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ASSESSING THE EFFECTIVENESS OF CLIMATE SMART AGRICULTURE: A CASE STUDY OF DISTRICT PESHAWAR, PAKISTAN

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Abstract

According to the latest report of the Pakistan Bureau of Statistics (PBS) agriculture is the largest part of Pakistan's economy, plays a role of like backbone. Twenty four percent are added to the Pakistan's Gross Domestic Product (GDP) by agricultures sector. According to the Climate Risk Index (CRI-2021) Pakistan is one of the top ten most vulnerable countries in the world to climate change, experiencing impacts of climate change such as; heatwaves, floods, and droughts. The crop production is being improved by Climate-Smart Agriculture (CSA). CSA practices plays an act of sustainable agriculture strategy to cope with the challenges of climate change; availability of water and food security. This study assessed that up to what extent Climate-Smart Agriculture (CSA) has improved agricultural resilience, profitability and productivity in District Peshawar, Pakistan in relation to walk-in tunnel tomato production. Mixed methods approach has been used. Smallholder farmers (including women farmers) are surveyed, participated in focus groups (FGDs), and conducted key informant interviews (KIIs) to get qualitative data and quantitatively from cost-benefit analyses. According to the results the CSA walk-in tunnels produced 797 kg from 480 square feet which is equal to 72,310kg per acre while conventional methods produced 215 Kilograms of tomatoes from 480 square feet (19,511 kg per acre). In comparison to conventional farming practices, the yield of CSA is increased by 270%. Improved yields and off-season market price of CSA walk-in tunnel is 82 PKR per Kg, relative to conventional farming, 45 PKR per Kg led to a net income increase of 271% per 480 square feet area. Training on enhancing farmers knowledge, integrated pest management, and careful input management reduced environmental consequences and resulted in 40 to 160% reduction in fertilizer and pesticides costs and use. Off-season yield reduced risk related to seasonal patterns, while CSA methods increased women's participation in agricultural activities, enhancing food security and farmers' income. The importance of adoptability was also assumed considering that the main precursors for the awareness were NGOs, social media, and reports from friends, government, and research. Polythene sheet, plastic mulch and packaging materials, raised environmental issues, revealing the necessity for biodegradable alternatives.

1.1 INTRODUCTION

The National Aeronautics and Space Administration (NASA) defines climate change as "a long-term change in the average weather patterns that have come to define Earth's global, regional, and local climates." In areas with food insecurity, specifically Asian countries, climate change poses a threat to agricultural yield. Numerous climate-driven extremes, such as heat waves, droughts, unpredictable and heavy rainfall patterns, floods, storms, and new insect pests, have had a damaging effect on farmers' livelihoods. Climate extremes prediction models anticipate that future rain will be more unpredictable and intense, and temperatures will climb considerably. Between 2040 and 2069, Pakistan's smallest temperature is predicted to increase by 2.2°C and its maximum temperature by 2.8°C (Habib-ur-Rahman et al., 2022). On a regional and worldwide scale, the effects of climate change and farming variation, such as reduced crop yields, water scarcity and degraded land, have significantly endangered food availability and livelihood (Khan et al., 2021). Global climate change poses serious threats to the region's natural systems, ecosystem and socioeconomic institutions. Extreme weather events of different types and intensities have happened at different times. Lack of rainfall and protracted dry periods have negatively impacted agriculture and livelihoods in the southern, northern, and eastern regions, causing misery and fatalities among people. Frequent droughts are caused by large yearly and regional changes in temperature and rainfall, which force people to move in quest of better opportunities and often result in mortalities (Sinore and Wang, 2024). According to the IPCC Sixth Assessment Report, the average global temperature increased by 0.99°C (0.84–1.10°C) over pre-industrial levels amid 2001 and 2020. Climate extremes have become more severe globally in tandem with this warming, with significant reductions in cold days and nights, an increase in heatwaves, and more frequent, severe, and extended compound extreme events that combine temperature, and precipitation (You et al., 2022). Producing sufficient food seems to be the biggest challenge facing the agri-food sector. Given the limited amount of existing agricultural land, this calls for large efficiency gains. Agriculture must undergo a significant transformation in order to increase productivity with sufficient resources (Ayaz et al., 2019).

1.1.1. History of CSA

The CSA strategy has drawn a lot of interest at international forums since the Food and Agriculture Organization of the United Nations (FAO) defined it and presented it at the 2010 Hague Conference on Agriculture, Food Security, and Climate Change The issue of climate change has received proper attention at the United Nations Framework Convention on Climate Change (UNFCCC) at the conference with the name of Conference of the Parties (CoP) that were held in Durban, Poland, and most recently Lima, Peru. Both development organizations and nations are chasing the idea. In September 2014, at the United Nations Secretary Generals' Climate Summit (UNSGCS), a Global Alliance for Climate-Smart Agriculture (GACSA) was formed with the aim of helping 500 million smallholder farmers adopt CSA (Rosenstock et al., 2016). Regional initiatives to promote CSA adoption are also under progress. To help increase the growth of CSA to 25 million and 6 million farm households throughout the continent by 2025 and 2021, respectively, the Alliance for Climate-Smart Agriculture in Africa (ACSAA) (Africa CSA alliance) of the New Partnership for Africa's Development (NEPAD) brings together a varied range of development and technical partners. On CSA, individual nations are also acting. Successful CSA implementations include sustainable grazing in China, genetic diversity in Peru, and agroforestry in Tanzania (FAO, 2014). The Green Climate Fund (GCF) recently designated CSA in Africa and Asia as one of its five priority investment areas, and the Global Environmental Facility (GEF) concentrates on CSA and food security in Africa. In the light of this, it is evident that CSA actions are made and executed at some levels by legislators, development partners and Non-Governmental Organization (NGOs). The phase of the advance program had some discussion on the presence of Climate Smart Agriculture (CSA). Howden et al. (2007) declare that much of this

disagreement rises out of confusion about Climate Smart Agriculture (CSA) - what is actually CSA?

1.1.2. The impact of climate change on the Agriculture sector

Climate Smart Agriculture (CSA) is an agricultural pathway that achieves food security and applies sustainable methods to food production in the face of climate change to the best degree possible. (Borham et al., 2020). The Community Supported Agriculture (CSA) pathway covers issue of food security, while the CSA pathway connects concerns of food security within the approach to, decreasing water use, advancing resilience, lowering Greenhouse Gases (GHG) emissions, enhancing production, while improving environmental sustainability, while dealing with the Sustainable Development Goal (SDGs). (Chandra et al., 2018). Climate Smart Agriculture (CSA) unlocks a number of chances for settle and altering the agricultural system to empower food security under shifting climate conditions. The CSA pathway regards food security and the production from agriculture as probable and an equilibrium, which tends to be a healthier successor framing. (Westermann et al., 2018). A closer look at the Climate Smart Agriculture (CSA) context displays the understanding of Climate Smart Agriculture (CSA) is improving. Lastly, the CSA framework has supported decision-making for agriculture that has the relations and trade-offs among the three major outputs front of mind. Liper et al. (2014), it has agricultural systems that support reasonable and sustainable improvements in agricultural profits and productivity; better adaptation and resilience of food systems along the whole chain from the farm to the national level to climate change; and potentially the removal and decrease of GHG emissions.
Since the CSA strategy aims to create "climate proof farms," "climate-smart food systems," and "climate-smart soils," its tactics are self-explanatory and are becoming more and more well-known. (Venkatramanan and Shah, 2019). To successfully adapt agriculture, nutrition, and livelihoods to climate difficulties, a thorough analysis of all the variables that affect resilience in particular situations is required. One of the primary objectives of the Sustainable Development Goals (SDGs) is to address climate change; this provides an illustration of the increasing awareness on a national, regional, and international scale of the value and efficacy of addressing several development goals simultaneously in a comprehensive manner. Additionally, tackling climate change supports the chase of other Sustainable Development Goals (SDGs), like health and nutrition, among others of the Sustainable Development Goals (SDGs) (Bryan et al., 2017). Climate Smart Agriculture (CSA) relies on three main aims: (a) a change from conventional farming methods to modern adaptive approaches that assure conservation of reserve use; (b) increasing agricultural yield, assuring nutritious food, supporting livelihoods or availability of food, and eventually improving well-being and health; (c) and, lowering the risk of global warming by decreasing Greenhouse Gases (GHG) release in respects to climate change (Gulzar et al., 2020). The CSA objective usually combines advanced to conventional practices, technologies and services tailored to a specific location's adjustment to climate change and variability (CIAT et al., 2014).

1.1.3. Climate-Smart Agriculture Worldwide

The Global Science Conference (GSC) in 2013 on Climate Smart Agriculture (CSA) in Davis, California, United States of America (USA) looked at world best practices for agriculture and climate as well as the state of world science. According to a consensus of the 2011 Global Science Conference (GSC) in Wageningen, Netherlands on Climate-Smart Agriculture (CSA), the participants of the GSC presented a good, and broad strategy for governments and science to improve food security, climate change adaptation and mitigation (Steenwerth et al., 2014). Climate-Smart Agriculture (CSA) Country Profile Series data was used for the studies, that look at the role of agriculture adaptation to potential impacts from climate change in the over thirty countries across Asia, Africa and Latin America. A study has been conducted based on expert assessment of a new dataset of CSA technology created, which provides the most extensive intent of climate-smart members, or activities from a global stand point. The results highlight differentiated strengths and weaknesses of climate-smart agriculture (CSA) technologies, and

place-based differences and challenges in agriculture. Sova et al. (2018) suggest that additional understanding of CSA would lead to better operationalization of CSA, as the relationships between production, climate change mitigation and adaptation is better understood. Agriculture is a vital part of the economy of many African countries, but faces many challenges, including limited access to markets, insecure land tenures, soil degradation, and climate change. CSA is another entry point for improving food security, resilience, and climate change mitigation through sustainable practices. CSA is strategic and focused, seeking local and ecosystem-based adaptation strategies in a finance-rich institution, and the government or NGOs will support it: policy-oriented work to enhance relevant policies, promotion of suitable technology, and capacity building of research. More capital, public spending, and risk-sharing mechanisms are needed, and adaptation needs to be prioritized over mitigation. However, there are co-benefits to mitigation, particularly around livestock and land rehabilitation. CSA could propel agricultural change, economic expansion, guarantee food security, and climate resilience in Africa (Williams et al., 2015). Numerous research has worked CSA technology and procedures as pilot plans, but several limitations have made it challenging to scale them up. Since there isn't enough data to evaluate and generalize CSA's actual application in Asia, a thorough assessment is necessary to give stakeholders and policymakers insightful information that will secure the program's long-term viability. As a result, studies thoroughly analyze CSA in Asia by going over important studies and reports, describing widely used CSA technologies, identifying performance results and enabling variables, highlighting noteworthy successes and difficulties, and providing policy recommendations for the future growth of CSA in the region (Nguyen et al., 2025).

1.1.4. Pakistan's Agriculture: Challenges and Innovations

One of the most crucial issues for economic development is the agricultural sector's resistance to climate change, as over two-thirds of Pakistan's population lives in rural regions and relies on it for their subsistence and livelihood (Abid et al., 2016). Furthermore, due to its detrimental effects on food prices and cereal crop yield, climate change may have major consequences for Pakistan's local food security. 37% of Pakistan's daily calories come from wheat alone, which was cultivated on 8.66 million hectares in 2013 (Prikhodko and Zrilyi, 2013). Abid et al. (2016) states that the current national average output of wheat (2797 kg/ha in 2013) is much lower than the worldwide average yield of wheat (3268 kg/ha in 2013). Agriculture is a major component of Pakistan's economy, and economic prosperity and agricultural expansion are closely related. The nation's rapidly growing population and changing eating patterns have led to significant demand for vegetables. Tunnel farming is a feasible option that can raise the value of the farmer's supply because it prolongs the growth season for the vegetables (SMEDA, 2003). Agriculture is the backbone of Pakistan's economy. About 20.9 percent of Pakistan's GDP is derived from this industry. In addition to contributing to Pakistan's GDP, 43.5 percent of the rural population in the country makes their living from it (Government of Pakistan, 2015). Plastic tunnels have grown in popularity since they were first used in Pakistan in the 1980s, and a sizable portion of land is currently being farmed. By manipulating environmental conditions, tunnel farming helps to solve the problems associated with food demand. The technique boosts off-season vegetable production and yield per acre by utilizing state-of-the-art technologies. Modern interventions like tunnel farming become crucial for food security as Pakistan's agricultural industry faces difficulties, claim Jaffar et al. (2024).

1.1.5. Climate Smart Agriculture (CSA) in Khyber Pakhtunkhwa

Like other regions of Pakistan, Khyber Pakhtunkhwa's economy is based on agriculture. Most people (78%) rely on agriculture either directly or indirectly (GoKP, 2015). The climates of Khyber Pakhtunkhwa and other provinces vary greatly from one another. In the north, the annual temperature is below zero degrees Celsius, while in the south, it exceeds four hundred and fifty degrees. Its diverse environment makes it possible for a wide range of crops, fruits, and vegetables to grow. If quality factors are appropriately addressed and adequate attention is

paid, Khyber Pakhtunkhwa's vegetable industry has a lot of promises. Jalal-ud-Din (2011) asserts that in addition to financial limitations, growers are often ignorant of the latest technical applications. The demand for off-season veggies has been rising even while their supply is comparatively limited. Because it is expensive to produce winter vegetables in the summer in an artificial environment, Khyber Pakhtunkhwa cannot use this practice on a large scale. However, it is possible to grow vegetables in the summer and harvest them in the winter with the help of tunnel technology, which is economical. To keep the sun's energy in and give the vegetables grown in the tunnel enough temperateness, plastic sheets are used. This type of farming is commonly called "Tunnel Technology." The farmers cover the crops in the tunnels with plastic sheets to give them the optimum heat they need. Compared to glass sheets, plastic sheets are far cheaper (Khan et al., 2020). Plastic sheets are less expensive, and cost-effective than glass sheets. Different kinds of tunnels, such as a high tunnel up to 12 feet high, a walk-in tunnel up to 6.5 to 10 feet high, and a low tunnel up to three feet high, are used for the cultivation of vegetables during the off-season. However, our study has stressed on the walk-in tunnel. In some climates, walk-in tunnels have economically and successfully prolonged the growing season for warm- and cool-season crops (Wells and Loy, 1993). Cucumbers, bottle gourds, tomatoes, squash, bitter gourds, strawberries, pepper, and other vegetables are frequently growing in tunnels. While there are many types of tunnels used in the country to grow vegetables out of the growing season, the walk-in tunnel is often used for this purpose. Lamont et al. (2002). Climate change poses a serious threat to global food security because it affects water availability, agricultural productivity, and rural livelihoods. Climate-Smart Agriculture (CSA), which combines resilience development, climate adaptation measures, and emission reduction has emerged as a promising approach to mitigate these impacts. CSA facilitates agricultural sustainability through innovative practices like tunnel farming, which offers a true mechanism to increase off-season vegetable production in an environmentally sustainable way.

1.1.6. Tunnel Farming as a CSA practice

Tunnel farming technology is one of the best practices of climate smart agriculture (CSA) with good overall efficiency. Tunnel farming can be categorized into three types: low tunnels (1-4 feet height), walk-in tunnels (greater than 4 feet to 10 feet height), and high tunnels (greater than 10 feet height). Tunnel farming can be seen as an innovative way to grow vegetables in the limited pieces of land dedicated to agricultural production because of high population levels. Tunnel farming is best for producing vegetables in the off seasons. It is economically viable to produce the summer crops in the winter. According to Muhammad et al. (2015), during tunnel farming, polythene (transparent white plastic) sheets are used to cover crops provide protection from severe weather and the correct temperature for plant growth. In addition, mulching (Black plastic mulch) sheets minimize labor costs, decrease herbicide requirements for weed management, and limit lower water that might evaporate from the soil. For smallholder farmers, tunnel farming has emerged as a practical means to secure food security and to earn a living in Pakistan and especially in Khyber Pakhtunkhwa. Tunnel farming increases production and extends growing seasons by controlling conditions that can prevent crops from being maligned by adverse weather conditions; many forms, including walk-in tunnels, low tunnels and high tunnels, illustrate the flexibility and scale of this technology. Walk-in tunnels are a new technology, with the focus of research in Peshawar District, Khyber Pakhtunkhwa. While climate-smart agriculture (CSA) practices like tunnel farming have the potential to become generalized, low awareness or knowledge of CSA, limited funding or subsidies, and limited access to modern agricultural equipment are barriers to its generalization. Training, financial incentives, and government support could counter or minimize some barriers to increasing CSA uptake.

We have experimented with this walk-in tunnel technology as a CSA within the Peshawar district. We explore the effects of CSA practices on underserved communities and women, and how they can empower themselves to play a part and succeed economically. We also did a financial feasibility

analysis of the traditional farming cost benefit to determine how sustainable CSA (Walk-in Tunnel) farming is. The research will inform policy by providing experimental evidence of the benefits and shortcomings of CSA and helping smallholder farmers adopt more sustainable agricultural methods that are more resistant to climate change.

1.2. Problem Statement

One of the Climate-Smart Agriculture (CSA) activities in District Peshawar undertaken to enhance climate change resilience and agricultural production is the walk-in tunnel. But there is no data about its efficiency, particularly in comparison with the traditional farming. Climate change is a threat to food security in the region and women and the marginalized are the most vulnerable. Although walk-in tunnels and other CSA techniques present viable solutions, their effects on local communities—particularly regarding resilience and economic benefits—have not been sufficiently evaluated. The aim of this research is to evaluate walk-in tunnels' effectiveness as a CSA practice, weigh the disadvantages and advantages of this method against conventional farming, and investigate the socioeconomic effects on the area's most deprived populations.

1.3. Aim and Objectives

The purpose of this study is to compare the productivity, costs, and socioeconomic benefits of walk-in tunnels with traditional farming methods in order to assess their efficacy as a Climate-Smart Agriculture (CSA) practice in District Peshawar, especially for vulnerable communities. The specific objectives of the study are:

- To assess the effectiveness of climate smart agriculture in the study area
- To evaluate the impact of climate smart agriculture practices on women and marginalized community
- To conduct a cost benefit analysis of climate smart agriculture vs. conventional farming

1.4. Research Question:

How effective are Climate-Smart Agriculture (CSA) practices in improving crop productivity and socio-economic benefits compared to conventional farming in District Peshawar?

2. Literature Review

The available literature on Climate-Smart Agriculture (CSA) and its uses on a provincial, national, and international level is thoroughly studied in this section. It is divided into three parts. International studies that demonstrate different CSA techniques targeted at improving resilience, productivity, and mitigation are reviewed in the first section. The second segment highlights local inventions and climate-resilient farming practices with a stress on CSA implementations in Pakistan. The third segment focuses on Khyber Pakhtunkhwa (KP) and inspects research on CSA techniques that are suitable for the agroclimatic conditions of the region. As a climate-smart technique, tunnel farming receives specific attention since it allows farmers to prolong growing seasons, shield crops from unfavorable weather, and increase the efficacy of water and input use, all of which help susceptible areas adapt to climate change and ensure food security.

2.1 CSA Worldwide

Hanley et al., (2021) conducted a study in Myanmar proves improved dietary diversification but unchanged malnutrition, underscoring the need for longer-term monitoring and insufficient nutrition education. To assess the effect of CSA on dietary changes and food security, survey data from 527 farming families was gathered over a three-year period.

Scherr et al., (2012) have investigated the impact of CSA on food security in rural Ethiopia with an emphasis on biodiversity and social concerns such as community-based structures, climate change, and environmental conditions. It also strongly focuses on stakeholder engagement, policy context, and integrated implementation strategies.

Westermann et al., (2018) examined the following areas of focus: technology, human innovation, and/or strategies that should be developed to improve CSA policy engagement, implementation, and value chains. While these solutions are emerging, they also come with constraints regarding locational conditions, high-cost estimates, assimilation, and food security. However, scaling up

CSA will be challenging and will require some careful decisions to be made.

Bruce et al., (2019) wrote an article about their research conducted in Indiana about the limitations and opportunities of high tunnel production for specialty crops. They interviewed and surveyed twenty farmers. For the farmers, the main difficulties were not well-served winter markets, disease control, labor intensity, soil fertility, and complex production. The opportunities they identified were enhanced crop quality, longer shelf life, premium prices, crop diversification, and year-round income. The results suggest developing better tunnel management advice and research to reduce barriers and lead to better farmer support systems. A high tunnel can be a great addition to all kinds of farms, but by understanding these human dimensions, extension educators and conservation staff can increase farmer knowledge and ensure the best use of high tunnels for the small and diverse farm.

Bano et al. (2021) reviewed Climate-Smart Agriculture (CSA) to transform farming systems to ensure food security with climate change. Agricultural production and food markets are sensitive to changes in temperature and precipitation that could impact lives. Reducing risks by providing farmers with better resources and enhanced efficiencies to adapt to Climate Smart Agriculture (CSA) suggests that flexibility allows for developing situation-specific approaches supported by policy and funding streams, to ensure farmers adapt. CSA will focus on a bottom-up synthesis of empirical evidence to support farmers in increasing their adaptive capacity. Hi-tech horticulture is a modern technology that maximizes the production output with a lower input while providing increased economic stability. It is therefore an integral part of sustainable food systems, particularly in India, to improve agricultural resilience, economic security, and productivity.

2.2 CSA in Pakistan

Ali, (2022) explored the development system of CSA of Pakistan, highlighting its main opportunities and challenges. It demonstrates that better legislative frameworks, increased information sharing, and greater stakeholder engagement are required to develop more resilient agricultural practices and contribute to a more sustainable food future for the region.

Shahzad et al., (2021) showed that CSA techniques increase farm net returns and reduce hazard risk in agroecological conditions. The problems encountered by the CSA system of Pakistan are discussed. Study Design: We conduct a mixed-methods study to explore the adaptation implications of CSA in rural areas of Pakistan through semi structured qualitative interviews followed by quantitative surveys with farmers.

Mustafa et al., (2024) used the CSA approach In Pakistan for wheat growing, the practice increased both the productivity and cost effectiveness. According to the research, the non-adopter cold increases output yield by 20%, which helps combat poverty and ensure food security. Using a mixed-method approach, Probabilistic Frontier Analysis (PFA) is combined with surveys and interviews.

Imran et al., (2022) conducted a study in 450 households of Punjab, highest populated province of Pakistan. It concentrated on the CSA approach's wheat-based farming system. The study assumed that people who used the CSA technology saw significant financial and resource efficiency gains. Utilizing efficiency metrics, comparison analysis, and questionnaires, the performance and sustainability of conventional producers and CSA adopters were also evaluated.

Sardar et al., (2021) conducted in Punjab, province of Pakistan. The study examined 420 farmers who used CSA technology and discovered that institutional factors and financial resources had a significant influence on CSA adoption. Utilizing surveys and regression analysis, the study highlighted that farm revenue, CSA acceptance, and its positive benefits on crop productivity are some of the elements that affect CSA.

2.3 CSA In KP

Miller et al., (2021) analyzed that Khyber Pakhtunkhwa (KP), a northwest province of Pakistan, is one of the vulnerable towards climate change. Climate change has a negative impact on agricultural output. One of the finest strategies for overcoming these obstacles is CSA. Numerous CSA methods promote resilience, sustainable farming, and increased resource efficiency. It is crucial to

emphasize the importance of stakeholder participation, policy support, and capacity building in order for quarantining to address environmental issues and food security through the use of CSA techniques. The CSA strategy is desperately needed to mitigate the effects of climate change.

Zakirullah et al., (2024) has done study in the KP on CSA techniques, discovered that compared to planting the pea and barley crops alone, intercropping (CSA approach) generated 32% more revenue (Rs. 109,392 per hectare). Despite lower yields, the larger Land Equivalent Ratio (LER) is thought to highlight its potential productivity. The study employed a Randomized Complete Block (RCB) design for assessment.

Komal et al.) conducted a study and he believed that the irrigated agroecosystem's improved carbon sequestration and climate change mitigation are due to the CSA techniques, according to a study done in Peshawar, the capital of KP, Pakistan. The CSA encourages sustainable practices in vulnerable agricultural regions to improve food security and resilience.

Khan, M.B., and Khan, J. (2020) conducted a study analyzing the economics of tunnel farming for off-season vegetable production in Peshawar. The study contrasted the productivity of open-field cultivation and tunnel farming using data from 84 farmers. The findings showed that tunnel farming produced noticeably higher yields, with tomatoes yielding the highest returns, followed by bottle gourd and cucumbers. Tunnel farming was ultimately successful in spite of increased costs of inputs and tunnel infrastructure. This study highlighted the importance of providing adequate training for farmers, the availability of finance, and the need for the construction and maintenance of colling facility for adequate storage to help improve their profitability and to promote increased uptake of the tunnel system. All-in-all tunnel farming is ideal for sustainable agricultural development in the locality as this method enables vegetables to be grown year-round, gives farmers confidence in obtaining higher prices for market sales, and leads to improved food availability because of increased production

Pervaiz, U., Khan, M.Z., and Khan, A. (2022) conducted a study on off-season vegetable production in Peshawar that evaluated challenges, income, yield and extension services. According to the data obtained from sixty farmers, an identified 6.7% of farmers participated in the training that would be part of the 48.3% of farmers that were either beckoned to the production by extension personnel. Provided the profitability of yields for tomatoes was much higher than others, even if the tunnel farming infrastructure was more expensive. High installation costs, storage, finance, and a shortage of certified seeds were major obstacles. To boost the adoption of tunnel farming and raise off-season vegetable yield in the area, the study suggests more training, government funding, and agricultural insurance.

3. Material and Methods

To enhance agricultural productivity and handle climate-related issues including temperature swings, and Irregular rainfall, the walk-in tunnel has been accepted as a vital Climate-Smart Agriculture (CSA) technique. In the context of the RE-FOOD (Resource Efficient Food Production Pakistan) initiative, this study has exactly assessed the efficacy of walk-in tunnels in District Peshawar, Khyber Pakhtunkhwa (KP), Pakistan. This initiative, which was sponsored by BMZ Germany and implemented by the Foundation for Rural Development (FRD), has been in operation in 9 Union Councils located in the District of Peshawar.

The primary goal of this study has been to determine the impacts of walk-in tunnels on crop yield, profitability, and water use of tomato crops compared to conventional farm management practices. The project beneficiaries have been interviewed through focus group discussions (FGDs), surveys, and key informant interviews (KIIs) for quantitative and qualitative information. Field trials comparing the performance of tomatoes grown using CSA techniques with those grown using conventional farm techniques and a Cost-Benefit Analysis (CBA) have also been carried out.

3.1 Study Area

Peshawar is the capital of KP, Pakistan. It is situated in the country's northwest. Its coordinates are 34° 01′ North Latitude and 71° 35′ East Longitude. The region has an average elevation of 1086 feet. The Peshawar's geographical area is 1,273 square

kilometers in size. According to the Census of 2023, the population of Peshawar is about 4.7 million, making it the most populous city in Khyber Pakhtunkhwa and the sixth most populous city in Pakistan. Peshawar district is surrounded by other KP districts and Pakistani tribal agencies (Khan et al., 2019). The mean maximum temperature during the summer season (the period from May to September) is more than 40 °C, and the mean minimum temperature is 25 °C. Winter is initiated in the middle of November and lasts till the beginning of April (Begum et al., 2021). The study is carried out in 9 UCs of the district of Peshawar. The UC are Mathra, Urmer Bala, Gari Sherdad, Panam Dheri, Malakandher, Shahi Bala, Wadpaga, Surezai Payan, and Palosai.

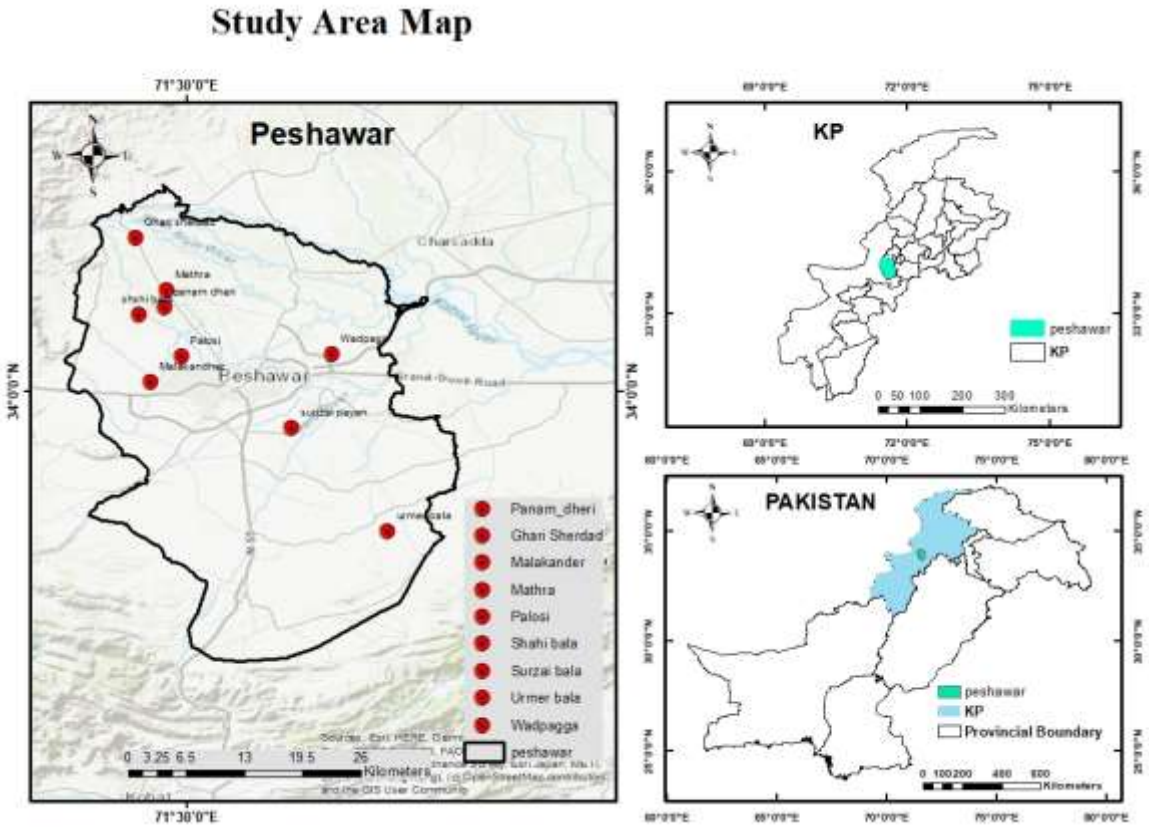

Figure 3.1: Location of the study Area (Peshawar)

3.2. Research Variables:

3.2.1. Dependent Variables

- Farmer satisfaction/perception
- Cost-Benefit Ratio (CBR)
- Water Reduction

3.2.2 Independent Variables:

Independent variables play an important role in determining the uptake and performance of Climate Smart Agriculture (CSA) practices. Some of the factors that affect both the availability of resources and farmers' decisions include gender, age, and location. A range of factors affect an individual's level of understanding and willingness to implement CSA, including awareness levels, training exposure, and information sources. The volume of water used, the number of crops planted in the field, the type of crops planted in the field, the price, and the size of the tunnel can give us an idea of the outcome. Opportunities and constraints related to CSA have been identified through understanding the motivations, barriers, participation of women, and subsidy requirements. When looking at sustainability and the impact of CSA, the context of these factors is key.

3.3. Data Collection

Primary and secondary data will serve as the foundation for this research.

3.4. Primary Data:

Since primary data offers firsthand insights into the attitudes, behaviors, and results of CSA treatments, it is crucial for comprehending the efficacy of CSA in the context of District Peshawar, Pakistan. Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), questionnaires, and direct observations are some of the techniques I use to collect primary data for my research. A thorough grasp of the region's smallholder farmers' interactions with CSA technologies, their difficulties, and the effects on their farming methods and means of subsistence is made possible by these data collection methods.

3.4.1. Qualitative Data

For this study, focus group discussions (FGDs), interviews, and in-person observations were used to gather qualitative data. Three focus groups have been conducted: one with the ladies of the union council, Wadpaga, Urmer Bala, and Shahi Bala, and two with male farmers. Each FGD has had four to eight participants in total. FGDs are conducted using a focus group guide. Six key informant interviews have been done, including two with widow farmers, two with progressive women farmers, and two with disabled farmers. Guides for FGDs and interviews are used. FGDs and interviews with male farmers were recorded using a voice recorder, however due to cultural and religious constraints, recordings of female farmers were not allowed.

In order to evaluate the efficacy of CSA in the research region, in-depth field observations have also been made at a number of places. FGDs and KIIs are used to collect narrative data that reveal farmers' subjective experiences, especially with regard to how CSA technology affects their income, productivity, and general well-being.

3.4.2 Quantitative Data

A questionnaire online survey has been used to gather quantitative data from project beneficiaries who have firsthand experience with the walk-in tunnel technology in the Peshawar valley. Nine union councils where the project is being implemented are the sites of the survey. Urmer Bala, Surezai Payan, Shahi Bala, Gari Sherdad, Mathra, Panam Dheri, Malakandher, Palosai, and Wadpaga are the names of these union councils. The influence of CSA in the Peshawar district is ascertained by the survey. Questions about the impact of CSA and its specifics were included in the questionnaire. There were 305 project beneficiaries, and 98 of them completed the questionnaires.

In order to evaluate tomato output under Climate-Smart Agriculture (CSA) employing walk-in tunnels with their traditional open-field farming, ten tomato growers were chosen from Union Council Urmer Bala and Surezai Payan for a second survey. Because they are Re-Food project beneficiaries and have grown their tomato crops both conventionally and in a walk-in tunnel, these growers stand out from other farmers. The crop's treatment and area were taken identically. The area of each walk-in tunnel was 480 ft^2 (40 × 12 feet), and the same area was used for the conventional tunnel.

3.5. Secondary Data:

- Books
- Journals
- Project reports
- Articles
- Internet source
- Research Papers

3.6. Data analysis:

The data collected has been analyzed by using different statistical techniques.

3.6.1. Statistical Techniques:

The quantitative information gathered via surveys was statistically examined and computed as percentages and averages, which were then displayed in tables and graphs. For this, computer programs including PowerPoint, Microsoft Excel, and SPSS were also utilized.

Formula for Estimating Yield per Acre from a 480 sq. ft Tunnel Plot

$$Y_{acre} = \left(\frac{Y_{480}}{480}\right) \times 43560$$

Where:

Y_{480} =Yield from 480 square feet (kg)
Yield $_{Acre}$ = Estimated Yield per acre in (kg)
43560 = Total square feet in one acre

3.6.2. Thematic Analysis

Thematic analysis has been used to examine qualitative data gathered from FGDs and interviews. With the aid of coding, themes were found, and the findings were then displayed as models and text.

4. RESULTS AND DISCUSSION

This section presents and analyzes the findings in the study based on the information obtained through surveys, focus groups (FGDs), key informant interviews (KIIs), field tests, and secondary sources. The results support the study's objectives by comparing the efficiency of walk-in tunnels and other Climate-Smart Agriculture (CSA) practices to traditional farming practices in District Peshawar. Quantitative and qualitative data are examined to assess cost-benefit dynamics, productivity results, water efficiency, and socioeconomic effects of water pollution on communities (especially women). To highlight key findings, implications, and the broad importance of CSA adoption in the region, the discussion integrates these findings with already published studies.

4.1 Quantitative Data Analysis

4.1.1 Cost Benefit Analysis of CSA vs. Conventional Farming

In order to evaluate tomato output under Climate-Smart Agriculture (CSA) employing walk-in tunnels with their traditional open-field farming, 10 tomato growers were chosen from Union Council Urmer Bala and Surezai Payan to participate in the survey. Because they are Re-Food project beneficiaries and have grown their tomato crops both conventionally and in a walk-in tunnel, these growers stand out from other farmers. The crop's treatment and area were taken identically. The area of each walk-in tunnel was 480 ft² (40 × 12 feet), and the same area was used for the conventional tunnel. It was estimated that roughly 90 tunnels could be built per acre (43,560/480 ft2), since one acre is equal to 43,560 ft².

4.1.1.1 Cost ratio of CSA vs. Conventional Farming

Indeterminate tomato seeds, crop net, GI wire, transparent polythene sheets, iron arcs (for structure), fertilizers, black plastic mulch and insecticides were all utilized in the CSA practice. However, indeterminate variety seeds, herbicides, and fertilizers are employed in the conventional technique.

4.1.1.2 Labor cost ratio

The average labor cost of CSA is 10500 PKR while the conventional farming is 2537 PKR.

4.1.1.3 Inputs cost ratio

While the average cost of conventional farming is 2152PKR, the input cost of the walk-in tunnel is 120000PKR (the tunnel is quite expensive, but it lasts for a decade and produces two harvests annually, thus the cost of a single crop is just 6000PKR). This includes mulch, polythene sheet, crop net, fertilizer, seeds, pesticides, and other items.

4.1.1.4 Post Harvest cost ratio

The average post-harvest cost of CSA is 12460PKR including harvesting, packing materials, transportation etc. while the post-harvest cost of conventional farming is 4416PKR.

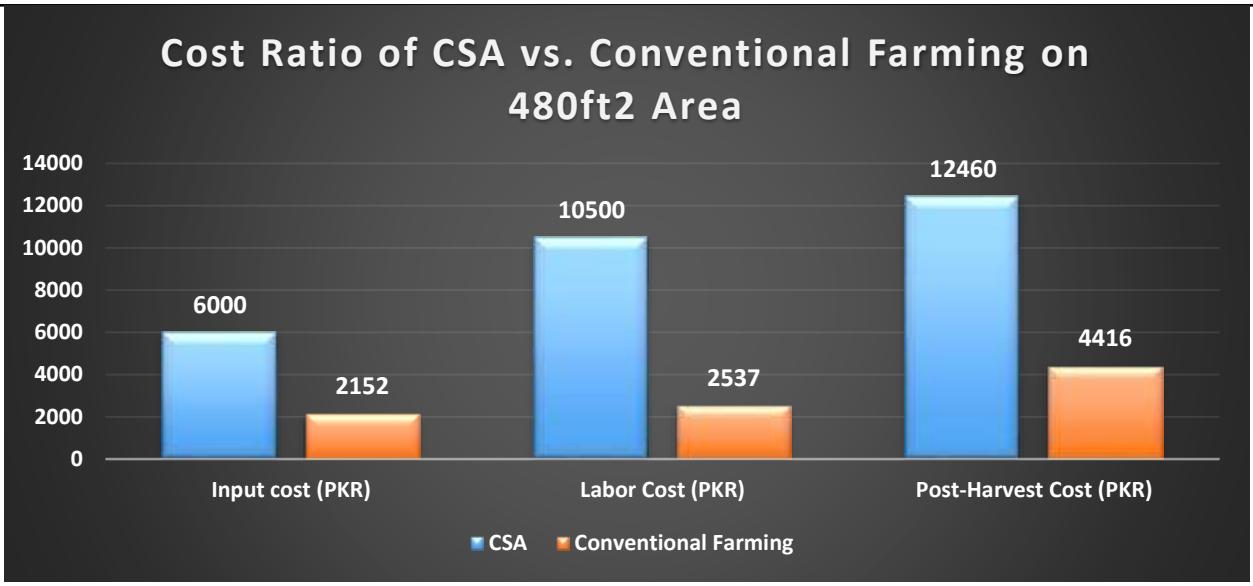

Figure 4.1: Cost ratio of CSA vs Conventional Farming

4.1.2 Benefits ratio of CSA vs. Conventional Farming

4.1.2.1 Average Yield ratio

Total average yield of the CSA is 797 kg per 480ft^2 tunnel area while the total yield of conventional farming is 215kg.

4.1.2.3 Average Unit Price Ratio

The average price per kilogram of CSA is 82PKR while average conventional is 45PKR.

4.1.2.4 Average Income Ratio

The average net income is 66008PKR and net income 8726PKR while the gross and net revenue of the conventional are 9862 and 2353 respectively.

Table 4.1: Average Income Ratio of CSA vs. Conventional Farming

Parameter	CSA	Conventional Farming
Total Yield	797	215
Per Kg price	82	45
Gross income	66008 (@82PKR/Kg)	9862 (@45PKR/Kg)
Net Income	8726*	2353

The cost-benefit analysis makes it abundantly evident that although walk-in tunnels used in Climate-Smart Agriculture (CSA) practices require a larger initial investment, including costs for black mulch, crop nets and tunnel construction, the financial returns are substantially higher. This conclusion is corroborated by yield data, which indicates that CSA tunnels generated an average of 797 kilograms per 480 square feet, almost 3.7 times more than the 215 kilograms produced using traditional farming techniques. CSA tunnels produced about 72,310 kg/acre when scaled to one acre, while conventional methods only produced 19,511 kg/acre.

With CSA, productivity has increased by 270%, demonstrating its exceptional efficacy and efficiency in tomato farming. Similarly, because tunnel-farmed tomatoes were produced during the off-season and were of higher quality, their average market price was higher (82 PKR/kg compared to 45 PKR/kg). This produced an extrapolated income of 785,340 PKR per acre and a net income of 8726 PKR per tunnel, which is 271% more than traditional farming. These

results are consistent with the study conducted by Khan and Khan (2020), who found that, in comparison to open field cultivation, tunnel farming enhanced tomato yield by 177%. According to their research, yields under tunnels were 32,434 kg/acre, whereas yields in open fields were 11,700 kg/acre. This nearly threefold increase in yields demonstrated the important role that shielded cultivation plays in production

4.1.2 Water Consumption Analysis

Water use was measured by counting the numbers of irrigations from the land preparation till last harvesting. According to the survey tunnel tomatoes need 16 numbers of irrigation while conventional needs 25 numbers of irrigations. Each irrigation consumed 90-100 liters water.

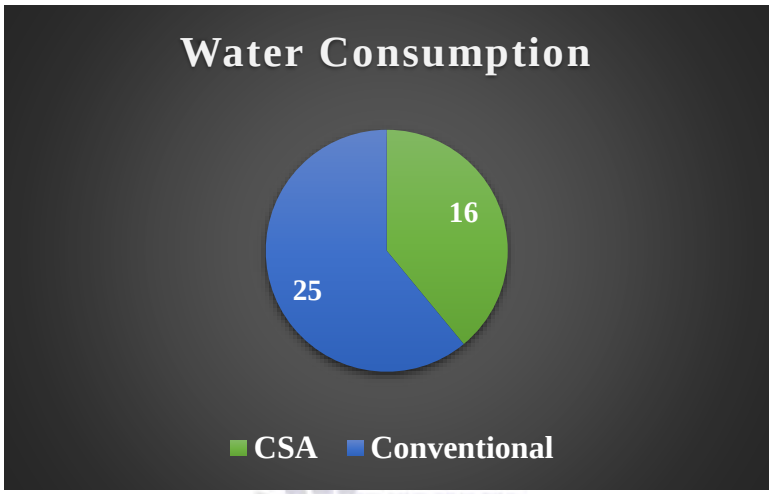

Figure 4.2: Water Consumption of CSA vs. Conventional

Tunnel tomatoes with mulch needs less irrigation. Mulches retain moisture, suppress weeds, regulates soil temperature, reduces evaporation. Polythene sheet on the tunnel prevents water loss through evaporation. These help to conserve water, reduce run-off and promote healthy plants growth.

4.2. Qualitative Data Analysis

Having demographic characteristics is a major underpinning for understanding the perspectives, actions and choices of respondents when it comes to their agricultural actions. It is important to understand who you are getting information from. In this research, I obtained information from 98 farmers of various ages, genders, educational backgrounds, and union councils. The other subsections provide further detail on the distribution of respondents by demographic characteristics.

4.2.1. Age Distribution of Respondents

The age distribution of the 98 respondents is provided in Table 4.1. As demonstrated, a majority of farmers are working-age farmers. A total of 29 (29.6%) were in the age range of 18 to 30 years, 34 (34.7%) were in the age range of 31 to 40 years, and 29 (29.6%) were in the 41–50 years range. Only 5 (5.1%) were in the 51 to 60 years range and only one farmer (1.0%) was 60 years of age or older.

Table 4.2: Age wise distribution of the respondents

Age Group	Frequency (n)	Percentage (%)
18–30 years	29	29.60
31–40 years	34	34.70

41–50 years	29	29.60
51–60 years	5	5.10
Above 60	1	1.00
Total	**98**	**100**

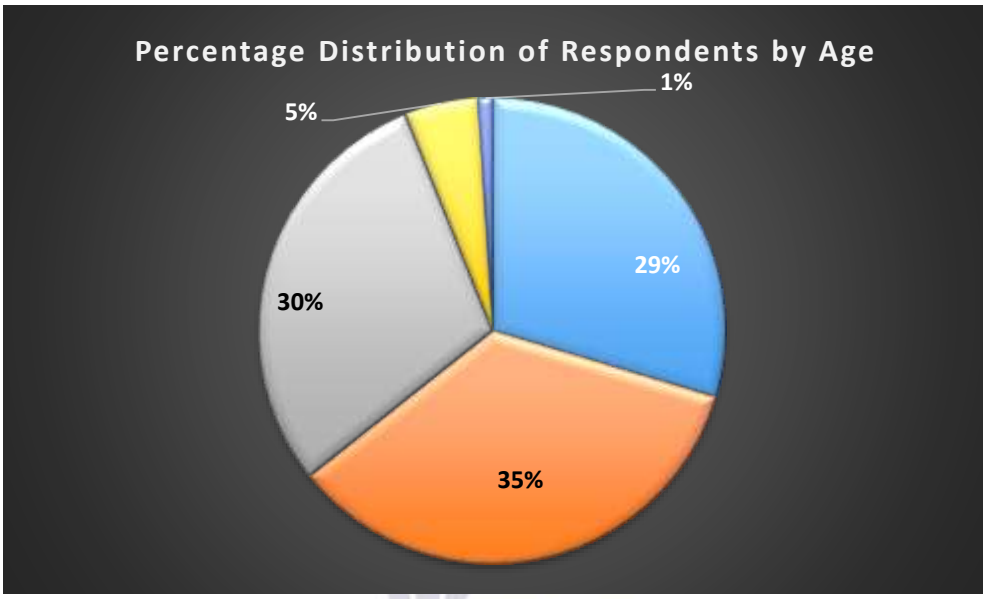

Figure 4.3: Percentage Distribution of Respondents by Age

The results reveal that a significant number of respondents fall into the age group most likely to be innovative, physically active, and open to new agricultural practices. Typically comprised of younger farmers; observed agricultural and rural development surveys presented a pattern in these age ranges with a preponderance of middle-aged farmers (31-50 years) indicating a middle ground between youthful vigor and farming experiences. This demographic is particularly relevant to climate-smart agriculture (CSA) as younger and middle-aged farmers are more open to modern technology, as older farmers may have more reliance on traditional practices.

4.2.2. Distribution of Respondents by Gender

Gender distribution in this study is indicated in Table 4.2, with 66 (67.3%) male farmers, and 32 (32.7%) female farmers presented from the 98 respondents. It is impressive that there are a fair number of women surveyed; in attending to community agriculture, it typically male dominated.

Table 4.3: Gender wise distribution of the respondents

Gender	Frequency (n)	Percentage (%)
Male	66	67.30
Female	32	32.70
Total	**98**	**100**

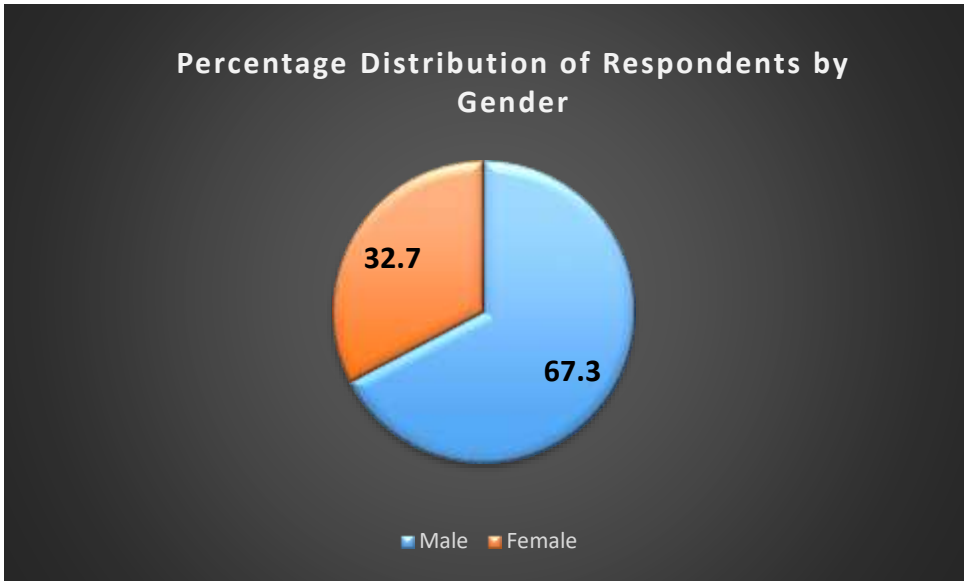

Figure 4.4: Percentage Distribution of Respondents by Gender

The inclusion of women farmers in this study was important because women play an important role in household-level food production, post-harvest activities, and nutrition security. Participation of women in CSA projects helps with sustainability, as women are more likely to integrate practices that directly support food availability and family welfare. The split of gender also emphasizes the inclusiveness of the project, by allowing male and female inputs to be reported in the assessment of CSA adoption.

Table 4.4: Union Council wise distribution of the respondents

Union Council	Frequency (n)	Percentage (%)
Gari Sherdad	6	6.10
Malakandher	8	8.10
Mathra	16	16.30
Palosai	17	17.30
Panam Dheri	13	13.20
Shahi Bala	11	11.20
Surezai Payan	9	9.10
Urmer Bala	11	11.20
Wadpaga	7	7.10
Total	**98**	**100**

4.2.3. Distribution of Respondents by Union Council

Distribution of respondents by union councils (UCs) are provided in Table 4.3. Overall, 6 respondents (6.1%) were from Gari Sherdad, 8 (8.1%) from Malakandher, 16 (16.3%) from Mathra, 17 (17.3%) from Palosai, 13 (13.2%) from Panam Dheri, 11 (11.2%) each from Shahi Bala and Urmer Bala, 9 (9.1%) were from Surezai Payan, and 7 (7.1%) respondents were from Wadpaga.

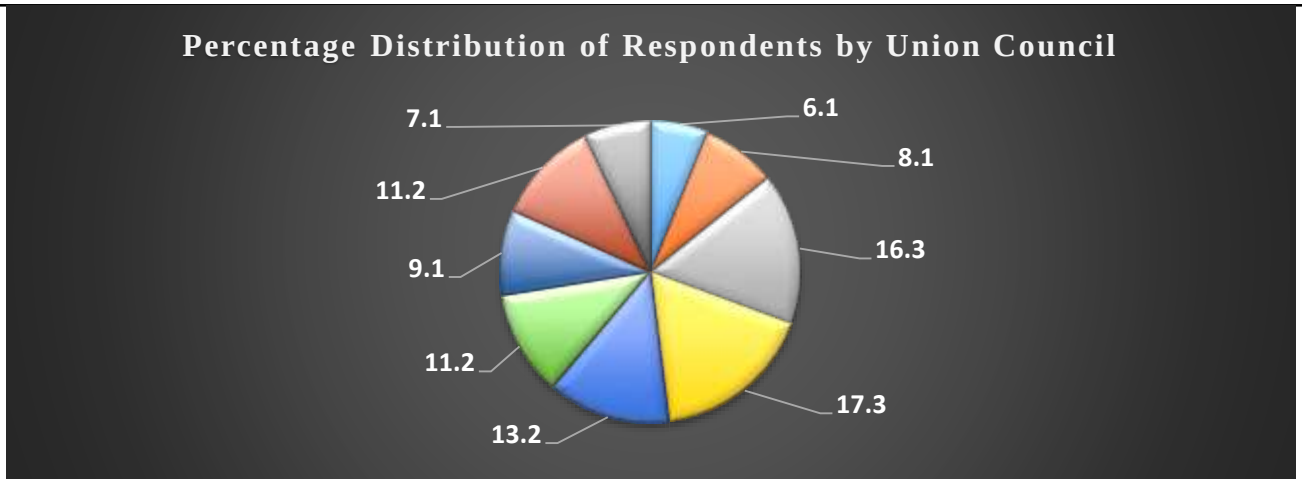

Figure 4.5: Percentage Distribution of respondents UC based

The large coverage of the sample being distributed among nine union councils ensures that we have representativeness and diversity in perspectives about the particular CSA practices documented here. Each UC is geographically and socio-economically different in ways that may influence the uptake and effectiveness of CSA. For example, communities prone to flooding or water shortages may be more likely to accept technologies such as water-efficient irrigation or tunnel farming.

4.2.4. Distribution of Respondents by Education Level

Education Level of Respondents is summarized in Table 4.4. Respondents have a diverse educational profile. The majority of the candidates of the survey in the categories of education that were BA/BSc (16.33%). MA/MSc qualified were 15.31%, FA/F.Sc. (13.27%), and Primary (13.27%). About 11.22% are the matriculated and 10.20% are the middle passed of the population. About (16.33%) of the total have no formal education or illiterate. Those who had MPhil qualifications accounted for only 3.06% of respondents.

Table 4.5: Distribution of respondents by educational level

Education Level	Frequency (n)	Percentage (%)
BA/BSc	16	16.33
MA/MSc	15	15.31
FA/F.Sc	13	13.27
Primary	13	13.27
Matric	11	11.22
Middle	10	10.20
MPhil	3	3.06
No Formal Education	16	16.33
Total	**98**	**100**

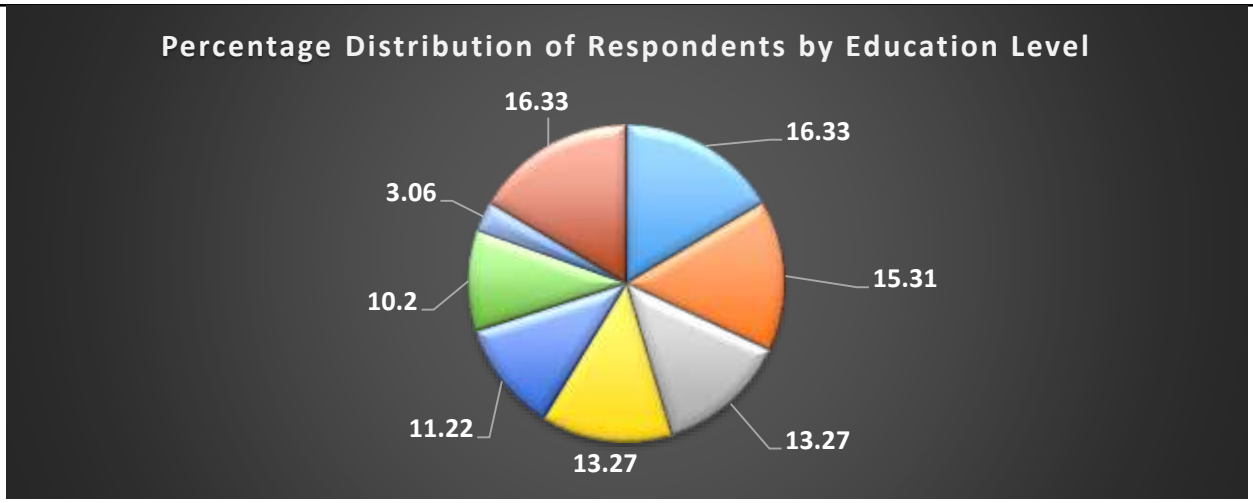

Figure 4.6: Percentage Distribution of Respondents by Education Level

This distribution shows a mix of education levels, with the balance of well-educated individuals and no or very little education. The inclusion of educated respondents is vital because educated individuals are normally more aware of climate change, better decision-makers, and have a proclivity to change to new farming practices and technologies. However, having less educated and uneducated farmers provides participants who reflected the real-life circumstances within rural communities, ensuring the analysis includes perspectives across the literacy scale. Variation such as this allowed the analysis to reveal new insights about how education influences farmers adopting CSA practices.

4.2.5. Awareness Sources of Tunnel Farming (CSA)

Most of the informed farmers who engage in tunnel farming—72 percent—learned about the practice through agricultural projects and non-governmental organizations (NGOs), highlighting the critical role that these organizations show in advancing climate-smart agriculture and bringing pertinent technologies to rural communities (Ali et al., 2021). However, just sixteen percent of the respondents said that government-sponsored workshops and training sessions were the source of their knowledge. This recommends that for public sector extension facilities to effectively reach rural communities, regular efforts and more focus may be needed. The very little effect of digital and informal data sources in the study area is demonstrated by the fact that peer learning reported for 4 percent of knowledge acquisition, compared to just 2 percent from social media and 1 percent from academic study. These results are aligned with those of Jaffar et al. (2024), who revealed that although NGOs often lead awareness campaigns, online outreach and state backing must be combined to increase the acceptance of climate-resilient agricultural technologies in Pakistan. As explained by one FGD participant:

I started farming in 2000, but we were using conventional methods to cultivate common commodities like rice, wheat, sugar cane, and maize. Technical farming, such as tunnel farming, was unknown to us. After that, an NGO visited our neighborhood and gave us a briefing on tunnel farming. However, we didn't think they could explain how a little plot of land could produce a large amount of fruit. They gave practical instructions on all phases, from clearing the ground to harvesting, and we were pleased with the outcome (Participant 7

Table 4.6: Distribution of the respondents Awareness Sources of Tunnel Farming (CSA)

Source	Frequency	Percentage
NGOs	60	68.18%

Training/Workshops	16	18.18%
Government Department	5	5.68%
Friends	4	4.55%
Social Media	2	2.27%
Research (others)	1	1.14%
Total	**98**	**100**

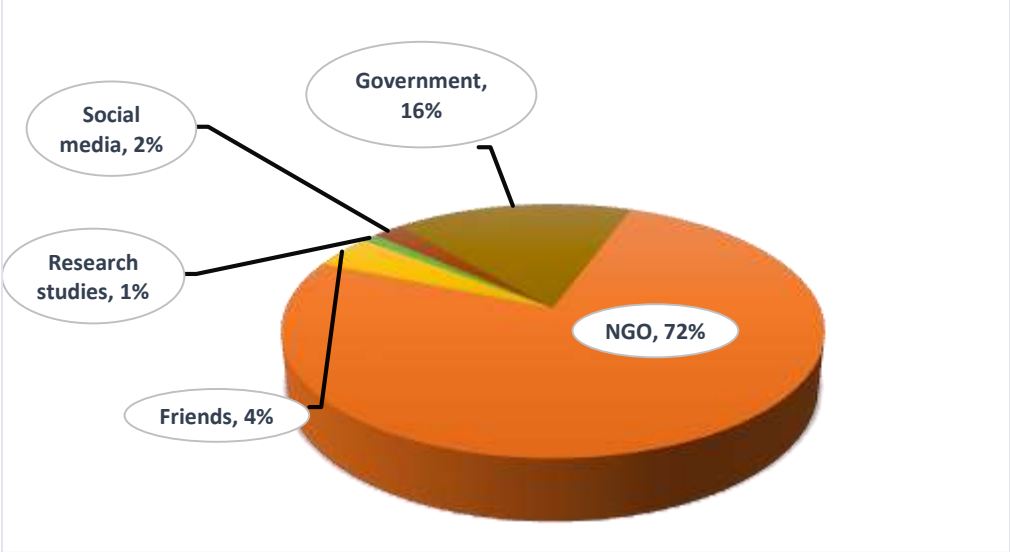

Figure 4.7: Sources of Awareness About Tunnel Farming (CSA)

4.2.6. Yield Distribution of Farmers from Tunnel Farming

The yield analysis of 98 farmers employing 40x12 foot standardized walk-in tunnels reveals a broad range of production outcomes, with 19.4% harvesting 401–500 kg and a significant fraction (20.4%) harvesting between 301–400 kg. These results show promising productivity levels for tunnel farming smallholder farmers. There was some variation in yield, though; 15.3% reported reduced yields (1–100 kg), while a smaller group (2%) experienced total crop harm because of severe weather or livestock-induced tunnel damage. It's interesting to note that variations in yield, even with consistent tunnel size and input support, point to the impact of outside variables like pest control, management techniques, and regional climate. These results are consistent with previous research by Muhammad et al. (2020), who found that post-installation monitoring and training quality were important determinants in yield performance and that tomato produces under protected cultivation systems varied similarly in Khyber Pakhtunkhwa. This variation in results emphasizes the necessity of ongoing professional assistance in addition to infrastructure support to optimize tunnel farming's advantages in climate-vulnerable areas. As explained by one FGD participant:

With CSA practices, we are getting more production from a small portion of land. Before, we needed larger area to grow the same number of crops, but now, even a small space gives us a good yield. It has helped us make better use of our land and increase our income without expanding the farm. The main object is that the crop grows vertically, and the variety is also one of the best for high production (Participant 1).

Table 4.7: Distribution of the respondents on the basis of their production

Yield Range	Number of Farmers	Percentage
0 kg	2	2.0%
1–100 kg	16	16.0%
101–200 kg	11	11.0%
201–300 kg	10	10.0%
301–400 kg	20	20.0%
401–500 kg	20	20.0%
501–600 kg	12	12.0%
601–700 kg	3	3.0%
701–800 kg	3	3.0%
800+ kg	3	3.0%
Total	**98**	**100%**

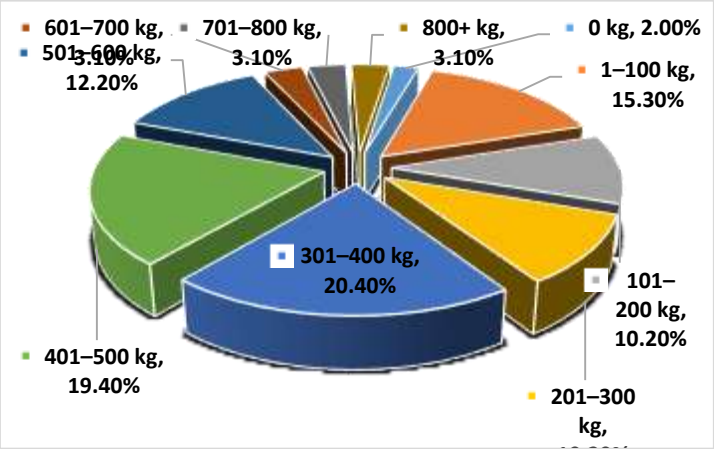

Figure 4.8: Yield Distribution of Farmers from Tunnel Farming (CSA)

4.2.7. Challenges in Adoption CSA

Economic and technical limitations are the main obstacles preventing smallholder farmers from applying tunnel farming. About half of the respondents have cited that the high initial investment is one of the major problems, suggesting that affordability is still a main problem, particularly for farmers with little resources. Furthermore, not being aware of technical knowledge was a concern expressed by 35% of farmers. However, there was also a continuing need for capacity building and practical training, and a lack of access to land (5%) and a lack of access to the market (10%) were also cited as key challenges. These findings are similar to other studies, such as Nawaz et al. (2019), who reported that technical inefficiencies and lack of financial resources are two significant reasons for inactive adoption of climate-smart technology in Khyber, Pakistan, and Punjab. By designing suitable extension services and subsidies, coupled with a stronger link to markets, the challenges of tunnel farming can be met in a way that keeps the practice more sustainable and scalable in fragile agricultural communities. As one FGD participant explained: It is very challenging for us small farmers to initiate tunnel farming because the initial investment is too high. Even if we manage, we don't have the technical knowledge to preserve it properly. Some of us also struggle to find land or a good market for our produce. Without proper support and training, many farmers like us cannot have an advantage fully from tunnel farming (Participant 7).

Table 4.8: Distribution of the respondents on the basis of challenges in the adoptation

Challenges	Number of Farmers	Percentage
High initial investment	47	47.0%
Lack of technical knowledge	33	33.0%
Land Availability	4	4.0%
Limited inputs access in market	15	15.0%
Total	98	100%

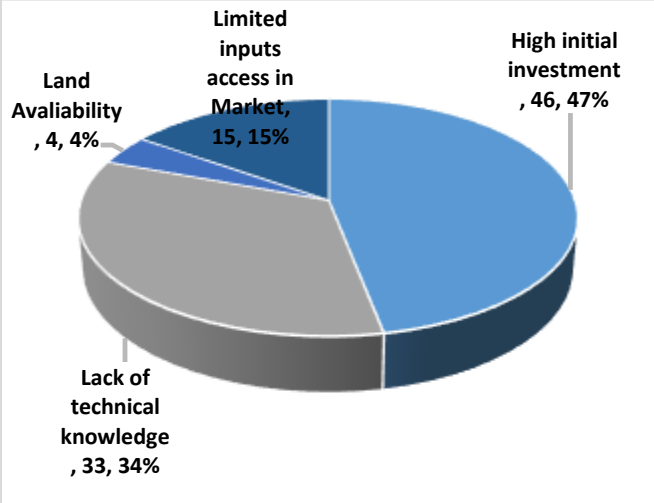

Figure 4.9: Challenges in Adoption of CSA

4.2.8. Motivations for Adaptation

Fig 4.4 The results show that several observable advantages encourage farmers in District Peshawar to hold tunnel farming. Improved production potential was cited as the most persuasive motivation by 35.71% of the 98 farmers polled, confirming tunnel farming's ability to boost revenue and productivity. In the interim, 24.49% of respondents valued the high market value of vegetables cultivated in tunnels, especially because they are available during off-season and fetch higher prices. Another significant driver for 22.45% of farmers was climate resilience, who stated that defending their crops from irregular weather patterns was essential. The longer harvesting window made possible by tunnel systems, which allows a longer marketing time and more foreseeable income, was also highlighted by 19.39% of the respondents. These rewards are consistent with research by Ahmad et al. (2020), which found that tunnel farming was becoming increasingly popular among farmers in Punjab and Khyber Pakhtunkhwa because of its potential to boost profitability, production, and climate change resilience—all of which are important elements of climate-smart agriculture measures. As explained by one FGD

participant:We grew spinach on half an acre in the normal season, but unexpectedly, the small 480 square feet tunnel gave us even more income! The prices were higher too—better than the normal seasonal tomatoes. The best part was that the crop stayed
harmless in the controlled environment, no matter the weather outside. It really showed us the power of tunnel farming (Participant 2).

Table 4.9: Distribution of the respondents on the basis of Motivation in the adoptation

Benefit	Number of Farmers	Percentage
High Market Price	24	24.0%
High Yield	29	29.0%
Long Production Period	18	18.0%
Protection from Climate Change Impacts	29	29.0%
Total	98	100%

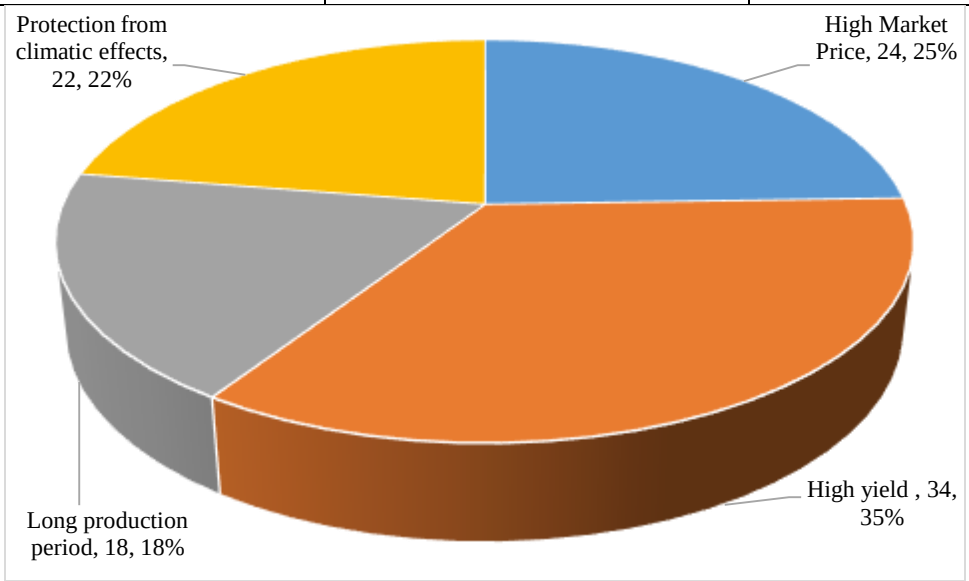

Figure 4.10: Motivations for Adoption

4.2.9. Farmers Support Priorities for Tunnel Farming Adoption

Several important areas are highlighted by the farmers' replies about supportive measures for implementing or enhancing tunnel farming in District Peshawar. Of the 98 respondents, a sizable majority—63.3%—emphasized the necessity of awareness and training initiatives, indicating a general need for more technical capability to efficiently oversee tunnel farming. Also, 18.4% supported government subsidies, highlighting the need for policy-level actions to reduce financial strains. The status of both direct financial assistance for initial setup costs and improved market access was emphasized by an equal 13.3% of farmers, highlighting the necessity of both viable marketing channels and economic support. These results are consistent with former research by Khan et al. (2021), which highlighted the need for market infrastructure development, institutional grants, and farmer education to promote tunnel farming in Pakistan for it to be scalable and sustainable. As explained by one FGD participant:

We're ready to work hard, but most of us don't know where to start with tunnel farming. If we get appropriate training and guidance, we can manage it ourselves. Also, without government help or good market links, it's hard to make a profit even after a good product (Participant 5)

Type of Support	Number of Farmers	Percentage
Better Market Access	13	13.0%
Financial Assistance	14	14.0%
Government Subsidies	19	19.0%
Training and Awareness Program	54	54.0%
Total	**98**	**100%**

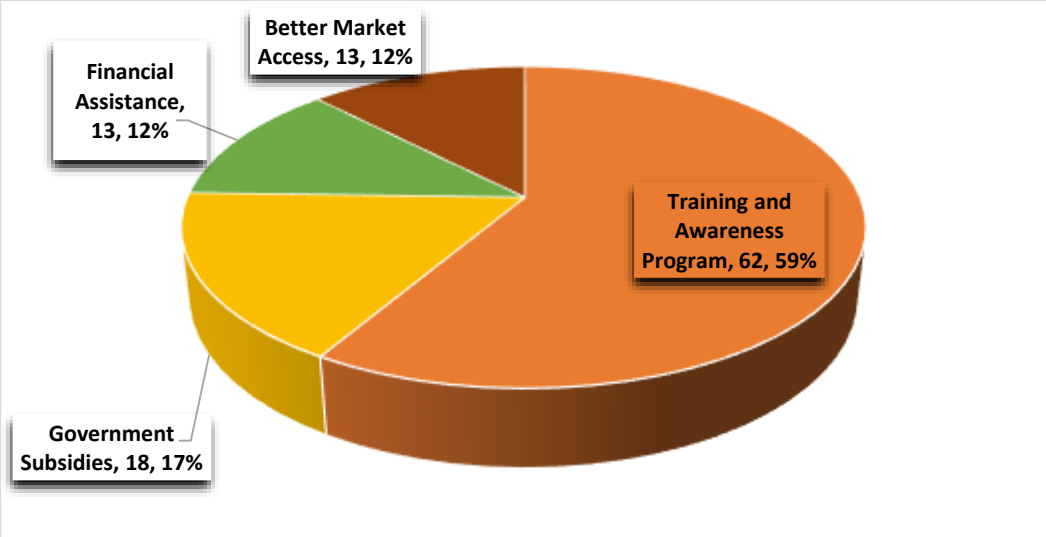

Figure 4.11: Farmers' Support Priorities for Tunnel Farming Adoption

4.2.10. Level of Women's Involvement in Tunnel Farming

A shifting and dynamic role of women in agricultural techniques is exposed by the data on their participation in tunnel farming throughout Peshawar district. Most farmers reported varied levels of participation, although 9.2% reported no female involvement, indicating enduring traditional norms or segregation from agricultural decisions. Interestingly, 14.3% of respondents said that women were totally (100%) involved in tunnel farming, strong female leadership or representing instances of equal household participation. With 10.2% claiming 20% involvement, 25.4% reporting 40%, 18.3% reporting 60%, and the highest group—22.8%—noting 80% participation, intermediate degrees of involvement were also predominant. With many women actively participating in farm labor and management, these figures point to an encouraging trend toward gender inclusion. This change is consistent with research by Ahmed et al. (2020), who found that supporting interventions and changing sociocultural dynamics are encouraging women's participation in climate-resilient farming methods like tunnel farming in Pakistan. As explained by interview participants:

Before, women in our family couldn't contribute much in farming because of cultural and religious limitations. But since we installed the tunnels inside our home, they feel comfortable working in them. The tunnels are protected, so they can manage the crops easily without any hesitation. They are more involved now, and they even make their own

decisions about farming work. It's good to see them taking an active role (Participants 5).

Tunnel farming has made work easier compared to conventional farming. There's no heavy labor involved, so women can participate with more energy and passion. They take care of the crops inside the tunnel, and when there's extra produce, we (men) take it to the market and sell it. The money we earn from it goes directly to them, giving them financial freedom as well (Participant 3).

Table 4.11: Distribution of the respondents on the basis of Level of involvement of women in farming

Involvement Level	Number of Farmers	Percentage
0%	9	9.0%
20%	10	10.0%
40%	20	20.0%
60%	17	17.0%
80%	22	22.0%
100%	22	22.0%
Total	**98**	**100%**

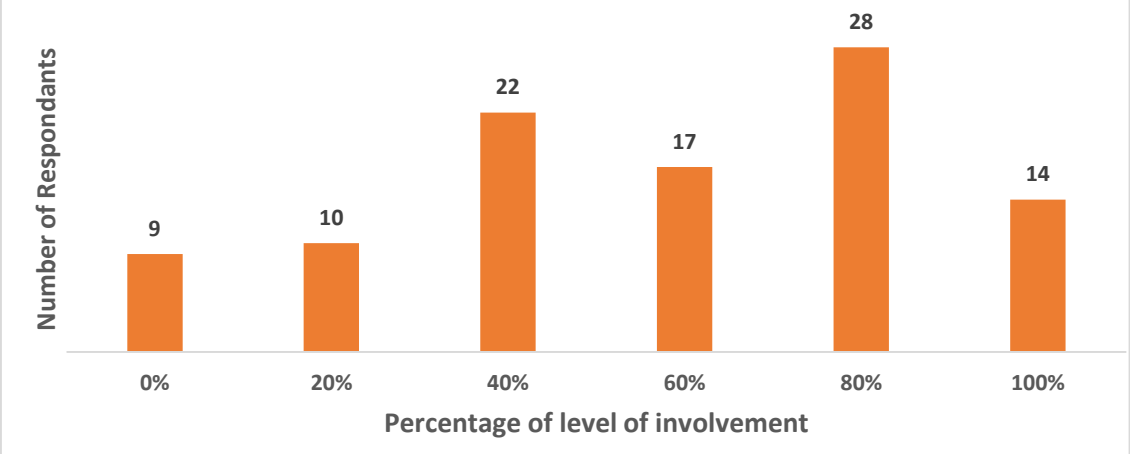

Figure 4.12: Level of Women's Involvement in Tunnel Farming

4.2.11. Reduction in Fertilizer and Pesticide Costs

The results demonstrate how well tunnel farming works to drastically lower the price and usage of pesticides and fertilizers by smallholder farmers in District Peshawar. Of those 98 who responded to the survey, 37 (37.8%) reported a reduction of 80%, 39 (39.8%) reported a remarkable reduction of 120%, and 12 (12.2%) reported a reduction of more than 160%. Only one farmer reported that none of their pastures had changed, and only 12.2% reported a 40% reduction. These significant input reductions can be credited to the organized training that has been given in this project and the related advice on which brands to use, how, when, and with which practices to incorporate into Integrated Pest Management (IPM). This falls in line with the worldwide statistics, such as those reported by FAO (2021), that validate that the practice of climate-smart and tunnel farming leads to greater resource efficiency (by minimizing the loss of inputs), environmental sustainability, and profitability through interventions and knowledge-based methods. According to one FGD participant:

Before this tunnel farming, we sprayed and used fertilizer without any concept. After training, they told us which brand, how much, and when to use. We use less, save more money, and our vegetables

taste better. This really simplified matter for us. (Participant 4).

Table 4.12: Distribution of the respondents on the basis of level of reduction in fertilizers and pesticides cost

Reduction Level	Number of Farmers	Percentage
0%	1	1.0%
20%	11	11.0%
40%	27	27.0%
60%	38	38.0%
80%+	8	8.0%
Not sure / Others	15	15.0%
Total	**98**	**100%**

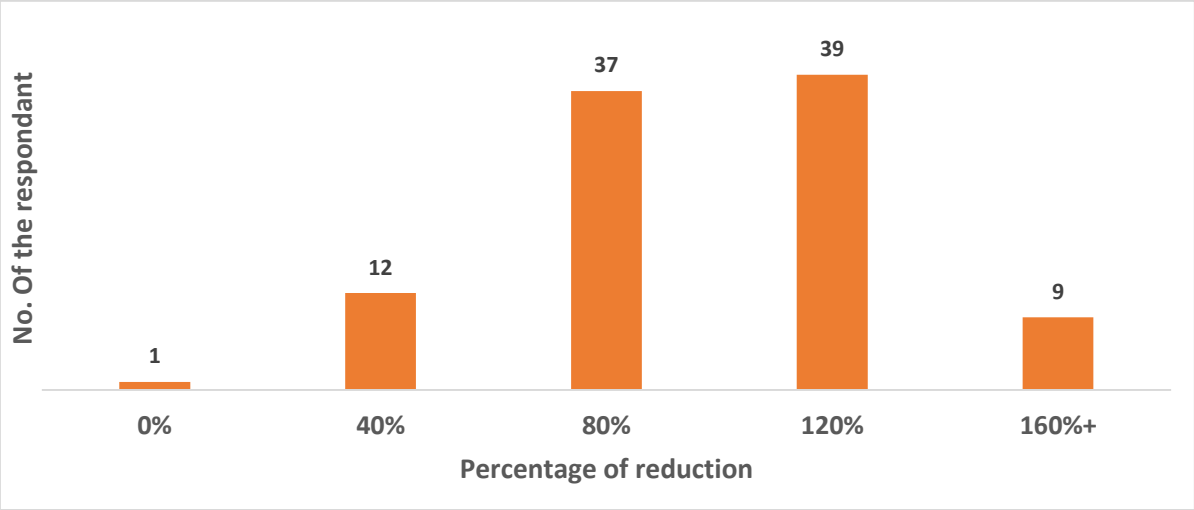

Fig 4.13: Reduction in Fertilizer and Pesticide Costs and use

5. CONCLUSION, FINDINGS AND RECOMMENDATIONS

5.1. Conclusion

The study clearly shows that Climate-Smart Agriculture (CSA) is a very fruitful and sustainable approach for raising agricultural resilience, productivity and profitability in Peshawar District, especially when executed with walk-in tunnels. According to the cost-benefit analysis (CBA) off-season production, better quality, and lower losses resulted to a significant rise in tomato production, up to 270% higher as compared to conventional methods. Due to farmer training and the cost and use of fertilizer and pesticide have significantly reduced. Non-Government Organizations (NGOs) and government programs improved the implementation of climate-smart agricultural practices and the comprehension of climate-smart agricultural practices for smallholder farmers particularly for women. Qualitative data from focus group discussions (FGDs), key informant interviews (KIIs) and surveys illustrated the evidence to confirm the adoption of climate-smart agricultural practices was certainly benefitting environmental sustainability with a reduction in the need for chemical use and reliance on inputs. Therefore, our study concluded that climate-smart agriculture is promoting a socially and economically inclusive pathway, as well as a technical innovation for producing climate resilient food for smallholders in highly vulnerable areas like Peshawar.

5.2. Major Findings:

- Walk-in tunnel farming under CSA tomato per 480 square feet produced 797 kg, extrapolated to 72,310 kilogram per acre—270% higher than the 19,511 kg/acre yield of conventional methods.
- Net income per tunnel was 271% higher due to increased yield and better market prices (82 PKR/kg vs. 45 PKR/kg).
- Farmers experienced a 40–160% reduction in pesticide and fertilizer costs due to advance training and input management.
- CSA practices led to more efficient use of water and other inputs, reducing economic and environmental burdens.
- Women's engagements in farming activities increased under CSA, enhancing income and food security at the household level.
- Off-season production in tunnels gave farmers a strong market advantage and reduced their exposure to seasonal risks.
- Most knowledge transfer occurred through project staff, NGOs, and field training, underlining the role of extension services.
- The use of plastic mulch and packaging raises environmental alarms, suggesting the need for biodegradable alternatives.

5.3. Recommendation

- With a focus on smallholders and underprivileged farmers, extend CSA walk-in tunnel farming to other districts of KP that are at risk.
- Provide subsidies and loans to cover the upfront expenses of crop nets, mulch, and tunnels.
- Encourage adoption of drip-irrigation in CSA tunnels to improve water efficiency and reduce wastage.
- Organize frequent community-based training on irrigation, IPM, tunnel management, and CSA procedures.
- Encourage ecosystem friendly packaging and biodegradable mulch to cut down on the plastic waste that is seen in CSA fields.
- As demonstrated in project areas, assurance women's involvement in CSA through inclusive training and assistance.
- Increase knowledge of the benefits and market potential of CSA through local media and extension services.
- By creating storage and farmer-market connections, you may elevate market accessibility and lower post-harvest losses.
- For ongoing financial and institutional support, incorporate CSA into regional agricultural policies.
- Set up routine impact monitoring to measure yield, income, and gender participation.

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