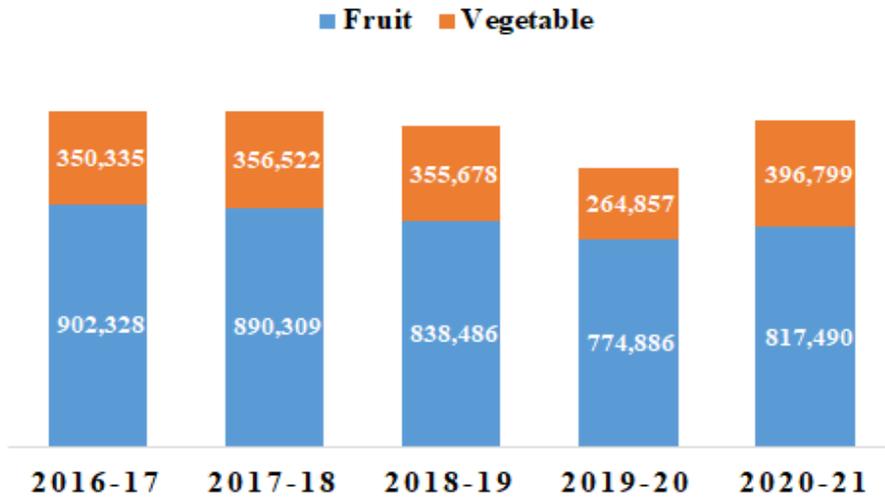
The data of area (Figure 1) and production (Figure 2) of high value crops suggests that the area under HVA remained stagnant, but productions of different HVA crops improved which depicting those interventions helped in improving crop productivity in terms of yield but still could not gain confidence of farming community, hence area under HVA could not be enhanced.

Figure 2.
Production of Different High Value Crops during 2012 to 2021 in Punjab
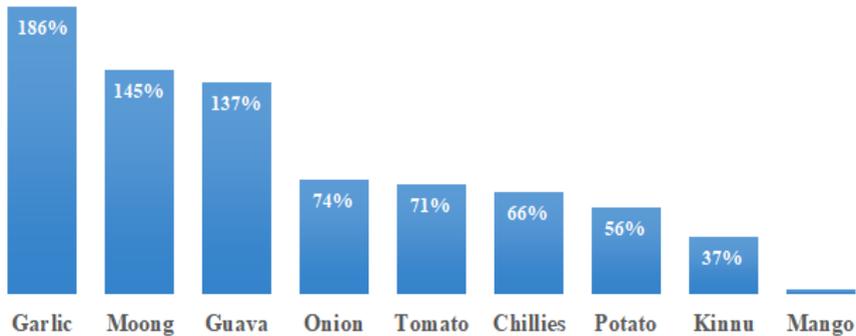
Further examination suggests that Government of the Punjab focused on CSA practices relevant to HVA in Punjab. In the wake of emerging challenges like climate change, food security, environmental issues and water scarcity, the current situation demands continuity of the ongoing efforts for enhancing water productivity through improved irrigation practices at farm level. Horizontal and vertical development of HVA can be achieved through integrated approach based on adopting and promoting the highly efficient modern conservation technologies.

1.1. Statement of the Problem

High-value agriculture contributes around 2-4 % of the total agricultural GDP of Pakistan. Since the last decade, the agriculture sector in the province of Punjab has been facing the challenges of climate change and the adoption of modern climate-smart techniques. The government of Punjab has been focusing on HVA and climate-smart agriculture for a decade now, as 74% of the development budget of the Agriculture Department in the last ten years (Rs. 81 billion) has been invested in promoting climate-smart agriculture. However, despite this investment and alignment of agriculture with SDGs such as poverty eradication, food security and sustainable economic development, HVA growth in Punjab remains insufficient.

- What are the significant challenges impeding the successful promotion of High-Value Agriculture in Punjab?

- How can farmers' adoption level for climate-smart technologies be enhanced to improve the growth of high-value agriculture?

1.2. Significance and Scope of the Study

Punjab Government has been trying to transform the agriculture sector by imparting more focus on HVA as 74% of development budget of Agriculture

Department pertaining to last ten years (Rs. 81 billion) has been invested in promotion of Climate Smart Agriculture practices to enhance the production of HVA crops. However, it is quite evident the growth rate of HVA is still not overwhelming in Punjab Province despite of efforts made by the Government. The scope of instant study is limited to HVA crops and climate smart technologies in province of Punjab. Moreover, it aims to identify the gaps regarding adoption of CSA practices to boost the growth of HVA crops. Moreover, the components of this study are to identify gaps at level of policy, farmers, and other stakeholder to boost the growth of HVA crops. The overall objective of the project is to document the causes of stagnant growth of HVA and to conclude recommendations for sustainable HVA system in Punjab by adopting climate smart techniques.

2. Literature Review

Available scholarly research on the use of Climate Smart Agriculture (CSA) practices in improving production system of High Value Agriculture (HVA) is reviewed in this section. It will also look at the existing research on effects of climate change on global agriculture. The review of literature will look at the mitigation strategies devised by different scholars in studying the relationship between CSA and HVA under the current situation of climate change and insights taken from such studies to develop a framework of literature analysis that best relates to this research paper. The strategies and interventions adopted by the Punjab Government in last decade along with the hindrances faced by farmers in adoption of CSA practices for high value production will also be reviewed in this section. Literature review section will help in devising a strategy to significantly improve the growth rate of HVA in Punjab and Pakistan while shedding light on the innovations it encompasses.

Predominantly Pakistan is an agricultural economy but most of the governments could not be able to provide the sector with a suitable environment where it can take off at its original potential. Small & marginalized farming community of Pakistan faces huge challenges in competing with the farmers around the world due to lack of access to latest knowledge and modern technology to understand and mitigate the direct effects of climate change on farming in general and on HVA in particular. The focus of Government policies has been shifted towards HVA and CSA in Pakistan and Punjab (Punjab Agriculture Department), which is evident from design of Annual Development Programs since 2011-12. The positive relationship between HVA production and adoption of CSA practices has been well established and stressed in multiple studies (Bhattacharjee, 2022; Seppelt, 2022). But the farmer adoption levels and development of other stakeholders remains at lower level despite of the potential of Punjab and Pakistan for production of high value crops like vegetables, fruits, flowers etc. (Tanti, 2022)

Hence, agriculture sector of Pakistan needs focused investments in research &

development, infrastructure, technology and good quality inputs. In the absence of an efficient, productive and market-based agriculture sector, Pakistan faces food-security threat. The major component in attaining this paradigm shift from traditional agriculture to high value agriculture is the availability of knowledge and technology within the buying power of the farming community. This environment of availability of knowledge and technology at the door-step of farming community is need of hour.

2.1. Variation in Climate Change Indicators and Their Effect on High Value Agriculture

There are multiple environmental conditions relevant to agricultural production which are directly being affected by Climate Change (Seppelt, 2022). Analysis of increase in global temperature showed that the duration of agricultural droughts has been increased by 22% and also became more common (+51%), and there are considerable evidences regarding increase in droughts during 1981–2010 (Arnell, 2019). The landscape of Agriculture is also changing as there is potential increase observed in agricultural land under rising temperatures, like maize in Europe and North America can be expected to increase up to 20% in cultivated area. On the other hand, South America, Oceania and Africa are expected to lose cultivated area up to 40% (Ramirez-Cabral, 2017). Such increase in temperature results in the loss of soil carbon (30%), which is a main component of maintenance of soil fertility (Crowther,2016). Moreover, the increase of such events of rising temperatures leads to more frequent crop failures, as the frequency of heat waves can increase by more than 97% (Arnell, 2019). However, based on modelling techniques it has been found that 7-18% of the agricultural yield loss can be prevented simply by adjusting the sowing dates of available varieties (Deryang, 2011). On the other hand, high value crops (vegetables, legumes, and fruits) can face yield loss up to 9% due to increased ozone concentrations, up to 35% due to water scarcity, and up to 32% due to rise in temperature (+4 ℃) (Scheelbeek, 2020). Further these crops depend on pollination, which is at risk because of shifts in flowering times and insect dynamics induced by changing temperatures.

The impacts of climate change are highly variable with respect to location and different climatic zones all over the world. But, some of the trends and challenges are observed to be common. A brief overview of the potential impacts of global climate change on high-value agriculture is given as under;

a. Varying Cropping Seasons: Climate change can cause to change the duration of growing seasons which results in adverse effects on crop productivity. Average temperature changes and variable rainfall patterns can disturb the optimal conditions which are very crucial for high-value crops, and this situation ultimately leads to shifts in sowing and harvesting times. The report of Inter-Governmental Panel on Climate Change (IPCC)

elaborated the details of impacts of climate change on agriculture and crops.

b. Irrigation Water Availability**:** The changes in rainfall patterns and frequent droughts can impact water availability for high-value agriculture. These patterns affect on-farm irrigation practices and water management strategies.

c. Extreme Weather Events: It is quite evident that increased intensity and frequency of extreme weather events such as storms, heatwaves, and heavy rainfall are due to global climate change. These events can have damaging impacts on high-value agriculture ultimately leading to crop damage and yield losses.

d. Market Volatility and Trade: The World Trade Organization (WTO) publication titled "The Impact of Climate Change on World Agriculture" describes that impacts of climate change can influence global market dynamics through uncertainties in the global trade of high-value\ agricultural commodities. Changes in crop yields, product quality and its availability due to climate change can affect market prices and trade patterns.

3. Research Methodology

In order to develop the correct methodology and tools required to conduct this study, the material shared by Agriculture Department, International and National journals, reports were carefully studied. The set of evaluation questions provided in the scope were considered, refined and categorized according to evaluation criteria. To collect information for all of these components, the following set of tools was utilized:

- Key Informant interviews
- Focus Group consultative session
- Primary and secondary data

3.1. Individual interviews

Individual interviews are a qualitative research method that was used to gather in-depth information from the practicing farmers (being major stakeholder) and their experiences on climate smart- High Value Agriculture. Unlike focus group discussions, individual interviews provide a private and confidential setting for participants to express their views without the influence of others.

3.2. Prepare the Questionnaires

Preparing questionnaires for data collection involves careful planning and attention to detail. Accordingly, following steps were considered at the time of

preparing questionnaires. A well-designed questionnaire was created to collect the necessary data effectively and accurately for identification of potential of High Value Agriculture (HVA) in the Punjab through use of Climate Smart Technology implemented in agriculture sector at farmers' field level.

3.3. Data Sampling

To draw a sample of activities for collection of portal data for the assessment of potential and impact of climate change, simple random sampling technique was used by giving equal opportunity to all the beneficiaries. A data list of 950 HVA farmers was obtained from the Agriculture Department. Sample sites were selected by counting the number falling immediately after random interval from the list of beneficiaries. Lottery method was used to pick the first beneficiary. The list was used for selection and identification as candidate sample to evaluate the resultant benefits of the project intervention for studying the climate smart agriculture interventions. Benchmark/baseline information was used as reference to compare with the information by collecting portal data and comparing the new values with the old ones leading to conclude impact of the project intervention.

- Consolidated the list and arranged in ascending order with regards to date of subsidy.

- Randomized sampling procedure was adopted at 95% confidence level and 5% acceptable margin of error using statistical approach representing each district.

- First sample was selected through lucky draw method and rest of the samples were selected at a proper interval (avg.).

3.4. Data Analysis and Report Writing

A detail data analysis was conducted on the data being collected during the survey through questionnaire. Analyzed outcomes of the questionnaire determined the success of the climate smart interventions. Sound survey data analysis is key to getting the information for make better decisions.

3.5. Interview Method

After finalization of questionnaires and data sampling, the assessment survey was conducted in almost twenty-four districts of the Punjab, covering almost all agro-ecological zones of Punjab. Interview of the sampled project beneficiaries / farmers who have adopted high value agriculture (HVA) with & without climate smart agriculture (CSA) was recorded through telephonic and google forms. (Annex- 1).

3.6. Focus Group Discussion

Focus Group Discussion (FGD) is a qualitative research method that involves

bringing together a small group of participants to discuss a specific topic or issue of interest. It was used to gather in-depth insights, opinions, and experiences from researcher and academia in a structured and interactive setting for climate smart High Value agriculture. Focus group discussions provided rich qualitative data that complements other research methods. They are particularly useful for exploring perceptions, attitudes, preferences, and experiences related to a climate smart agriculture practice being conducted in Punjab.

Table 2.
Focus group discussion methodology adopted during research

Sr. No	Group Discussion	Detail
1	Institute:	Participant: AARI, UAF, CRI, OFWM
2	Agenda:	• Current major challenges hindering the promotion of High Value Agriculture in Punjab • Potential and opportunities to promote high value agriculture in Punjab using Climate Smart Technology
3	Opening Remarks:	• To discuss and identify the key challenges under high value agriculture in Punjab, Pakistan. This discussion will make an important milestone in our ongoing efforts to enhance agricultural practices and unlock the full potential due to climate scenario in Punjab.
4	Panel Discussions:	• Global Climate Smart Technology practices and key issues of Climate smart technology adoption by the Punjab farmers
5	Interactive Discussions:	• Following tools are adopted for interactive discussion with Participants Encouraging Participation, Open and Respectful Dialogue, Facilitating Group Dynamics, Probing Questions, Active Moderation and Documenting Key Insights:
6	Brainstorming and Recommendations:	• Set clear Objectives • Create a Safe and Non-Judgmental Environment: • Encourage Quantity and Diversity of Ideas • Refine and Develop Recommendations

Sr. No	Group Discussion	Detail
7	Wrap-up and Next Steps	• Identification of Key Challenges in HVA • Innovative Solutions to promote the CSA-HVA • Policy and Regulatory Framework required • Collaboration and Partnerships with other countries and institutions • Capacity Building of farmers

4. Analysis and Findings

4.1. Climate Change Scenario in Relevant Policy Documents

4.1.1. Policy Review

Policy review in Climate-Smart High-Value Agriculture (HVA) involves assessing existing policies and frameworks specifically tailored to promote and support CSA practices in the HVA sector. The findings and recommendations of the policy review can inform the development or revision of policies, strategies, and programs to create an enabling environment for promoting climate-smart practices in high-value agriculture.

Table 3.
Review of National & Provincial Policies in terms of Climate Smart Agriculture

Sr. No.	Name of Policy Document	Publishing Organization	Key Recommendations
National Policy Documents			
1	Report on Food Securiy by Task Force 2009	Planning Commission of Pakistan	• Drip irrigation for high value horticulture crops such as citrus, apples, mango, grapes and fruits in selected areas. • Achieving the objectives of the Strategy will be expensive. It will require major investment initiatives on the part of the government. Financing will need to be derived from government reserves, foreign borrowing and investment by the private sector.
2	National Climate	Ministry of Climate Change,	• Improve crop productivity by enhancing water use efficiency

Sr. No.	Name of Policy Document	Publishing Organization	Key Recommendations
	Change Policy, 2012	Pakistan	• Develop simulation models for assessment of impacts induced due to climate change on different aspects of agricultural production systems
			• Adopt modern farming techniques such as laser land levelling
3	Framework for Climate Change Policy (2014 - 2030)	Ministry of Climate Change, Pakistan	• Drive 'farmers' awareness' campaigns to sensitize local farmers regarding importance of climate smart Agriculture
			• Support agriculture research system to identify the cropping mix package that would be most suited to that area under new vulnerabilities.
			• Facilitate technology transfer of climate smart technology to small farmers through subsidy programs.
			• Research on innovative techniques for farming systems and their promotion
4	Pakistan Vision 2025 (2015)	Minister for Planning Development & Special Initiatives/ Planning Commission of Pakistan	• Promotion of long-term sustainability, conservation and protection of natural resources.
			• Invest in proven methods and technologies to minimize wastage (e.g. in the agricultural sector), promote conservation and gain efficiencies through rationalization of pricing
			• Optimization of production and supply as per current and projected needs
5	Sustainable Development Goals (SDGs) 2030 (2016)	United Nations (UN)	• SDG-2: Agricultural Productivity
			• Indicator 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land,
			• Indicator 2.4: By 2030, ensure sustainable food production systems

Sr. No.	Name of Policy Document	Publishing Organization	Key Recommendations
			and implement resilient agricultural practices that increase productivity and production,
			• number of people suffering from water scarcity. SDG-13: Climate Action
			• SDG-13: Climate Action
			• Indicator 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
6	National Water Policy, 2018	Ministry of Water Resources, Pakistan (approved by CCI)	• Investment of Rs. 800 billion in conservation measures like lining of distributaries and minors, HEIS Projects, improvement of conveyance efficiency and telemetric monitoring
Provincial Policy Documents			
7	Punjab Growth Strategy 2018	Planning & Development Board (P&DB) Punjab	• On farm water conservation through promotion of HEIS such as drip and sprinkler systems
			• Inefficient use of water is one of the major issues confronting the agriculture sector. Irrigation system is inefficient and has large losses in every component of the delivery system across Punjab and Pakistan
8	Punjab Agriculture Policy 2018	Punjab Agriculture Department	• Consistent efforts for efficient use of water, crop diversification and promotion of high value crops
			• Increase farmer profitability by reducing cost of inputs
			• Diverting funds to high priority areas like climate smart agriculture and promotion of high value
			• Helping farmers to adopt climate-friendly practices without sacrificing productivity to mitigate the effects of climate change by reducing GHG emissions
9	Punjab Growth Strategy	Planning & Development Board (P&DB)	• Key investment areas in the agriculture sector are Drip Irrigation

Sr. No.	Name of Policy Document	Publishing Organization	Key Recommendations
	2023	Punjab	and Fruits and Vegetables production
			• Re-designing of agro-ecological zones redesigning will help farmers to grow the suitable crops in their areas.
			• The farmers of the province will have to use the available water more productively – 'more crop per drop' will have to be the strategy going forward

The policy review outcome in climate-smart high-value agriculture can lead to several positive impacts and improvements in the agriculture sector with respect to climate change scenario. Some of the key outcomes that can be expected from a policy review are:

a) Policy Alignment with Climate Goals: The policy review reveals that the existing agricultural policies align with national and international climate goals, such as the Paris Agreement but it is required to make policy adjustments to prioritize climate-smart high-value agriculture and integrate climate change adaptation and mitigation strategies into agricultural planning.

b) Increased Investment Opportunities: It has been highlighted that the importance of climate-smart high-value agriculture and increased investment is needed. Public and private sector stakeholders may recognize the potential for sustainable growth and improved resilience in agriculture and may allocate more resources to support research, technology adoption, capacity building, and infrastructure development in this sector.

c) Promotion of Modern Climate-Smart Technologies: It has been learnt that the promotion of climate-smart technologies in high-value agriculture includes efficient irrigation systems, precision farming techniques and remote sensing technologies to enhance productivity, climate resilience and resource efficiency. Frameworks can be designed to incentivize the adoption of these technologies through subsidies, technical support and capacity-building programs. The extension services to enhance knowledge base and on-farm skills relevant to climate-smart high-value agriculture. In this regard frameworks can be developed to formulate training programs, modules, workshops and demonstration farms to educate farmers about sustainable practices, climate change adaptation strategies and the cultivation of high-value crops. Further there is strong need to build the capacity of local industry to manufacture indigenized equipment and parts.

d) Policy Integration and Coordination: It has also been identified that there is considerable need for better coordination between relevant agencies of public and private sector involved in agriculture, rural development and climate change. Policies can be formulated to improve collaboration in sharing of existing data and knowledge and joint futuristic planning to design an inclusive strategy for growth of climate-smart high-value agriculture. This can lead towards streamlining of existing regulations, effective implementation of policy recommendations and better governance in the agricultural sector.

Hence, a policy review in the field of climate-smart high-value agriculture can help in developing improved policy frameworks, promotion of latest technology, higher investments, improved farmer knowledge base, better marketing facilities and a coordinated system among all stakeholders i,e government, farmers, private sector, researchers, academia, traders, importers and exporters etc. These outcomes can contribute to the sustainable transformation of agriculture, addressing climate change challenges, and unlocking the potential for high-value agricultural practices.

4.2. Situational Analysis

Interview of the sampled beneficiaries/ farmers who have adopted high value agriculture (HVA) with & without climate smart agriculture (CSA) was recorded through different methods like telephonic conversations and face to face meetings. During finalization of questionnaires, demographic questions were included for gathering basic information about the characteristics of the respondents. Demographic questions typically cover factors such as age, gender, education level, occupation, and geographic location. The representation of the respondent covers all Agro-Ecological zone of the Punjab.

Table 4.
District wise representation of HVA sample farmers

Sr. No.	District	No. of Respondents	Sr. No.	District	No. of Respondents
1	Attock	5	13	Layyah	2
2	Rawalpindi	1	14	Multan	2
3	Chakwal	7	15	Lodhran	1
4	Sargodha	2	16	Kasur	1
5	Khushab	1	17	Pakpattan	1
6	Bhakkar	3	18	Sahiwal	1
7	Faisalabad	1	19	Khanewal	2
8	Jhang	2	20	Bahawalnagar	1

Sr. No.	District	No. of Respondents	Sr. No.	District	No. of Respondents
9	Okara	5	21	Gujranwala	2
10	Pakpattan	1	22	Jhelum	1
11	Gujrat	3	23	Toba Tek Singh	2
12	MB Din	1	24	Nankana Sahib	1
Total					**49**

The following data collected from interviews conducted with above mentioned 49 farmers regarding the adoption of high-value agriculture through climate-smart agriculture provides valuable insights into the demographics and characteristics of the respondents:

Table 5.
Demographic information of the respondent

Sr. No.	Age (Years)	No. of Respondent	%age
1	up to 20	0	**0%**
2	21-30	3	**6%**
3	31-40	18	**37%**
4	41-50	14	**29%**
5	51-60	11	**22%**
6	61-70	3	**6%**
	Total	**49**	

Examining the age distribution of the respondents, the data reveals that 37% of the farmers surveyed fell within the age range of 31-40 years, while 29% of the respondents were aged between 41-50 years. Therefore, the highest portion of the respondents (66%) falls under the category of 31-50 years age bracket. These results suggest that the middle-aged farmers represent the majority of the sample population and are likely to play an important role in the adoption of high-value agriculture practices.

Furthermore, the data suggests that there is a normal distribution pattern in age distribution within the sample population. Hence, the majority of the respondents of sample population cluster around the average age, indicating that the farmers surveyed represent a diverse range of ages and experiences. Different age groups may exhibit varying levels of adoption for latest

technologies and farming practices. As the maximum farmers falling within the range of 31-50 years age, hence this age group is more prone towards innovation and convinced to adopt climate-smart agriculture practices. Another important aspect highlighted in the data is the literacy level which was categorized as middle of the majority farmers. Though, it becomes important to consider other demographic factors like access to resources, socio-economic status as these factors can also influence the farmers' decision-making process (Diaz et al., 2022).

4.2.1. Farming Particulars

The data regarding farming experience of the respondents was also collected which includes information about types of farming and the size of their farms.

Table 6.
Experience of the farmers in practicing High Value crops

Sr. No.	Farming Experience (Years)	No. of Respondent	%age
1	0 to 5	2	4%
2	6 to 10	10	20%
3	11 to 15	7	14%
4	16 to 20	11	22%
5	21 to 25	3	6%
6	26 to 30	5	10%
7	More than 30	11	22%
	Total	**49**	

The abovementioned results indicate that all 49 respondents were experienced with hands-on knowledge in agriculture. The significant majority (96%) of the respondents had more than 5 years of experience. Further, 11 respondents had more than 30 years of farming experience which suggests that the sample population was consisted of highly experienced farmers. Hence, the sample population represents a diverse mix of farmers with varying levels of expertise.

The analysis also revealed that 70% of the respondents, were owners of their farms with ownership of more than 12.5 acres of land. This finding suggests that a majority of the surveyed farmers have larger landholdings, it reveals that HVA is adopted by the farmers having larger farm sizes, whereas, according to the Agricultural Census 2010, there 3.35 million (out of total 5.25 million farms) agriculture farms in Punjab.

Furthermore, the data regarding nature of cultivation, particularly mode of irrigation (Canal irrigated or rainfed (barani)), revealed that 38 respondents had land in irrigated areas, while 3 respondents had rainfed land. However, 8

respondents reported to have both irrigated and rainfed options available. It reveals that irrigated area farmers have more interest towards HVA at their Farms. Whereas, the total irrigated area of the Punjab is 27.2 million acre as under (Punjab Agriculture Department).

Table 7.
Experience of the farmers in practicing High Value crops

Size of Farm (acres)	No. of Farms (million)	Percentage of farms	Farm Area (million acre)	Percentage of Area
under 1.0 to under 5acre	3.35	64%	6.51	22%
5 acres to under 12.5	1.41	27%	10.48	36%
12.5 acre & above	0.49	9%	12.34	42%
Total	**5.25**	**100**	**29.33**	**100**

Figure 2.
Land Use Distribution of Punjab
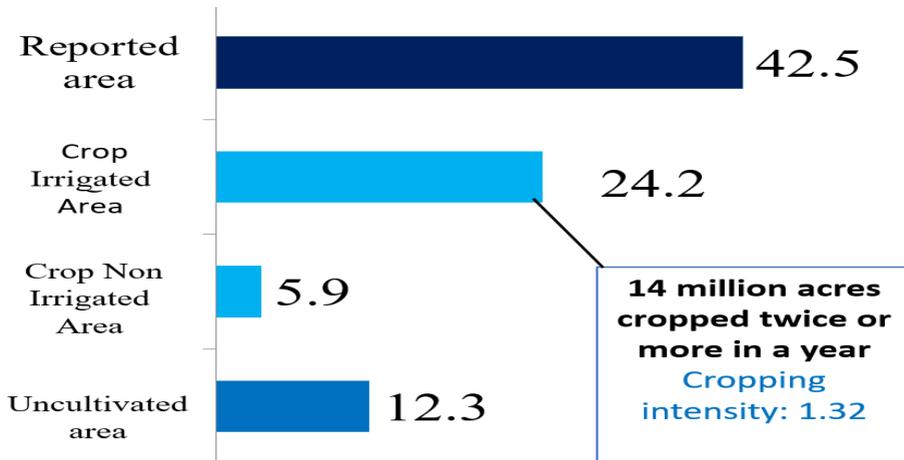
The data on farming experience, land ownership, and the nature of cultivation helps presents the situation in a more comprehensive manner regarding agricultural backgrounds and expertise of the sample farmers. This information is very important for understanding the context within which the farmers live and make the decisions regarding adoption of high-value agriculture practices. Experienced farmers with larger landholdings may be in better position to implement new technologies, while the diversity in cultivation types suggests that there is a considerable need for tailor made

approaches for climate-smart agriculture based on specific on-site environmental conditions and available resources.

4.2.2. Cropping Pattern

Cropping patterns play a vital role in agricultural systems as they can be highly dynamic and influenced by different factors such as climate change, on-going market demands, farmer interests and government policies. The selection of a suitable cropping pattern involves seeking a balance between profitability and productivity, risk management, sustainability and goals of the particular farming system.

The data highlights the cropping patterns adopted by the respondent farmers. Most of the farmers (53%) focused on cultivating major field crops such as wheat, rice, and sugarcane. The three major crops are wheat, cotton, and rice—used around two thirds of Punjab's total cultivated land (Punjab Agriculture Sector Profile -2018). In Pakistan and particularly Punjab, these crops are linked with staple food production hence having higher and sustainable market demands, which makes them economically suitable. Hence, the dominance of field crops among the surveyed farmers highlights the preference for traditional agriculture and lesser risks for marketing aspects.

Table 8.
Cropping pattern adopted by the Respondent

| Sr. No.	Type of Cropping Pattern	No. of Farmers	%age
1	Field Crop	11	22%
2	Major Crop	15	31%
3	Vegetables	5	10%
4	Orchard	5	10%
5	Vegetable-Field Crop	2	4%
6	Orchard-Field Crops	1	2%
7	Major Crops-Vegetables	2	4%
8	Orchard- Major Crops	8	16%
	Total	**49**	

It is important to recognize that cropping patterns are not fixed and can change over time. Market demands and consumer preferences can shift, and government policies or incentives may also influence farmers' choices. Climate change is another crucial factor that can impact cropping patterns, as farmers may need to adapt their practices to cope with changing weather patterns, water availability, or pest and disease pressures.

To optimize cropping patterns, it is essential to consider a range of factors, including market dynamics, environmental sustainability, and the socio-economic context. Encouraging diversification in cropping patterns, such as promoting vegetable production, can offer several benefits, including improved nutrition, income diversification, and reduced vulnerability to market fluctuations.

Figure 3.
Crop Area as Percent of Total Cropped Area (Agri Census 2010)
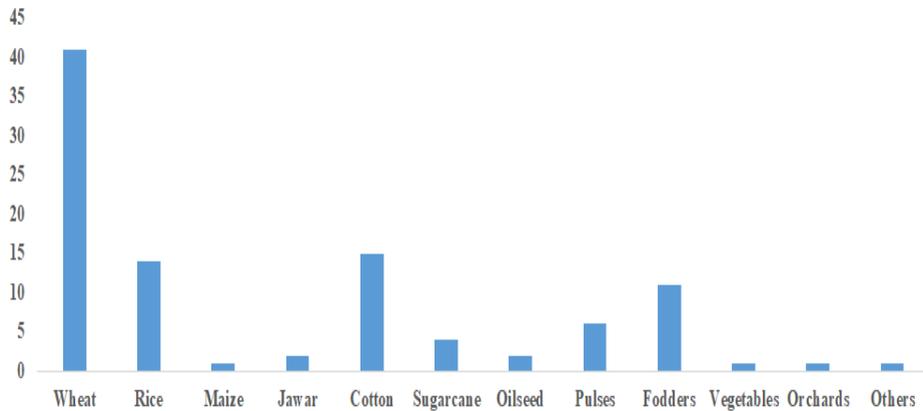
4.2.3. Crop Affected by Climate Change

The data presented below shows that climate change imparts a significant impact on the agricultural activities and crops performance of surveyed farmers as all of them reported to experience some level of impact on their crops and livestock.

Table 9.
Percentage Distribution of Climate Factors Affecting Crop Growth

Factors Impacted the Crop	% of Respondents
Heat Wave	45
Uneven Rainfall	27
Pest Attack	10
Onset of Summer & Winter	18

Among the climate change events reported by the farmers, heat waves were found to be the most dominant, affecting 45% of the respondents. Heat waves can lead to reduced yields due to increased crop stress which imparts adverse effects on crop health and productivity. Irregular and uneven rainfall was identified as another important climate change event which was reported to

affect 27% of the farmers. Uneven rainfall patterns can hinder crop growth, disturb sowing and harvesting times and can also increase the risk of water related problems like flooding or shortage at particular crop growth stage.

The data highlights the varied range of response of farming indicators by climate change events as experienced by the farmers which clearly suggests that there is a dire need for resilience-building measures and adaptive strategies. As far as climate change continually poses challenges to agricultural systems, it is required to develop and implement climate-smart agriculture practices that can allow the farming community to mitigate the negative effects and protect their livelihoods by enhancing their resilience.

Climate change adaptation requires a multilayered approach that should consider both farming practices and policy level interventions. Farmers can adopt the mitigating measures like improved on-farm water management techniques, diversified cropping patterns, conservative agriculture, and the selection of climate-resilient crop varieties to counter the negative impacts of heat waves and uneven rainfall. Moreover, policy support and frameworks in the form of crop insurance schemes, access to real-time information regarding climate and access to credit can help farmers in managing risks associated with climate change and building their own adaptive capacity (Schwarze and Sushchenko, 2022). Additionally, collaborations between researchers, policymakers and farmers are very crucial in developing tailored solutions to address issues related to climate change.

4.2.4. Impact of Climate change on Crop Growth

The opinion of farmers regarding impact of climate change was sought in the current study and they reported that following factors are mostly affecting their crops:
- Changes in temperature
- Altered precipitation patterns
- Changing water availability
- Altered pest and disease dynamics
- Changes in growing seasons
- Increased frequency of extreme weather events
- Impact on crop quality and nutritional content

In view of above, the mitigation of adverse impacts of climate change on agricultural crops and future food security requires implementation of adaptation strategies. These strategies encompass the utilization of climate-resilient crop varieties, the adoption of enhanced irrigation methods, and the implementation of sustainable farming practices. Direct, indirect, and socioeconomic implications of climate change on agricultural output are illustrated in figure-5.

Figure 4.
Direct, indirect, and socioeconomic implications of climate change
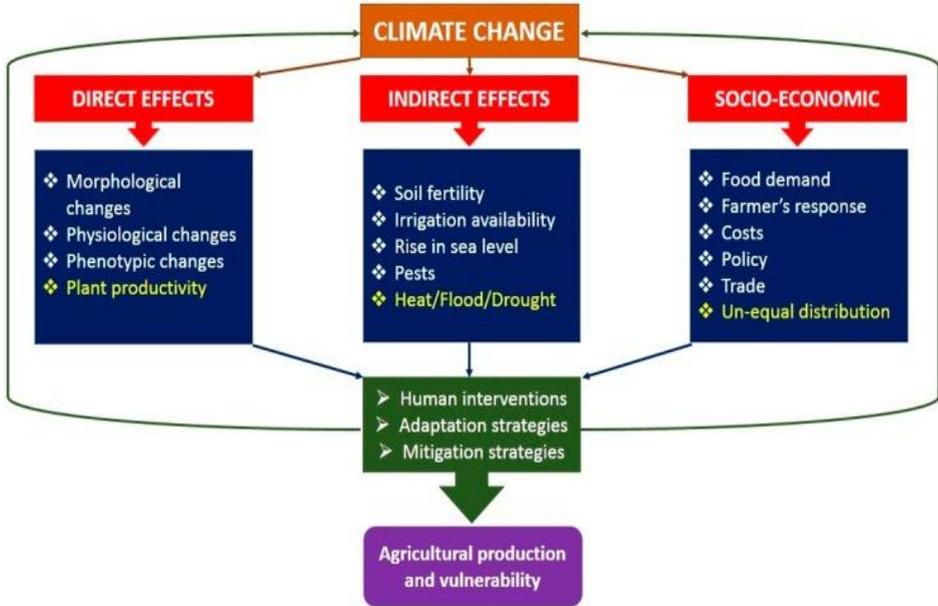
By incorporating these measures, it becomes possible to alleviate the detrimental effects of climate change on agricultural productivity and ensure a stable food supply for the coming years. The data revealed that mostly crops were damaged and reduced their crop yield as shown in the graph below.

4.2.5. Reduction in crop yield due to climate change impact

The respondent farmers were asked about the reduction in crop yield due to extreme weather events and following is the response of the farmers:
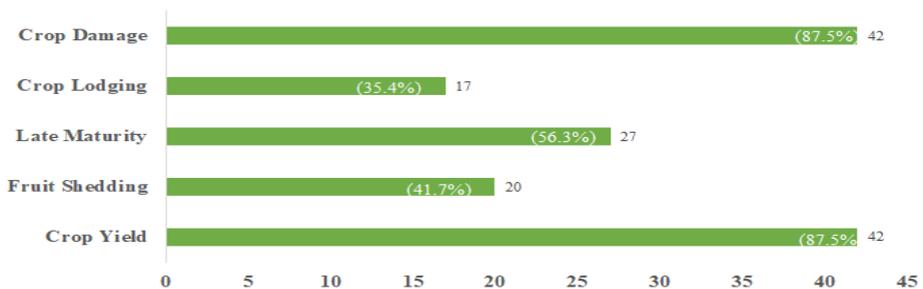
Figure 5.
Impact of Climate Change on Crop

Table 10.
Reduction in crop yield (%)

S. No.	%age	No.
1	0 to 5	1
2	6 to 10	4
3	11 to 15	8
4	16 to 20	11
5	21 to 25	4
6	26 to 30	10
7	30 to 50	10
8	More than 50	1
Total		**49**

Crop yield is a crucial indicator that directly influences the income and financial well-being of farmers. Higher yields provide farmers with more produce to sell, enabling them to meet market demand, negotiate better prices, and increase their income. Conversely, lower crop yields can lead to lower revenues and financial instability for farmers (Giller et al., 2021).

Crop yield is not solely determined by the efforts of farmers in terms of their inputs and management practices. It is significantly influenced by weather and climatic conditions (Ali et al., 2017). Optimal weather conditions, including appropriate temperature and rainfall patterns, are essential for supporting crop growth and ensuring successful pollination, germination, and maturation. Adequate sunlight is necessary for photosynthesis, which enables plants to convert energy into biomass. Similarly, suitable humidity levels contribute to plant health and reduce the risk of diseases and pest infestations. Wind patterns can also impact crop growth, as excessive wind can lead to physical damage or water stress (Heeb et al., 2019).

Given the dependence of crop yield on weather and climatic conditions, farmers face inherent risks and uncertainties in their agricultural practices. Climate change further exacerbates these challenges, as it introduces more extreme and unpredictable weather patterns, making it even more difficult for farmers to predict and manage their crop yields.

Further, data revealed that most of the farmers (40%) think that their crops are being affected by climate change since last 5 to 6 years.

Table 11.
No. of Years of Crops Affected Due to Climate Change

S. No.	Years	No. of Respondents
1	0 to 2	2
2	3 to 4	17
3	5 to 6	20
4	7 to 8	5
5	9 to 10	2
6	11 to 15	2
7	15 to 20	1
Total		**49**

4.2.6. Level of awareness regarding climate change and its impact on agriculture

Raising awareness about the impact of climate change is crucial for encouraging individuals, communities, and governments to take action and mitigate its effects. Data revealed that farmers have 58% less awareness regarding climate and its impact on agriculture

Figure 6.
Level of awareness regarding climate change
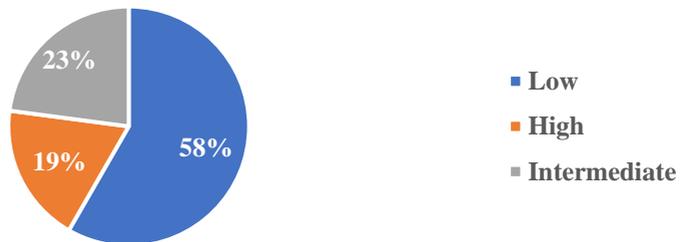
4.2.7. Implementation of Climate-Smart Agriculture Practices at Farm Level

Climate-smart agriculture (CSA) practices refer to a set of agricultural techniques and strategies specifically developed to enhance agricultural productivity, build resilience against climate change impacts, and reduce greenhouse gas emissions. The primary objectives of these practices are to address the triple challenges of ensuring food security, adapting to climate change, and mitigating greenhouse gas emissions. The data presented indicates

that a significant portion, 98% of the farmers surveyed, have adopted climate-smart irrigation technologies, such as drip irrigation systems. Additionally, 51% of the farmers are embracing innovative technologies, 49% are utilizing climate-resilient crop varieties, and 6% are implementing protective cultivation methods, as depicted in the provided table.

Table 12.
Climate Smart Agriculture Practices on Farm

Climate Smart Irrigation Technologies	Innovative Sowing Technologies	Climate resilient varieties	Protective Cultivation
48	25	24	3
98%	51%	49%	6%

A question regarding Management of soil health and fertility to enhance resilience and mitigate climate-related risks was asked from the farmers that either they using organic fertilizer or inorganic fertilizers to improve the soil health. Data revealed that 3 farmers were using organic fertilizer, 10 farmers were using inorganic fertilizer and 36 farmers using both fertilizers for improving soil health.

Table 13.
Soil health and Fertility Enhancement

Organic Fertilizer	Inorganic Fertilizer	Both
3	10	36
6%	20.40%	73.46%

The regime of climate smart agriculture remains incomplete without recognizing the importance of early warning systems in mitigating the consequences of natural disasters and extreme weather events as the same is of paramount importance (Šakić Trogrlić et al., 2022). These systems play a vital role by providing timely information and alerts to individuals, communities, and authorities, enabling them to take proactive measures and minimize potential damages. The data presented demonstrates that 23% of farmers received early warning alerts through SMS messages, 38% through social media platforms, and 48% via weather alerts, thus enhancing their awareness regarding weather patterns and potential pest attacks.

Figure 7:
*Awareness about early warning systems*
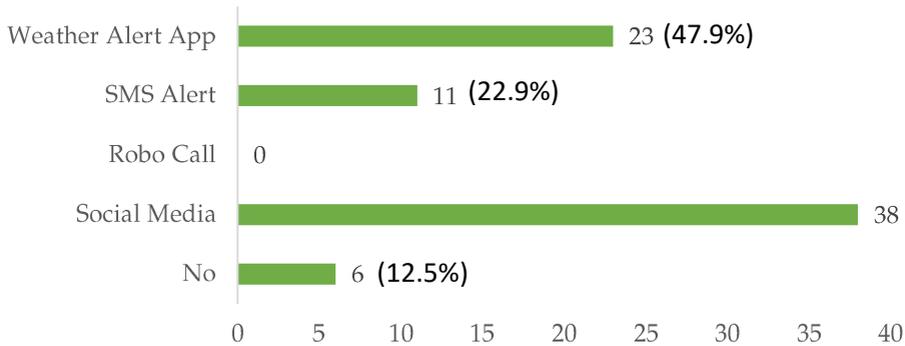
4.2.8. Challenges in Implementation of Climate-Smart Agriculture Practices

Implementing climate-smart agriculture (CSA) practices can face several challenges, which may vary depending on the specific context and region. Following are major challenges which are hindering in implementation:

a) **Limited access to information and knowledge:** Lack of availability or restricted access to resources, data, or educational opportunities that could enhance farmer's understanding is the biggest limitation that can hinder farming community from making informed decisions.

b) **Lack of awareness:** Lack of awareness may prevent farmers from recognizing problems, understanding available resources or taking advantage of opportunities that could improve their problematic situation.

c) **Non availability of CSA technologies:** Non-availability of CSA technologies refers to the absence or limited access to agricultural practices, techniques, or technologies designed to address climate change challenges.

d) **Financial Resources:** Financial resources refer to the funds, capital, or monetary assets available to farmer at the time of critical crop stages.

e) **Poor market system:** A poor market system refers to a situation where the economic system or infrastructure for buying and selling goods and services is inefficient, unreliable, or ineffective. This can include limited market access, lack of competition, inadequate transportation, and distribution networks, leading to difficulties for producers and consumers in trading goods and accessing essential services.

f) **Lack of value chain:** A lack of value chain refers to the absence or underdeveloped series of activities and processes that add value to a

product or service from its production to its final consumption. A robust value chain involves efficient coordination between producers, processors, distributors, and retailers, ensuring that goods or services are delivered to consumers effectively and at competitive prices.

Figure 8.
Major Challenges faced by respondents
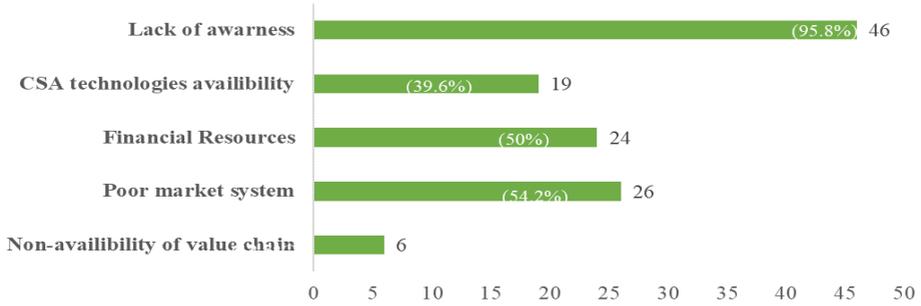
Addressing these challenges requires a multi-faceted approach involving government support, policy reforms, capacity building, financial mechanisms, all stakeholder collaboration and knowledge sharing. Data analysis reveals that 96% lack of awareness, 40% CSA technologies availability, 50% financial resources constraints, 54% poor market systems, and 13% non-availability of value chains are hindrances in implementation of climate-smart agriculture in High Value Agriculture in Punjab.

Figure 9.
Awareness level of respondents regarding CSA
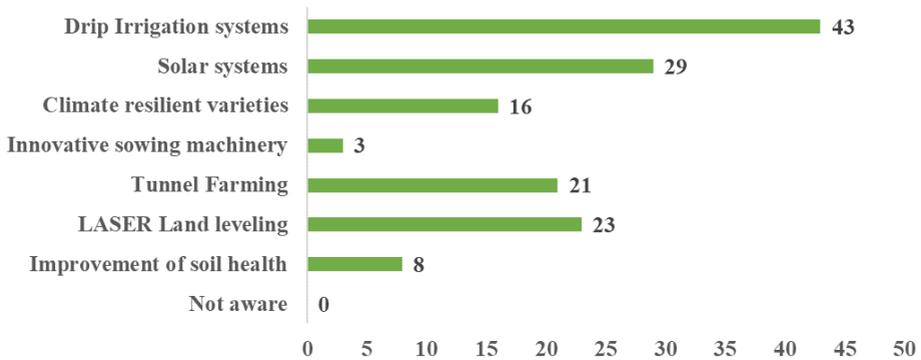
Further examination suggested that awareness level of farmers regarding CSA is strong regarding those CSA practices related to water availability like drip irrigation and laser land levelling, but awareness level regarding other practices like climate resilient varieties, new sowing techniques is very low.

Figure 10.
Major sources of information available for respondents
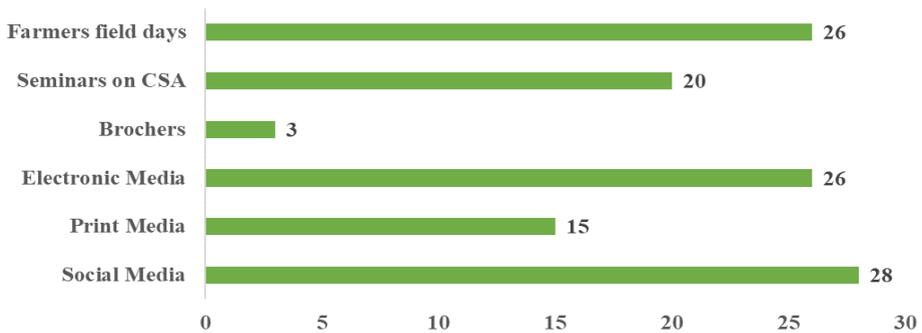
It has also been learnt from the data collected that lack of complete knowledge regarding all CSA practices to tap in all the important milestones for CSA and HVA is due to use of old and obsolete methods of knowledge sharing and capacity building i.e. farmer days, seminars, brochures etc.

4.2.9. Benefits of the Climate Smart Agriculture

The following data presents the percentage distribution of various benefits resulting from the adoption of certain agricultural practices. These benefits include improvements in crop health, reductions in pesticide and fertilizer usage, savings in irrigation water, decreased labor requirements, lower production costs, increased crop yield, and higher farm income (Asrat and Simane, 2017).

Table 14.
Benefit of Climate Smart Agriculture Practices

Benefit %age	Crop Health	Reduction in Pesticides Used	Reduction in Fertilizer Used	Saving in Irrigation Water	Reduction in Labor Use	Reduction in Cost Production	Increase in Crop Yield	Increase in Farm Income	Avg
0 to 5%	0	8	7	0	20	1	0	0	5
6 to 10%	10	17	6	3	12	10	6	2	8
11 to 15%	12	13	5	1	5	16	13	14	10
16 to 20%	14	9	12	8	3	6	13	17	10
21 to 25%	3	1	2	14	2	6	5	3	5
26 to 30%	8	0	5	10	5	5	7	6	6
31 to 40%	1	1	4	5	1	4	1	7	3

Benefit %age	Crop Health	Reduction in Pesticides Used	Reduction in Fertilizer Used	Saving in Irrigation Water	Reduction in Labor Use	Reduction in Cost Production	Increase in Crop Yield	Increase in Farm Income	Avg
41 to 50%	1	0	2	1	0	0	1	0	1
51 to 60%	0	0	5	1	1	1	3	0	1
61 to 70%	0	0	1	3	0	0	0	0	1

Analyzing the data, it is evident that the magnitude of benefits varies across the different percentage ranges. Following are some key observations:

a) **Crop Health**: The benefits related to crop health show a diverse range across the different percentage categories. The benefit percentage range of range of 16 to 20% came from the factor of crop health as responded by highest number of respondents (14), which indicates a notable positive impact on crop health through the adopted practices.

b) **Saving in Irrigation Water:** The benefit of water savings demonstrates a positive trend, with higher percentages in the 21 to 25% range. This suggests that the adopted practices are effective in optimizing water usage, which is crucial for sustainable agricultural systems.

c) **Reduction in Pesticides and Fertilizers**: The data suggests that there is a reduction in the usage of pesticides and fertilizers up to 6-10% benefit percentage as reported by 17 respondents. This indicates that the implemented practices contribute to more sustainable and environmentally friendly farming methods.

d) **Reduction in Cost of Production:** The data shows that 16 out of 49 respondents agreed that reduction in production costs exhibits a significant benefit percentage within the range of 16 to 20%. This suggests that the adopted practices have the potential to enhance cost-effectiveness and financial viability for farmers.

e) **Reduction in Labor Use:** The reduction in labor requirements followed a mixed pattern, with varying percentages across different ranges. However, the highest number of respondents agreed that labor use has been reduced up to 5%, indicating a potential for further improvement in labor efficiency.

f) **Crop Yield and Farm Income:** The results of the current study show that there are positive impacts on crop yield and farm income through adaptation of climate smart agriculture practices. The highest benefit percentages for both categories (Crop yield and farm income) fall within the range of 16 to 20%, as suggested by 13-17 respondents out of total sample population. Hence, there is considerable potential for substantial improvements to get higher productivity and financial gains.

Overall, the data indicates that the adopted climate smart agricultural practices have resulted in different as explained above. However, it is essential to note that the extent of benefits varies across the different percentage ranges, suggesting room for further improvements in certain areas. This data provides valuable insights for farmers and policymakers to assess the effectiveness of the implemented practices and identify areas for targeted interventions and enhancements.

3.1. Adaptation of Climate Smart Interventions in Punjab

Conducting a consultative session with academic and research institutes for High-Value Agriculture (HVA) involves engaging in a collaborative discussion to gather insights, expertise, and recommendations from scholars, researchers, and experts in the field. Following is the detail of Focus Group Discussion conducted:

Table 15.
Detail of discussion conducted with different Institute/Organization

S.No.	Institute/ Organization	Key members	Total Participants
1	Irrigation Department	• Dr. Wasif Khursheed; Secretary Irrigation (Ex-Chairman P &D, Secretary Agriculture, Finance)	01
2	Agriculture Department	• Rana Mahmood; Chief Planning & Evaluation Cell	05
		• Naeem Khalid Deputy; Secretary Planning	
		• Dr Kashif Bashir; Section Officer Planning	
		• Hafiz Abdur Rahman; Technical Advisor (Agriculture Delivery Unit)	
		• Kashif Jamshed; Project Director Establishment Of Model Farms Linked With Improved Supply Chain, Value Addition And Agri Marketing	
3	On Farm water Management & Extension	• Malik M. Akram; DG OFWM	04
		• Dr.Anjum Butter DG; Agriculture Extension)	

S.No.	Institute/ Organization	Key members	Total Participants
	wing	• Hafiz Qaiser Yasin; Dir HQ, OFWM • Tahir Mahmood; Agronomist, HQ Lahore	
4	Cotton and Mango research Institute Multan	• Dr . Khaild Chief Scientist Cri • Dr Abdul Ghaffar ;Chief Scientist Mango • Shahzad Sabir ;Director Ext	3
5	Ayub Agriculture Research Institute (AARI)	• Dr. Akhter DG Research • Dr. Qaiser Latif Cheema; Chief Scientist Vegetable Research Institute • Dr. Allaha Baksh; Chief Scientist Horticulture • Engr. Azhar Hussain; Agri Engineer	09
6	University of Agriculture, Faisalabad & Mian Nawaz Sharif University of Agriculture ,Multan	• Dr Iqrar Ahmad; Vice Chancellor Uaf. • Dr. Irfan Abbas Director Planning; Uaf • Dr. Amman Ullah Malik; Prof. Horticulture, Uaf • Dr Irfan Baig; Prof Horticulture Mnsua, Multan	4

Under FGD on Climate-smart interventions reference was made to practices and strategies implemented in agriculture to enhance productivity, resilience, and sustainability in the face of climate change. These interventions are aim to mitigate greenhouse gas emissions, adapt to changing climatic conditions, and improve the overall efficiency of agricultural systems. In light of these discussions here are some key climate-smart interventions which is being adopted in Punjab:

a) **Conservation agriculture**: Conservation agriculture involves the adoption of practices such as minimum tillage or no-till farming (zero tillage), crop

residue management, and diversified cropping systems (Nandan et al., 2021). These practices help improve soil health, reduce soil erosion, enhance water retention, and sequester carbon in the soil.

b) **Efficient irrigation and water management**: Climate-smart interventions focus on optimizing water use efficiency through techniques such as drip irrigation, precision irrigation, and improved water storage and conservation methods (Obaideen et al., 2022). These practices help cope with water scarcity, reduce water waste, and adapt to changing rainfall patterns.

c) **Climate-resilient crop varieties:** Developing and promoting climate-resilient crop varieties that are adapted to the changing climate is a crucial intervention (Cacho et al., 2020). These varieties exhibit traits such as drought tolerance, heat tolerance, disease resistance, and early maturity, allowing them to withstand climate-related stresses and ensure stable crop yields. Still in Punjab, there is lake of research and development in research and academic institute of the Punjab.

d) **Integrated pest management (IPM)**: IPM emphasizes a holistic approach to pest and disease management by integrating multiple strategies such as biological control, cultural practices, and judicious use of pesticides. Implementing IPM reduces reliance on chemical inputs, minimizes environmental impacts, and enhances the resilience of crops to pest and disease outbreaks (Heeb et al., 2019). As per my review and consultation with farmers it transpired that Punjab pest industry has very old dated formulation and pesticide sprays. The available pesticides could not meet the current climate change issue in vegetables and orchards.

e) **Nutrient management and fertilization**: Climate-smart interventions focus on optimizing nutrient management practices to minimize nutrient losses and improve nutrient use efficiency. This includes practices such as optimum fertilizer application, organic nutrient inputs, proper timing and placement of fertilizers to match crop needs and to reduce environmental pollution. For promotion of balance use of fertilizer, Government of Punjab is providing the yearly based Rs. 4-6 billion subsidies to farmer to increase the usage of fertilizer.

f) **Climate information and advisory services**: Providing farmers with timely climate information, weather forecasts and advisory services helps them make informed decisions and adapt their farming practices accordingly (Ngigi and Muange, 2022). Access to climate-resilient technologies, best practices, and training programs enhances their ability to cope with climate change.

g) **Renewable energy adoption**: Integrating renewable energy technologies, such as solar panels, wind turbines, or biogas digesters, into agricultural

operations reduces dependence on fossil fuels and reduces greenhouse gas emissions (Gorjian et al., 2022). Renewable energy can power irrigation systems, farm machinery, and provide energy for on-farm processes. this area needs further exploration in Punjab.

h) Farmer capacity building and financial support: Supporting farmers through training programs, capacity building initiatives, and ensuring their access to financial resources enables the adoption of climate-smart interventions (Kangogo et al., 2021). This includes providing financial incentives, grants, or loans to support investments in climate-smart technologies and practices.

Table 16.
Climate Smart Intervention and its Adoption Level

Sr. No.	Climate Smart Intervention	Adaptation Level (%)	Potential Level (%)
1	Conservation agriculture	0.82	99
2	Efficient irrigation and water management	8.3	91.7
3	Climate-resilient crop varieties	5.2	94.8
4	Integrated pest management (IPM)	0	100
5	Nutrient management and fertilization	37.2	62.8
6	Climate information and advisory services:	23	77
7	Renewable energy adoption	4.16	95.8
8	Farmer capacity building and financial support	7.6	92.3

Above table illustrates the conclusion of FGDs which indicated the gap between adoption and potential level of each climate smart intervention. Climate-smart interventions are context-specific and need to be tailored to local conditions, agroecological zones, and farmer needs. By implementing these interventions, agricultural systems can become more resilient, sustainable, and adaptive to the challenges posed by climate change. The above eight interventions are important to harness maximum potential of HVA in climate change scenario. But overall adoption level is low except nutrient management and climate information and advisory services. Hence, other climate smart interventions need focus of government and private sector entities to increase adaption level for enhancement of HVA.

5. International Best Practices

5.1. Climate Smart Agriculture Approach in Israel

Israel has gained considerable advancements in high-value agriculture, especially in arid and desert regions. Despite of limited resources of land and water, Israel has indigenously developed innovative agricultural technologies to enhance the productivity of high-value crops (Ward, 2022). Some notable examples of high-value agriculture in Israel are narrated below:

a) **Greenhouse Farming:** Greenhouse farming is featured by enabling controlled environments for optimal crop growth. These hi-tech greenhouses are equipped with advanced technologies such as irrigation management, climate control and pest control systems which provides ideal growing environment. Israel produces a long range of high-value crops in greenhouses such as cucumbers, tomatoes, peppers and herbs.

b) **Agricultural Biotechnology:** Israel has a thriving agricultural biotechnology sector focused on developing advanced seeds, genetic engineering, and biological pest control solutions. These technologies enhance crop traits, improve disease resistance, and reduce the reliance on chemical pesticides. Israel has made significant contributions to biotechnology research and development for various crops.

c) **Drip Irrigation:** Israel is considered to be pioneer in drip irrigation technology, which is designed for precise water delivery directly to the plant roots and in turn minimizes the water wastage. Israel has almost converted 70% of its cropping area under high efficiency irrigation systems. Drip irrigation has significantly enhanced water use efficiency and crop yields in Israel and has now been adopted by other parts of the globe. This technique is highly effective in arid regions where water is scarce.

d) **Organic Farming:** Israel has a growing organic agriculture industry, catering to the demand for organic products. Organic farming practices prioritize sustainable methods, avoiding synthetic fertilizers and pesticides. Organic produce from Israel includes fruits, vegetables, dairy products, and honey, among others.

e) **Vertical Farming and Hydroponics:** Israel has limited arable land due to which a considerable investment has been made in hydroponics and vertical farming systems. Vertical farming utilizes stacked layers to maximize space efficiency while hydroponics involves growing plants in nutrient-rich water solutions without soil. Adoption of these highly productive methods, Israel is now in position of year-round production of high-value crops such as strawberries, leafy greens, and herbs.

f) **Precision Agriculture:** Israel has embraced precision agriculture techniques to optimize crop production. This includes using sensors,

drones, and satellite imagery to collect data on soil conditions, water content, and crop health. This information helps farmers make informed decisions about irrigation, fertilization, and pest management, leading to improved yields and reduced resource wastage.

g) **Export of Exotic Fruits and Flowers:** Israel cultivates and exports a range of high-value exotic fruits, including avocados, mangoes, pomegranates, and citrus fruits. The country also produces and exports flowers such as roses, orchids, and other ornamental plants. These products are highly sought after in international markets due to their quality and unique flavors.

Through continuous innovation and research, Israel has established itself as a global leader in high-value agriculture. The country's agricultural practices focus on maximizing resource efficiency, utilizing advanced technologies, and producing high-quality crops suitable for local consumption and export markets.

## 5.2. Climate Smart Agriculture Approach in India

Climate change, being a significant global challenge, imparts its impact on agriculture and the same are also pronounced in India. India is a country which is heavily reliant on agriculture as a primary livelihood source. Established in 1984 as an Autonomous organization under the Ministry of Agriculture and Farmers Welfare, the Government of India registered the National Horticulture Board (NHB) as a society under the Societies Registration Act. NHB aims to develop production clusters for hi-tech commercial horticulture, enhance post-harvest and cold chain infrastructure, and promote the adoption of new technologies in the horticulture sector.

According to Figure 12, it is evident that the National Horticulture Board (NHB) has been successful in implementing its objective in a cluster-based approach. The data shows a significant increase in yield, which has continued to rise over time. This positive trend indicates the effectiveness of NHB's efforts in developing production clusters and achieving its goals in the horticulture sector.

Moreover, in India, several climate-smart agriculture practices are being implemented to mitigate the effects of changing climate and to ensure sustainable farming (Datta et al., 2022).

Figure 11.
Regional comparison of high value crop's yields
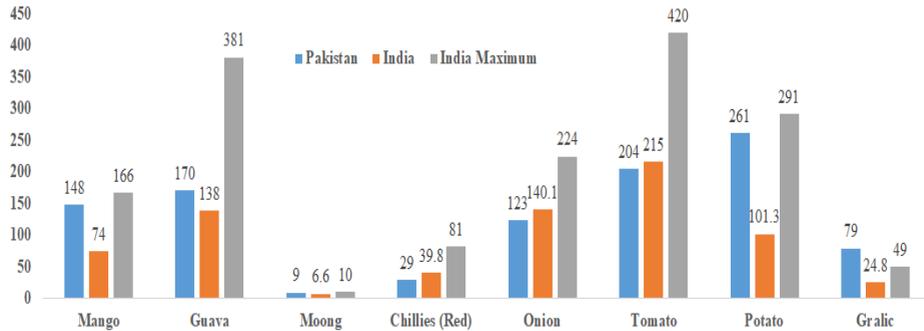
Following are some key practices being followed in India:

- **Drought-resistant crops:** India faces frequent droughts in various regions. The cultivation of drought-resistant and climate-resilient crop varieties is being promoted. Research & development efforts have been focused towards introduction of stress-tolerant crops like pulses, millets, wheat and rice which need lesser water and are better suited to the changing climate conditions.

- **Rainwater harvesting:** There are significant number of schemes and campaigns are being run for capturing rainwater during the monsoon season and storing it for irrigation during dry spells. This practice can help to tackle water scarcity. Hence for the purpose farmers are encouraged to build small-scale rainwater harvesting structures like percolation tanks, ponds and check dams to recharge aquifer and to ensure water availability during shortage periods.

- **Crop rotation and intercropping:** Management of intercropping and rotating crops can enhance soil fertility, reduce diseases and pests and improve resilience towards extreme climatic events. Diverse cropping systems are more resilient to extreme weather events and reduce dependence on a single crop.

- **Efficient water management:** Water-efficient irrigation systems such as drip irrigation and sprinklers are being implemented which are effective in conserving water and improving crop yields. Moreover, deficit irrigation is being practiced, which involves provision of water as per crop requirements at different growth stages, hence, in turn helps in optimizing water use.

- **Precision agriculture:** Moreover, efforts are being made for adoption of precision agriculture techniques which involve use of modern technologies

like sensors, drones and GPS. This kind of approach enables farmers to optimize and regulate the use of inputs like fertilizers, water and pesticides.

- **Climate-based advisory services:** Various government and private initiatives have been implemented through which farmers are being provided with climate-based advisory services through SMS alerts, mobile apps and radio programs.

- **Crop insurance and financial support:** Climate-smart agriculture requires higher initial investments. Therefore, financial support and crop insurance is a pre-requisite to be provided to farmers for easy adoption of these practices. There are number of initiatives are being implemented which involve financial support and insurance incentivization to facilitate the adoption of climate smart agriculture practices.

6. Conclusion and recommendations

6.1. Conclusion

High Value Agriculture (HVA) in Punjab is being enormously affected by extreme climatic events such as erratic rainfalls, heat waves and non-availability of climate-smart innovative technologies. On the other hand, the potential of HVA in the region is huge, as it has been found that there is a substantial gap between the current adoption levels and the maximum potential, which varies from 45% to 98%. However, realizing the full potential of HVA is riddled with challenges that requires immediate attention. A critical issue observed in the instant study is the lack of awareness among farmers regarding climate-smart agricultural (CSA) practices. The majority of farmers were found to be unaware of these practices, hindering their ability to adapt to changing climatic conditions effectively. Moreover, limited access to financial resources along with lower awareness levels, act as significant barriers in the adoption of climate-smart technologies. The scarcity of such technologies further exacerbates the problem, leaving farmers struggling to incorporate climate-resilient practices into their agricultural endeavors. The consequences of these challenges have been evident, with a substantial 40% of farmers facing losses due to reduced crop yields resulting from the non-adoption of climate-smart practices. These losses not only impact the livelihoods of farmers but also have wider implications for the region's food security and overall agricultural productivity.

The Focused Group Discussions and Policy Review revealed that addressing these issues requires a multi-faceted approach. One essential aspect is the development of climate-resilient crop varieties that can withstand the adverse effects of changing climate conditions. By investing in research and breeding programs, agricultural scientists can play a pivotal role in ensuring crop varieties that are better equipped to cope with extreme temperatures, erratic

rainfall, and other climate-induced challenges. Further, there is a pressing need to raise awareness among farmers about the significance of climate information and advisory services. By providing farmers with accurate and timely information, they can make informed decisions, implement appropriate agricultural practices, and mitigate the impacts of climate change on their crops. Capacity building workshops and training programs should be organized to equip farmers with the necessary knowledge and skills to adapt to a changing climate successfully. Hence the study concludes that the challenges faced by High-Value crop farmers in Punjab due to climatic factors and the lack of climate-smart technologies are substantial. However, by addressing the awareness gap, providing financial support, and fostering an enabling policy environment, the region can unlock its full potential in HVA. With the right measures in place, the adoption of climate-smart practices can lead to sustainable and resilient agricultural systems, ensuring food security and prosperity for farmers in the face of an ever-changing climate.

6.2. Policy Recommendations

The policy recommendations for promoting high-value agriculture (HVA) in Punjab through the use of climate-smart technology can include:

a) **Development and implementation of Climate-Smart Agriculture (CSA) policies**: The Punjab Agriculture Department should formulate and implement policies that promote climate-smart agricultural practices through Punjab Agriculture Research Board and research wing of agriculture department. The policy should emphasize the investment according to Agricultural GDP for adoption of climate resilient crop varieties, improved irrigation techniques and sustainable resource management to enhance agricultural productivity and resilience in the face of climate change.

b) **Revitalization of Research & Development**: The Punjab Agriculture Department in collaboration with academia needs to revamp its research capabilities through international collaborations, exchange programs, commissioned research grants, incentivization and royalty regime. Further, Government of the Punjab needs to invest in research infrastructure to improve the quality of research by introducing latest machinery and ICT tools.

c) **Financial incentives and support**: The government with the help of financial Institutions need to provide financial incentives, subsidies, and support mechanisms to encourage farmers to adopt climate-smart technologies and practices. This can include matching grants/discounted loan, interest free loans for purchasing climate-resilient crop varieties, irrigation equipment, and other climate resilient tools. Easy access to credit and enhancement of HVA insurance services should also be facilitated for

farmers to manage the climate-related risks. Moreover, there is strong need to incentivize the value addition solutions at farm levels and creation of forward and backward linkages for HVA farms to ensure best prices.

d) **Climate information and early warning systems**: Improving access to accurate climate information, weather forecasts and early warning systems can help farmers anticipate and prepare for climate-related challenges. The government should invest in the development and dissemination of localized climate information, along with establishing efficient early warning systems through telecom companies. This information can guide farmers in making informed decisions regarding crop selection, planting schedules and resource management.

e) **Stakeholder collaboration and knowledge sharing**: Collaboration among stakeholders, including policymakers, researchers, farmers and agricultural extension agencies is crucial. The government must develop ICT based platforms, incubation centers for knowledge sharing, networking, and collaboration among these stakeholders. This can include workshops, conferences and forums where experiences, best practices and innovative solutions related to climate-smart agriculture can be shared and discussed.

f) **Private Sector Led Initiatives**: Government agencies need to maintain ease of doing business environment for the private sector in areas of extension services, agriculture mechanization, high efficiency irrigation systems supply and services, water conservation, pest control, value addition and marketing etc.

g) **Localized Farm Based Services**: Initiatives need to be designed to identify the clustered areas for a specific crop (Mango in Multan, Citrus in Layyah & Sargodha, Olives in Chakwal and Potatoes in Sahiwal etc) and to incentivize the progressive farmers and other service providers to install small crop based specific value addition units like pulping units, concentrate units, sold storages etc.

h) **Horticulture Clusters**: Establishment and develop hi-tech commercial horticulture in identified belts, focusing on adopting advanced technologies, precision agriculture, and modern cultivation practices to create thriving horticultural clusters with enhanced productivity and profitability.

i) **Post Harvest Management:** Incorporate modern post-harvest management infrastructure as a fundamental part of all area expansion projects, ensuring that each cluster of projects has access to well-equipped facilities for efficient handling, sorting, grading, and packaging of horticulture produce.

j) Cold Chain Infrastructure: Strategically plan and invest in the development of an integrated, energy-efficient cold chain infrastructure, encompassing pre-cooling units, cold storage facilities, refrigerated transportation, and distribution centers, to maintain the freshness and quality of fresh horticulture produce from farm to market.

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