Greenhouse Technology: Agriculture Reality in Cold Arid Ladakh

Dissertation submitted to the Panjab University, Chandigarh for the award of degree of Executive Masters in Public Administration and Public Policy, in partial fulfilment of the requirement for the Advanced Professional Programme in Public Administration (2023-24)

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CERTIFICATE

I have the pleasure to certify that **Air Commodore V Anil Kumar** has pursued his research work and prepared the present dissertation titled "**Greenhouse Technology: Agriculture Reality in Cold Arid Ladakh**" under my guidance and supervision. The same is the result of research done by him and to the best of my knowledge; no part of the same has been part of any monograph, dissertation or book earlier. This is being submitted to the Panjab University, Chandigarh, for the purpose of Executive Masters in Public Administration and Public Policy in partial fulfilment of the requirement for the Advanced Professional Programme in Public Administration (APPPA) of Indian Institute of Public Administration (IIPA), New Delhi.

I recommend that the dissertation of Air Cmde V Anil Kumar is worthy of consideration for the award of Executive Masters in Public Administration and Public Policy of the Panjab University, Chandigarh.

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DECLARATION

I hereby declare that the work presented in this thesis titled "Greenhouse Technology: Agriculture Reality in Cold Arid Ladakh" submitted for admittance to the Executive Masters in Public Administration and Public Policy, Panjab University, Chandigarh has been carried out under the guidance and supervision of Prof (Dr) Ashok Vishandass. This work has not been submitted to any other university for the award of Degree, Diploma or Certificate, in part or full.

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List of Acronyms and Abbreviations

ASSOCHAM	: Associated Chambers of Commerce and Industry of India
CO_2	: Carbon-dioxide
CSS	: Centrally Sponsored Scheme
DIHAR	: Defence Institute of High Altitude Research
DRDO	: Defence Research Development Organisation
FPO	: Food Processing Order
FRP	: Fiber Reinforced Plastic
IAS	: Indian Administrative Service
J&K	: Jammu and Kashmir
KVK	: Krishi Vigyan Kendra
LAHDC	: Ladakh Autonomous Hill Development Council
MODI	: Mission Organic Development Initiative
NFSM	: National Food Security Mission
NGO	: Non-Governmental Organisation
NMAET	: National Mission on Agricultural Extension and Technology
NMSA	: National Mission on Sustainable Agriculture
NMOOP	: National Mission on Oilseed sand Oil-Palm
PKVY	: Paramparagat Krishi Vikas Yojana
PM-KISAN	: Pradhan Mantri Kisan Samman Nidhi
PMKSY	: Pradhan Mantri Krishi Sinchayee Yojana
RKVY	: Rashtriya Krishi Vikas Yojana
R&D	: Research and Development
SHG	: Self Help Group
SHM	: Soil Health Management
USD	: United States Dollar
UT	: Union Territory
UV	: Ultra Violet

ABSTRACT

Ladakh, encompassing 90% of India's cold arid region, faces a unique agricultural challenge. Its harsh climate allows farming for only four months, leaving villages with limited access to fresh vegetables during the eight-month winter. While traditional storage methods like vegetable cellars and pickling exist, most winter diets rely on meat, pulses, and dairy, leading to potential nutritional deficiencies.

To address this, farmers are increasingly adopting innovative solutions. Greenhouses, supported by government subsidies, enable year-round vegetable production, benefiting both personal consumption and supplying the region's defense personnel. However, their high cost necessitates alternatives like low-tunnel technology, costing only Rs 2,000 and offering portability.

For high-altitude areas of Ladakh, trench farms, known as "poor man's greenhouses" provide a cost-effective option for cultivating herbs and vegetables. Additionally, mulching techniques using plastics, pipes, and greenhouse glazing have been successfully employed to cultivate watermelons and muskmelons with high sugar content. These successful trials are now being adopted by local farmers, further diversifying their agricultural capabilities.

By embracing these innovative technologies, Ladakh's farmers are not only improving their own food security and nutrition but also contributing to the region's self-sufficiency and economic development. Ladakh's farmers are embracing a diverse range of greenhouse technologies to tackle the region's challenging climate. From traditional mud-walled and plastic sheet structures to modern polycarbonate and FRP greenhouses, each option offers unique advantages.

In 2021, the Defence Institute of High Altitude Research (DIHAR) revolutionized the scene with the Ladakh Greenhouse, a highly efficient passive solar design. This unique technology which has several advantages over the traditional greenhouses and after proving its effectiveness to grow vegetables in winter and summer was transferred to the Agriculture Department for large scale establishment of greenhouses in farmers' fields. The technology has proven its ability to cultivate vegetables year-round and has been widely adopted by the farmers with active support of Agriculture

Department. The initiative received the Prime Minister’s Award for Excellence in Public Administration under the Innovation category in the year 2022.

Moving forward, the focus needs to shift towards optimising the potential of these greenhouses. While household consumption remains important, exploring commercial and Hi-tech options will unlock further economic benefits. Diversification strategies should prioritize high-value crops with expanding domestic and international markets, ensuring sustainable growth for Ladakh's agricultural sector.

The study reveals a remarkable transformation in Ladakh's agricultural landscape, primarily due to the Ladakh Greenhouse technology, a collaborative effort between Defence Institute of High Altitude Research (DIHAR), an acclaimed lab of Defence Research Development Organisation (DRDO) located in the region and the Administration of UT Ladakh. These innovative year-round greenhouses empower farmers with a threefold increase in production, allowing them to cultivate a wider variety of vegetables even during harsh winter months. Compared to traditional open fields, yields have almost tripled from 1.6 kg per plant to 4.5 kg leading to a significant increase in farmers’ income to the tune of Rs. 60,000-80,000 per greenhouse annually. This not only enhances food security and reduces hidden hunger in the region but also ensures access to fresh produce even in remote border villages. The UT administration plays a crucial role in promoting greenhouse adoption through subsidies, quality seeds, and composting units. Challenges like aphid infestation and water scarcity are actively addressed through good agricultural practices, subsidized borewells, and the introduction of low-cost greenhouse alternatives. With plans to build an additional 6457 greenhouses in the next five years, the future of Ladakh is is poised to be on higher trajectory of growth on sustainable basis.

CHAPTER-1

INTRODUCTION

1.1 Introduction

Ladakh is characterised by a rugged topography of high mountain region with its typical elevation of exceeding 3000 m above sea level. The Great Himalayan Range alienates it from the Indian subcontinent with Karakoram Range at on its north. The expanse is distinguished with intense temperature differences and low precipitation. Snow, high wind velocity, thin plant density, lean atmosphere with high UV-radiation and delicate ecosystem are peculiar to the region. In winters, the temperature goes to as low as -30ºC. The annual cropping season is cut down due to lengthy and harsh winters to only four to five months. Here single-cropping prevails. Feasibility of double-cropping exists only in a limited area that is below around 3000 m of height. Agriculture is entirely dependent on irrigation. More than half of the year the region remains cut-off due to intense snowfall. Due to lack of locally grown fresh vegetables which are available only during summer months, the food consumption of locals suffers dietary deficiencies. The accessibility to fresh vegetable dwindles considerably during the extended winter periods here, thus resulting in imbalance of dietary intake. Shortfall in micronutrients and deficiency in intake of vital vitamins namely vitamin A, vitamin B6 and vitamin B12 and folic acid are more common in the region. Many communities experience "hidden hunger" due to seasonal food shortages and limited variety leading to micronutrient deficiencies.

Achieving food self-sufficiency in the region proves challenging due to the significant gap between what's locally produced and what's necessary to meet the demand. Transporting essential agricultural commodities across the Himalayas adds to the challenge. During summer, trucks traverse difficult terrain routes as high as 5,300 meters above mean sea level, covering 480 km from Manali or 420 km from Srinagar to Leh. Winter, however, paints a different picture. Fresh vegetables become a luxury, flown in from Delhi or Chandigarh at exorbitant air freight costs of Rs 80-100 per kg. Such high prices lead to 2.7 times higher retail prices in Leh compared to Delhi. The

situation clearly highlights the immense hurdles faced in ensuring food security in the region.

In Ladakh's harsh winters, growing leafy greens seemed impossible until the arrival of passive solar greenhouses. The first attempt, a glasshouse in 1964, struggled with logistics, cost, and expertise. To counter these issues, innovative minds at DRDO's Defence Institute of High Altitude Research (DIHAR) developed the low-cost trench greenhouse in the late 1960s, inspired by trench warfare. Its openness and lack of wall protection, however, exposed it to stray animals, limiting its widespread adoption.

Later, a more practical solution emerged in the form of the Ladakh Greenhouse. Combining mud walls on three sides with a south-facing plastic cover and a roof on the north, it offered ease of construction and superior heat retention. This allowed spinach, lettuce, and coriander to thrive even in winter, making it a favorite among farmers. Government incentives further boosted its popularity.

Standardized greenhouse practices now empower cultivation of early nurseries, winter greens, and even summer vegetables of diverse climates. Besides the iconic Ladakhi design, numerous other passive solar greenhouse structures have been successfully tested in Ladakh's rugged terrain, demonstrating the adaptability and potential of this technology. Against this backdrop, this paper endeavors to study various aspects of greenhouse technologies in trans-Himalayan cold arid Ladakh region, overall impact of schemes for adoption of the technology and improvements this has brought in agri production in the region.

1.2 Statement of the Problem

Extreme temperatures pose intense challenges for open-field crop production throughout year in the cold arid regions of Ladakh. During the extreme and long winters availability of locally grown fresh crops is restricted and is a cause of concern for food security and nutrition. Beside this, the farmers have very limited opportunity to earn income through agriculture. Greenhouse technology is one solution for sustainable crop production in this region of such harsh climates. Various types of greenhouses technologies are available globally which are being implemented in Ladakh. Despite growing popularity for winter vegetable and spring nursery

production, current greenhouse designs in Ladakh face limitations. While successful for select leafy greens and root crops in winter, these structures often become unusable in summer due to excessive heat buildup. Recognizing this, researchers have experimented with various passive solar greenhouse designs suitable for the harsh trans-Himalayan environment. However, further improvements are crucial to enhance economic viability and technological feasibility, particularly for diversifying winter crop production and maximizing year-round usage.

There is a need to examine various types of greenhouses commonly employed in trans-Himalayan Ladakh viz a viz their individual designs, advantages, limitations and identify most suitable ones which can take on the challenges of high altitude regions of Ladakh and facilitate adequate qualities of crop cultivation for farmers throughout the year especially the harsh winter periods. Technological innovations to mitigate these challenges need to be explored and government schemes examined to promote adoption of greenhouse technologies in agriculture so that crop cultivation not only addresses the nutritional requirements of the population in the region especially during the harsh winter times but also enhance the income for farmers from agriculture.

1.3 Research Objectives

The objectives of the research are:-

(I) To study implementation of different types of greenhouse technologies in crop husbandry in the cold arid mountain regions of Ladakh.

(II) To study changes in agriculture production in Ladakh due to adoption of greenhouse technologies and its economic impact.

(III) To examine the advantages, effectiveness and limitations of greenhouse technologies in mitigating the challenges of long and extreme winters in the regions of Ladakh.

1.4 Research Strategy and Research Design

The study seeks to provide insights into various greenhouse technologies employed in Ladakh region. The Agriculture Department of Administration of Union Territory of Ladakh has been serving the farming community of the region from disseminating scientific technologies for increasing the crop production, seed distribution, supply of farm machineries, off season vegetable cultivation, introduction of new vegetable varieties. Various schemes of UT Ladakh are promoting adoption of greenhouse technologies by the farmers. Its impact in improving the living standard of the people and boosting the economy of the farmers during the course of time needs to be assessed.

The research approach is by use of both qualitative and quantitative research methods with descriptive research design. The research is based on primary data collected through two questionnaires canvassed, one to the farmers of the region and the other to Department of Agriculture Ladakh. Secondary data sources are the data published/released by Agriculture Departments of the Centre, State/UT, relevant research papers, articles and journals, analysis of related Government policy documents, published reports and other study reports.

1.5 Rationale / Justification

Agriculture in cold arid region of Ladakh presents many challenges and greenhouse technologies may help contain or mitigate these challenges. Greenhouse crops during winter months in the high altitude areas of Ladakh is a formidable challenge and the production is limited to about three months in summer. Therefore, the vegetables/crops have to be imported at high costs in winters. Higher prices hits harder to resource poor people. There are over 300 sunny days per year, so potential exists to use greenhouses in winter. Technological innovations could make cultivation possible throughout the year, with possibility of scaling up for commercial exploitation. These greenhouses were tried with some success due to inadequate adaptation to local conditions. With various technologies available and government schemes for farming, the greenhouses are expected to bring better nutrition and better

life to local people and higher income to the farmers. The overall impact of the use of greenhouse technologies needs a closer examination.

The research seeks to explore linkages between promoting greenhouse technologies in agriculture schemes and its economic impact on the people in the region. The outcome of the research will provide a greater understanding of implementation of greenhouse technologies in ensuring self-sufficiency of nutritional crops in Ladakh region and enhanced earnings to the farmers.

1.6 Research Questions

The research questions are as under:-

(a) What are the different greenhouse technologies practiced in the cold arid region of Ladakh?

(b) What improvements greenhouse technologies have brought in agriculture production in the Ladakh region?

(c) What are the advantages, effectiveness and limitations of greenhouse technologies in mitigating the climatic challenges of Ladakh?

(d) What is the overall impact of various schemes of the government for greenhouse technology adoption on crop production in Ladakh?

A well thought out and technologically appropriate application of greenhouse for crop cultivation by Ladakhi farmers would make increased availability of nutritional crops at lower prices throughout the year and increase in the farmers' income from their farm output even during the periods of extreme weather conditions of winter season.

1.7 Chapterisation Scheme

The dissertation is organised as under:-

(a) **Chapter 1: Introduction** provides a brief overview of agriculture economy in Ladakh region including challenges faced by the sector in the cold arid regions and importance of greenhouse technology in dealing with these challenges. The chapter will also lay down the Statement of Problem, Rationale or Justification for the study, Research Design, Research Objectives and Research Question.

(b) **Chapter 2: Literature Review** presents brief review of relevant academic work that has been undertaken.

(c) **Chapter 3: Greenhouse Technology for Agriculture in Ladakh** briefly touches upon the traditional agricultural practices in Ladakh, their limitations and constraints. It outlines types of greenhouse technology employed in Ladakh, advantages of greenhouse farming in the cold arid regions and challenges specific to implementation of greenhouses in Ladakh.

(d) **Chapter 4: Impact and Challenges of Greenhouse Farming** covers the benefits and impacts of greenhouse farming over a range of aspects like crop yield and diversity, economic benefits to farmers, sustainability and resource conservation besides dwelling on the challenges and constraints of greenhouse farming.

(e) **Chapter 5: Public Interventions in Promoting Greenhouse Technology in Agriculture**. This chapter delineates the support and incentives for greenhouse farming including NGOs and international organisations. Effectiveness of policies and schemes for technology adoption for agriculture in the region are also studied to understand their overall impact in the region and what improvement the greenhouse technology has brought out in agriculture production in Ladakh.

(f) **Chapter 6: Conclusion and Recommendations** presents conclusions and recommendations.

1.8 Scope / Limitations/ Delimitations

The study seeks to draw from primary and secondary data sources. Given the paucity of time, resources and harsh climate in the region, the study leaves collection of primary data through two questionnaires. The study dwells into greenhouse technologies that are adopted/used in the Ladakh region with the support of local government. The study is limited in scope in that the details available as open source information and alongwith primary and secondary data information are used for analysis. The study remains focussed on the technologies already implemented in the region and its impact on locals. It does not cover the technologies available in other parts of the world and unnecessary details of these are avoided.

1.9 Research Methodology

The research methodology adopted is qualitative and quantitative with the data gathered from primary and secondary sources. The research would be descriptive, analytical and empirical as applicable to some aspects being analysed.

1.10 Sources of Data/Information

Academic literature including articles, journals and previous research work on the subject available with the IIPA library including those by individual researchers and various research agencies would be utilised as secondary data. Information from government policy documents, Reports of Krishi Vigyan Kendras (KVKs), ASSOCHAM and available information on the subject on the internet will also be exploited.

CHAPTER-2

REVIEW OF LITERATURE

2.1 Introduction

As in any research work, this study identified relevant literature on the subject and reviewed them. The current chapter delves into an extensive literature review conducted for the dissertation. This comprehensive review aims to provide a thorough understanding of the existing body of knowledge surrounding the research topic. Through a meticulous examination of academic journals, books, and other relevant sources, the literature review synthesizes the key findings, theoretical underpinnings, and methodological approaches employed in previous studies. This in-depth exploration of the literature serves to establish the context for the present research, identify gaps in knowledge, and pave the way for a meaningful contribution to the area of research.

2.2 Details of Studies/Reports/Journals

The following literatures in terms of books, articles and research papers have been reviewed:-

2.2.1 Aseeya Wahid et al (2022)[1] in their thesis observes that the the Ladakh region's diverse climate-adapted farming practices, highlighting greenhouses and polyhouses that enable year-round vegetable cultivation. The study carried out in districts Kargil and Leh comes out with status of different such protected cultivation through survey of farm households from a selected village in Kargil and Leh with different land holding sizes. The study through a detailed survey observes that the cultivation of vegetables like sweet pepper, cucumber, brinjal, and chilies in summer under polyhouses is picking up. The production of vegetables had marked increase inside the polyhouses compared to the outside cultivation. It delves into methods of protected cultivation adopted in the region and brings out the significance of

[1] Wahid, A., Ali, A., Dixit, J., & Shukla, R. M. (2022). Prospect of protected cultivation under cold arid region of Ladakh, India: Status and future prospect.

greenhouse technology for sustainable development in the hilly region. Beyond simply making off-season greens accessible, this technology, bolstered by government and non-governmental initiatives, presents exciting possibilities for even less privileged farmers. The implementation of financial assistance programs, such as low-interest loans, could significantly enhance the adoption of these transformative technologies, empowering even resource-constrained farmers to reap the benefits of protected cultivation. By bridging the financial gap, such programs have the potential to unlock a wider range of agricultural possibilities for the Ladakhi community, fostering a more sustainable and food-secure future Research methodology adopted is quantitative exploratory. Research gap: The advantages, effectiveness and limitations of greenhouse technology in mitigation of climatic challenges of the region is not discussed.

2.2.2 Aqleema Banoo et al (2022)[2] in their thesis observe that execution of protected cultivation present huge opportunity and it supports small-scale farmers of cold arid region of Ladakh. It discusses criteria to determine site for farming under different protected cultivation construction and estimates that the yield under greenhouse farming can reach around 4-5 times that of open field. The study delves into practices of protective cultivation adopted as a cropping procedure wherein the micro climate around the plant is controlled, as per the specific need of the variety of the plant that is grown, during their period of growth and has the ability to generate variety of fresh vegetables even in harsh winter. It studies different methods within these techniques and among these, identifies greenhouses as extremely useful for round-the-year vegetable husbandry in the Ladakh region. It observes that though implementation of these protected cultivation technologies has the potential to improve the livelihood security of the farmers, there is lack of awareness amongst them which is limiting adoption of these technologies. The study exhorts that the farmers should think of adopting polyhouses instead of working in the open fields. Research methodology adopted is qualitative descriptive. Research gap: The economic impact of schemes of technology adoption on agriculture is not discussed.

[2] Banoo, A., Hussain, S., Khan, F. S., Rasool, S., Dar, R. D., & Rasool, R. S. (2022). A review on economic aspect of protected cultivation in Ladakh.

2.2.3 Sindhu V and Ranjit Chatterjee (2020)[3] in their study discuss various aspects of vegetable cultivation to identify approaches that maximize financial viability and profitability. The authors examine the use of different protected structures for off-season vegetable production. This include growing of summer vegetables in winter months, growing winter vegetables in summer months and winter vegetables in rainy seasons. It also discusses various challenges faced by the farmers in off-season vegetable production under protected structures also citing the lack of awareness among farmers about the possibilities of protected vegetable production which is impeding cultivation on a large scale. Research methodology adopted is mixed approach. Research gap: The schemes for technology adoption on agriculture production and their overall impact is not discussed.

2.2.4 Angmo et al (2019)[4] in their paper brings out that almost every household in Ladakh have a greenhouse and these need to have ingenious designs in order to make it cost effective and technically sound to cultivate different crops particularly in winter periods. Various types of passive solar greenhouses and their components are discussed in detail including pros and cons of each of these structures. The study covers varying temperature, humidity conditions, light intensity etc inside the greenhouses and the marketable yield and production of vegetables under such varying parameters. A door-to-door survey by the authors found that the passive solar greenhouses are used by farmers in winter and spring seasons but they remain unused in summer months. They observe that there is a vast scope to improve designs of greenhouse so that the constraints to grow crops can be overcome. Research methodology adopted is mixed approach. Research gap: The schemes for greenhouse technology adoption on agriculture production and their overall impact is not discussed.

[3] Sindhu, V., & Chatterjee, R. (2020). Off-Season vegetable cultivation under protected structures: a promising technology for doubling farmer's income. *Int. Arch. App. Sci. Techno*, *11*, 208-214.

[4] Angmo, P., Dolma, T., Namgail, D., Tamchos, T., Norbu, T., Chaurasia, O. P., & Stobdan, T. (2019). Passive solar greenhouse for round the year vegetable cultivation in trans-Himalayan Ladakh region, India. *Def Life Sci J*, *4*(2), 103-116.

2.2.5 Negi et al (2013)[5] in their study argues protected cultivation as the only appropriate technology to cultivate vegetables in high-altitude regions like trans Himalayan regions. The study is carried out in high altitude Garhwal Himalaya region. In the study experiments are undertaken on the effectiveness of protected cultivation for brinjal, beans, cabbage, capsicum, cauliflower, coriander, peas and tomato, further making evaluation of the yield to farmers across diverse geographical terrains, ranging from the air-thin heights of the mountains to the lower elevations with varied climates. The study also highlights how capacity development of cultivators in off-season and protected vegetable farming would provide a sustainable livelihood alternative for locals in the region. Research methodology adopted is qualitative exploratory. Research gap: The greenhouse technology adoption schemes on agriculture production and their overall impact not covered in the study.

2.2.6 Ummyiah et al (2017)[6] in their paper discuss the great potential of protected cultivation techniques of vegetables in offering quality, productivity and favourable prices in the market for cultivators thus increasing their income in off-seasons. In the study, the authors observes various pros and cons of greenhouse, however, the lack of awareness about the greenhouse technology and illiteracy are cited as major impediments for the technology not getting the necessary adoption. The study provides certain suggestions to overcome these shortcomings, how to push for technology adoption in the region and harvest its full potential. The study recommends considerations in site selection for greenhouse cultivation further highlighting how crop productivity is influenced by different components of crop micro-climate around it. The study brings out significance of raising healthy nursery for successful growing of crops and healthy harvesting of greenhouses' full potential with specific reference to common vegetables namely tomato, sweet pepper and cucumber. Research methodology adopted is mixed approach. Research gap: The greenhouse technology adoption schemes on agriculture production and their overall impact not covered in the study.

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[5] Negi, V. S., Maikhuri, R. K., Rawat, L. S., & Parshwan, D. (2013). Protected cultivation as an option of livelihood in mountain region of central Himalaya, India. *International Journal of Sustainable Development & World Ecology*, *20*(5), 416-425.

[6] Ummyiah, H. M., Wani, K. P., Khan, S. H., & Magray, M. M. (2017). Protected cultivation of vegetable crops under temperate conditions. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1629-1634.

2.2.7 Dame Jiliane (2018)[7] in his article brings out the prospect of vegetable production in cold arid region of Ladakh. It outlines achievements in the vegetable production scenario in the region wherein it has progressed from need driven to market driven as against what was prevailing before 1990s and where DIHAR, Leh has played a very significant role in terms of technology perfection in cultivation, quality and standardisation of seeds/vegetables. The paper suggests measures for making the region self reliant in agriculture with feasible strategies that could be adopted to improve financial capacities of people in the region. Greenhouse technology adoption and enhancing winter vegetable production in this cold region is one such measure cited in the paper. Research methodology adopted is qualitative and exploratory. Research gap: The greenhouse technology adoption schemes on agriculture production and their overall impact not covered in the study**.**

2.3 Conclusion

The review of literature from the above sources clearly brings out that research gap exists regarding understanding of the advantages, effectiveness and limitations of greenhouse technology in mitigation of climatic challenges of the region. Also the schemes of technology adoption on agriculture in the region are not found to have covered in any literature including its economic impact in the region. Therefore, the study is duly justified to examine these important issues.

[7] Dame, J. (2018). Food security and translocal livelihoods in high mountains: Evidence from Ladakh, India. Mountain Research and Development, 38(4), 310-322.

CHAPTER-3

GREENHOUSE TECHNOLOGY FOR AGRICULTURE IN LADAKH

3.1 Introduction

Ladakh, a high-altitude desert region in the Himalayas, is home to a unique and resilient agricultural system. Traditional agricultural practices in Ladakh have been developed over centuries to adapt to the region's harsh climate and limited resources. These practices are characterized by their sustainability and their close integration with the natural environment.

3.2 Key Features of Traditional Agricultural Practices in Ladakh[8]

One of the key features is that agriculture here is primarily *subsistence-based*, where farmers produce food primarily for their own consumption. This focus on self-support has helped to ensure food security in the region. Farmers practice *crop rotation* to maintain soil fertility which also helps prevent pest and disease outbreaks. Common crops that undergo crop rotation are barley, wheat, peas, and beans. *Animal integration* is practiced with livestock playing an important role in traditional Ladakhi agriculture. Animals are used as they provide manure for fertilization, traction for plowing, besides milk and meat for food. Water is a precious resource in Ladakh, therefore, *water conservation* is innately practiced by the farmers by means of a variety of techniques to conserve it. The techniques practiced include irrigation channels, field bunds, and rainwater harvesting.

3.3 Limitations_and Constraints of Traditional Agricultural Practices in Ladakh

Traditional agricultural practices in Ladakh, despite their many advantages, face a number of limitations and constraints[9]. The most important problem is the *harsh*

[8] Stobdan T (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development. Beeja House, New Delhi, India

climate of the high altitude of Ladakh where short growing season and cold temperatures make it a challenging environment for agriculture. Another major issue is the limited water resources, *water scarcity* being a major constraint on agricultural production in Ladakh. Soil erosion and nutrient depletion are other problems in the region resulting in *soil degradation*. Farmers in Ladakh often have *difficulty accessing markets* for their products and this is a severe limitation. Traditional agriculture is also facing the brunt of *climate change* which is posing new threats in Ladakh, including increased temperatures, more extreme weather events, and changes in precipitation patterns.

Future of traditional agriculture in Ladakh is uncertain. While these practices have a long history of sustainability and resilience, the region is facing a number of challenges that include climate change, population growth, and economic globalization. To ensure sustainability of traditional agriculture of Ladakh, the limitations and constraints of these practices are required to be addressed with a combination of traditional knowledge and modern technology.

For the future of traditional agriculture in Ladakh, some specific recommendations would be by way of promoting sustainable land management practices (through practices like soil conservation, water harvesting, and afforestation), developing drought-resistant crop (which could facilitate reduce impact of climate change on agriculture), improving of access to markets (that could enable farmers to get better prices for their products) and investing in education and training (to help farmers to adopt new technologies and practices) would be the right approach. The limitations and constraints of traditional agriculture in Ladakh if addressed in this manner, will ensure that this unique and resilient system carries on to thrive for generations to come.

3.4 Passive Solar Greenhouses in Ladakh

Greenhouse technology has played a significant role to revolutionize agriculture in Ladakh, a region known for its harsh winters and short growing seasons. These are

[9] Dolker, P. (2018). An overview of transition in traditional agriculture of Ladakh. *Journal of Himalayan Ecology and Sustainable Development*, *13*, 26-48.

passive solar greenhouse structures established in Ladakh since 1980s. The technologies have been adapted and developed to suit the unique climatic conditions of Ladakh[10].Some commonly known greenhouses are Ladakh Greenhouse, Ladakhi polyhouse, trench, polycarbonate, FRP and tunnel. Of these Ladakh Greenhouse is the most effective one for Ladakh region. These are designed and developed in the rugged terrains of trans-Himalayan Ladakh by DIHAR for cultivation of vegetables during winter months. By extending the cultivation period, greenhouse farming has enabled Ladakhi farmers to grow a wider variety of crops in winter, extending effective harvest period, increase their yields, diversification to high value crops, alleviating hidden hunger, reducing CO_2 emission, women empowerment and providing new opportunities to agri-entrepreneurs.

3.4.1 Ladakh Greenhouse. DIHAR designed and developed the Ladakh Greenhouse to overcome the limitations of the popular greenhouses used in Ladakh, A very common type of passive solar greenhouse in Ladakh, it utilizes natural sunlight to heat the interior and is being established on farmers' fields since 2020 onwards. These have high capability to retain heat at night particularly during winter making them highly popular[11].

Ladakh Greenhouse is much different from traditional greenhouses with its east, west and north walls built with stones. The wall stores energy in the daytime thus acts as a thermal mass and releases it during the night. After construction, it requires least maintenance. Inside the greenhouse, the wall on the north side is used to fix racks that can be utilized for different purposes. A 16 mm triple-layer polycarbonate panel which is transparent and UV-stabilized is placed on the south-facing side. Apart from better heat retention capacity, the sheet maintains good transparency beyond 15 years of exposure to the harsh climatic conditions of the region. The greenhouse is sloped to the north with roofing that is coloured coated GI metal skin PUF (80-85 mm) on the north side. This regulates absorption of solar radiation on the inside surface. The GI also serves to prevent growth of molds and fungus, a main issue in the traditional

[10] Stobdan T (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development. Beeja House, New Delhi, India

[11] Angmo, P., Dolma, T., Namgail, D., Tamchos, T., Norbu, T., Chaurasia, O. P., & Stobdan, T. (2019). Passive solar greenhouse for round the year vegetable cultivation in trans-Himalayan Ladakh region, India. Def Life Sci J, 4(2), 103-116.

greenhouse with wooden roof. Besides, its durability this adds to the aesthetics of greenhouse. A layer of hay and soil as insulating material over rust-resistant pre-coated GI sheet is also used for roofing. Manually controlled ventilators with metallic frames on the south-facing frame and the west wall let easy operation. The ventilation can be conveniently operated from inside of greenhouse without the need of any additional support[12].

The mean minimum temperature inside remained higher than freezing during extreme periods in December and January. The night temperature increases by about 4°C when covered with a thermal blanket during winter. The greenhouse remains 24.1°C warmer during the day and 14.2°C at night in winter. In July, the maximum and minimum air temperature remains 42.1±4.0 and 16.1±1.3°C, respectively inside the greenhouse. Hence, the Ladakh Greenhouse can be used even in peak summers for growing crops of warm-season.

Figure 3.1 Ladakh Greenhouse

3.4.2 Trench Greenhouse. This type of greenhouse is partially sunk into the ground, taking advantage of the earth's natural insulation. This underground rectangular structure (30’x10’x3’) is built in north-south orientation with stonewall on four sides. The sunken design helps maintain a stable temperature inside the greenhouse, even during extreme weather conditions. Five cylindrical galvanised iron

[12] Stobdan, Tsering. (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development.

pipes (5 cm diameter, 13' long) are placed horizontally in east-west direction at 6 feet gap on top of the trench at ground level to hold the cladding material.

3.4.3 Polytrench Greenhouse. A hybrid of the passive solar and trench greenhouses, this greenhouse combine the benefits of both designs. The polytrench greenhouse features a transparent polythene cover over the trench structure, enhancing heat retention and sunlight penetration. It overcomes shortcomings of Trench greenhouse design, particularly its openness and the absence of retention wall above ground level which renders it susceptible to intrusion of stray animals.

Figure 3.2 A Trench Greenhouse

Figure 3.3 A Polytrench Greenhouse during winter

3.4.4 Polycarbonate Greenhouse. These passive solar greenhouses are usually of size 120’x30’x10’ and utilize a three layered 8 mm thick polycarbonate sheets on roof and all four sides as covering material, providing excellent insulation and durability.

Polycarbonate greenhouses are often naturally ventilated to regulate temperature and humidity. It has a service life of 15-20 years.

3.4.5 FRP Greenhouse. Fiber-reinforced plastic (FRP) is another popular material for greenhouse construction in Ladakh. The FRP greenhouse size is typically 100'x30'x11' in east-west orientation with FRP sheet on all four sides and the roof. These greenhouses offer high strength, light weight, and resistance to extreme weather conditions.

Figure 3.4 A Polycarbonate Greenhouse during winter

Figure 3.5 A FRP Greenhouse

3.4.6 Polynet Greenhouse. Polynet greenhouses are typically of 90'x27'x9' dimension in east-west direction, constructed using a lightweight netting material, providing a semi-enclosed environment for crops. Polynet greenhouses are

particularly suitable for shade-loving crops and allow for natural air circulation with the provision for lifting the polythene sheets from east and west side walls. The coloured shade net provides shading effect during day time. It also permits higher retention of heat at night thus limiting extreme temperature variation inside the greenhouse.

Figure 3.6 Polynet Greenhouse

3.5. Advantages of Greenhouse Farming in Ladakh

Greenhouse farming offers numerous advantages for agriculture in Ladakh's cold arid regions as enumerated below:-

3.5.1 Extended Cultivation Period. Greenhouses extend the growing season beyond the short outdoor growing period, allowing farmers to cultivate crops throughout the year.

3.5.2 Crop Diversification. Greenhouses enable farmers to grow a wider variety of crops, including vegetables, fruits, and flowers, which were previously not possible due to the harsh climate.

3.5.3 Increased Yields. Greenhouses provide a controlled environment, protecting crops from pests, diseases, and extreme weather conditions, leading to higher yields and improved quality.

3.5.4. Water Conservation. Greenhouses minimize water evaporation and allow for efficient water usage through drip irrigation systems.

3.5.5 Year-Round Income. Greenhouse farming provides farmers with a consistent source of income throughout the year, improving their economic stability.

3.5.6 Food Security. Increased local production of vegetables and fruits enhances food security in Ladakh, reducing reliance on imported food items.

3.5.7 Employment Generation. Greenhouse farming creates employment opportunities in rural areas, contributing to the overall economic development of Ladakh.

3.5.8 Reduced Environmental Impact. Greenhouse farming reduces the need for chemical pesticides and fertilizers, promoting sustainable agricultural practices.

3.6 Advantages of Ladakhi greenhouse over traditional greenhouses

Ladakh Greenhouse is designed to overcome the limitations of traditional greenhouses. The mean temperature inside Ladakh Greenhouse being above freezing points even in December and January in Leh, the plant growth is more vigorous in winter. Cabbage, cauliflower, broccoli, mushroom, and tomato are being successfully cultivated in peak winter in Ladakh Greenhouse, which is otherwise impossible in traditional greenhouses.

Unlike polyethylene sheets in traditional greenhouses, here there is no necessitating of taking out of polycarbonate cladding material even in summer months. The ventilation does not allow excessive heat to build up inside the greenhouse, even during summer months. The average service span of polycarbonate sheets is 15 years in Ladakh condition. It endures high wind speed and extreme climatic conditions. As a cladding material, the triple-layer polycarbonate is suitable for region receiving intense snowfall with its smooth curved design allowing snow to slip off. The structure bears up the load of snow which remains on it.

The stone wall, metallic door, and ventilator frame need minimal maintenance for this greenhouse. Racks are fixed on the `inside of its north wall which can be used for different purposes, thus making use of above-the-ground space of the greenhouse. The triple layer polycarbonate cover, fixed metallic structures, and the wall working as a

thermal mass makes it possible for higher heat retention due to high thermal retention properties and minimum heat escaping gaps.

The normal life of Ladakh Greenhouse is 15 years with minimum or minor maintenance requirement to its walls, metallic frame, and PUF roof to keep the greenhouse functional. Against one or two crop cycles in the traditional greenhouses, the Ladakh Greenhouse could provide for three cycles of crops cultivation. It has aesthetically pleasing interior space, which is vital for a person to form an attachment to the greenhouse. The chief drawbacks of Ladakh Greenhouse are that the greenhouse construction is not easy to set up with high material and installation costs besides requiring of qualified personnel to establish the structure.

3.7 Challenges for Agriculture in Ladakh

The agriculture economy of Ladakh is in a beleaguered state today[13]. There are more and more employment opportunity open to the locals in the form of the army, tourism, and varied jobs. With this, their need to depend on the land based economy is diminishing. However, due to several factors, this euphoria is proving to be a short-lived. The current economic boom that Ladakh is experiencing cannot be considered sustainable. As a result, most Ladakhis nowadays sport an attitude of disregard towards the land-based economy which could cost them dearly. There is an immediate attention required to lift the land-based economy out of the muddle it finds itself and make the region more self-reliant than it used to be.

Ladakh faces massive challenges related to agriculture. These involve increasing affluent population, shrinking agricultural land, rural-urban migration, shrinking agro-biodiversity, increased dependency on imported food, scarcity during winter, seasonal availability of fruits and vegetables, hidden hunger, post-harvest losses, poor market access, threatened traditional farming cultures and climate change. These multitude challenges are not only multidimensional but also require coordinated and targeted approach that can contribute to attain sustainable development in agriculture.

[13] Stobdan T (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development. Beeja House, New Delhi, India

3.7.1 Increasing affluence. Majority of people (77.39%) in Ladakh live in rural areas. However, the region is going through a rapid population growth and also a decline in per capita farm sizes. The population of Ladakh has increased from 1,05,292 in 1971 to 2,74,289 in 2011. In that the rise in urban population has gone up from 7.5 percent in 1971 to 22.6 percent in 2011. Moreover, the lifestyles in villages are also undergoing a fundamental change from rural roots to urban civilization. In addition, to the sizeable strength of army in the region, it's floating population is increasing swiftly. There has been significant increase in the number of tourists visiting Ladakh between 1991 and 2022. Therefore, the ability of small and marginal farmers to feed themselves and their families has been impacted by the effect of population growth on agriculture. To meet the growing requirements of farm produce for the local and the floating population in this delicate mountainous area is a difficult challenge.

3.7.2 Rural-urban migration. Rural-urban migration is a global phenomenon. With no helping hands in old age this aspect is taking painful proportions in the region. Small agricultural lands are often neglected due to migration also largely affecting the rural lifestyle and thus the unique culture of Ladakh. The rural population in Ladakh which was 92.5 percent in 1971 has come down to 77.4 percent in 2011. This trend needs to be discontinued from the way it is progressing. Subsistence farming is not providing the necessary conditions and opportunities sought by young people. Agriculture needs to become economically feasible as well as socially attractive. Other reason for giving up farming and urban migration is the shrinking and fragmented agricultural land holdings in rural area. Also education, improved social services, and job opportunities in urban is an attraction. The growing trend of agricultural land abandonment has become a grave threat to farming systems for the region.

3.7.3 Shrinking agricultural land. There is an increase in agricultural land at the aggregate level; however, that land availability to do farming by individual households has declined in a considerable manner. The major decline in land holding is ascribed to land fragmentation due to increased population as also to new trend of nuclear families by way of the breaking up of joint family systems. Ladakh has witnessed a increase in population by about 2.6 times between 1971 and 2011. This

has resulted in small and marginal holdings of less than 2 hectares of agricultural land account coming down to 79.8 percent in Leh district and 94.7 percent in Kargil district. A small land holding is thus becoming non-viable for farming and livelihood. Farmers do not have adequate agricultural land to grow substantial crops to meet the requirement of food and income for their family in order to have a sustainable living.

3.7.4 Seasonal availability of vegetables and fruits. The crop growing season is restricted due to climatic condition of the region in Ladakh. This scenario remains during the period of May-September in open-field conditions. Vegetables are reaped from June to September. Crops such as potatoes, onions, cabbage, etc. are produced from later part of August to September. Fruits yields are between July to October. "The region sees excess of fruits and vegetables during the period, in contrast to an acute scarcity of fresh produce in winter"[14]. "During winter, passive solar greenhouse cultivation is the only source of locally produced fresh leafy vegetables. Crops such as potatoes, radishes, carrots, cabbage, onion, and turnip are stored in underground pits and root cellars for their consumption in winter months"[15].

3.7.5 Food dependency. Ladakh is becoming excessively dependent on the outside world for essential needs. It has become a net food importer of cereals, fruits, vegetables, pulses and cooking oil. Leh's dependency on vegetable import is approximately 67 % and on fruits is around 85%. Self-sufficiency in food is a key issue for the region. Filling the demand and supply gap in respect of fresh farm produce is difficult. Limited quantity of fresh vegetables is brought in during the winters from Chandigarh or Delhi by air. As much as Rs 110 per kg is shelved for air freight. Fresh vegetables are hence 2.7 times costlier in Ladakh compared to big city of Delhi[16]. Meeting the increasing demand for fresh farm produce at a reasonable price in the region is a formidable challenge.

[14] Stobdan T, Angmo S, Angchok D, Paljor E, Dawa T, Tsetan T, Chaurasia OP (2018). Vegetable production scenario in trans-Himalayan Leh Ladakh region, India. Def Life Sci J., 3: 85–92

[15] Ali Z, Yadav A, Stobdan T, Singh SB (2012). Traditional methods for storage of vegetables in cold arid region of Ladakh, India. Indian J Tradit Knowl., 11: 351–353

[16] Angmo P, Dolma T, Namgail D, Tamchos T, Norbu T, Chaurasia OP, Stobdan T (2019). Passive solar greenhouse for round the year vegetable cultivation in trans-Himalayan Ladakh region, India. Def Life Sci J., 4: 103–116

3.7.6 Hidden hunger. Survey results conducted in 2008 of 200 households on the assessment of the extent of malnutrition and related health problems have established that only 19.4% of the people of the Ladakh are well nourished. The study also brings out that 35% of people suffer from malnutrition-related diseases. Anemia, nigh blindness, scurcy, beri beri, and rickets are the most common diseases. A high prevalence of deficiency diseases is attributed to the low consumption of fruits, vegetables, milk and milk products[17]. A significantly high percentage (36.6%) of lactating women in the region is malnourished as against 19.3% in Jammu and 10% in Kashmir. Similarly, 45.5% of Ladakhi women had lower calorific intakes as against 41.3% of women in Jammu and 12.7% of Kashmiri women. A significant number of the women (36.6%) showed clinical signs of nutritional deficiency in Ladakh[18]. Therefore, there is an imperativeness to grow more nutritious food locally and make it accessible and affordable.

3.7.7 Rising cases of cancer. The region has a increasing trend of cancers and cancer related deaths. A hospital-based study in Kargil district for 10-year period from 2009-2019 found 31.5 cases per lakh population per year. The incidences of cancer are higher in males (69.4%) than in females (30.6%). The pattern of this disease in the region is unlike from rest of India, which could be because of the topography, unique food habits, peculiar culture and lifestyles. Stomach cancer is the most commonly seen in as high as 42.1% of patients. This is followed by lung, lever, esophagus cancers etc. The patients are mostly of 60-74 age group (47.3%), followed by 45-59 (26.1%), 75-89 (14.2%) and 30-44 years (5.4%). Studies[19] have shown connection between a higher intake of certain type of food and cancer risk. Main association has been seen between fruits consumption and cancer occurrences in Ladakh. Cancer is highest (58.8%) in patients taking less than one fruit serving per week, 24.6% in those taking one to four fruit servings per week and only 16.7% in those taking more than four per week[20]. Therefore, identifying the causes of the

[17] Dar RA, Rather GM (2014). Assessment of magnitude of malnutrition and related health problems in cold desert Ladakh-India. Eur Acad Res., 2(4): 4895–4919

[18] Khan YM, Khan A (2012). A study on factors influencing the nutritional status of lactating women in Jammu, Kashmir and Ladakh regions. Int J Adv Res Technol., 1 (4): 65–74

[19] Hussain S, Ali M, Jeelani R, Abass M (2019). Cancer burden in high altitude Kargil Ladakh: Ten year single centre descriptive study. Int J Cancer Treat., 2(2): 4–10

[20] Hussain S, Ali M, Jeelani R, Abass M (2019). Cancer burden in high altitude Kargil Ladakh: Ten year single centre descriptive study. Int J Cancer Treat., 2(2): 4–10

increasing number of cancer cases and growing food that could be associated with a lower risk of the disease is a major challenge.

3.7.8 Poor market access. The farmers in Ladakh are faced by certain biggest problems causing direct bearing on their prosperity. These are inadequate marketing skills and lack of wider market access. Most fruits and vegetable crops reach the harvesting stage in August and September. The perishability of fresh fruits and vegetables makes farmers worried of possible losses, which may occur during marketing. This turn them away from venturing into horticulture crops. Inadequacies in storage also result in limited crop production.

3.7.9 Shrinking agro-biodiversity. The agricultural biodiversity is richly embedded in traditional agricultural systems. So, people in Ladakh traditionally depend entirely on wild harvest collection for their requirements of vegetables. But, extensive trends towards change in food habits and increased shift towards cash crops has led to shrinkage in agro-biodiversity. Farmers with a market oriented farming system cultivate fewer crops and allocate less area to mixed crops than traditional farming. Many conventional farming lands have been rendered permanently fallow and unplanted.

3.7.10 Limited availability of organic manure. Ladakh is a cold desert with meagre area of just 141 km^2 under forest cover. This fact makes availability of organic matter for farming a key challenge. There is also a decreasing trend in number of livestock populations in the region as cited by Tesring Stobdan[21].

3.7.11 Accessibility during winter. For more than five months of a year Ladakh sees heavy snowfall and the region remains cut-off. The harsh reality of this winter isolation leaves the region vulnerable, with limited access to vital supplies.

3.7.12 Post-harvest loses. Approximately 40-60 % of the apricot produced in the region is wasted due to lack of cold-chain infrastructure for storing fresh fruit,

[21] Stobdan T (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development. Beeja House, New Delhi, India

hygienic processing and developing vale-added products[22]. The region sees a profusion of fruits and vegetables from August to September, which results in post-harvest losses. There is a need for an integrated value chain system which is market-oriented and sustainable.

3.7.13 Risk management and resilience. Farmers in the region are exposed to risks from various quarters. Seasonal variability is one of them, due to which certain years may not be favourable to fetch a good harvest. The weather affects the yield and quality of the produce. Insect pests and diseases can devastate crops. In general, the incidence of insect pests and diseases in the cold arid region is low. Euproctis similis is not a regular insect pest of the fruit crop in Ladakh, however, it emerged as a main pest of apricot during 2013-16 in the region's major apricot growing belts, inflicting a substantial economic loss on the growers[23]. Cereals in the region are affected by the major disease of loose smut and vegetables gets affected by significant insect pests like cutworm, onion maggot, aphid and cabbage butterfly.

3.7.14 Threatened traditional farming culture. Agricultural land has a major influence on social and cultural relevance in the region, in addition to economic and environmental factors. Ladakh farming system has evolved from nutritional needs and ecological adaptation. In that agriculture and horticulture have shaped Ladakh's unique natural landscape. The trend of cash crops and monoculture began decades ago in and around Kargil town, however, it is yet to extend to distant villages of Ladakh. The traditional close ties between agriculture and cultural development are still seen and felt in the region. The traditional farming culture is, however, declining slowly. It may face a grave threat of extinction if appropriate and immediate actions are not taken.

3.7.15 Climate Change. Climate change is a a global phenomenon and Ladakh is no exception. The region is now feeling the impact of increasing temperatures. Studies suggest that the maximum temperature for peak summer months showed a rise of nearly 0.5^{o}C between 1973 and 2008, and the minimum temperature by almost

[22] Stobdan T, Chaurasia OP, Wani M, Phunchok T, Zaffar M (2020). Improvement of apricot farming in Ladakh, India, Union Territory of Ladakh, India 50p

[23] Stobdan T, Angmo S, Angchok D, Paljor E, Dawa T, Tsetan T, Chaurasia OP (2018). Vegetable production scenario in trans-Himalayan Leh Ladakh region, India. Def Life Sci J., 3: 85–92

1°C for all winter months[24]. A study was conducted by Tsering Stobdan in 2016 through to a structured questionnaire and interview of farmers in order to gauge people's perception of climate change in Ladakh. In startling finding, all respondents stated that they had witnessed climate change in Ladakh, while 74% of them felt that the extent of climate change was extreme. Factors perceived as main indicators of climate change in the region are decrease in snowfall, receding glaciers, change in rainfall pattern and increase in temperature. Over 60% of the respondants believed climate change severely affected their lives. Urbanisation and an increasing number of motor vehicles are perceived as the main cause of climate change in Ladakh.

3.8 Strategies that could augment farmers' income in Ladakh's cold regions

Ladakh has unique cold arid climate and it presents specific challenges and opportunities for agriculture. Some key strategies that can be tailored to this region are suggested as follows:-

3.8.1 **Enhance productivity in harsh conditions**. This could be by way of developing cold-tolerant crop varieties and pushed through investing in research and development of climate-resilient crop varieties, including vegetables, fruits, and high-altitude grains, which are suitable for Ladakh's short growing season and harsh winters. Promote greenhouse technologies in the region is another approach wherein adoption of various greenhouse models may be expanded, specifically focusing on passive solar and trench greenhouses to leverage natural heat retention. Farmers be encourage to adopt bio-intensive farming methods through implementation of techniques like raised beds, mulching, and organic matter addition to improve soil fertility and moisture retention in cold conditions.

3.8.2 **Diversifying beyond traditional crops**. Here the approach should be to introduce high-value cash crops. In that cultivation of niche crops like sea buckthorn, goji berries, and medicinal herbs that thrive in cold climates and fetch premium prices could be encouraged. Besides this, also promote off-season production. For this, greenhouses and controlled environments could be utilised to cultivate vegetables and fruits out of season, fetching higher market prices due to limited availability. There

[24] Angmo T, Heiniger LP (2009). Impacts of climate change on local livelihoods in the cold deserts of the Western Indian Himalayan region of Ladakh and Lahaul & Spiti

should also be an effort to explo re high-altitude crops where experimentation could be done with traditional grains and pseudocereals like buckwheat etc that are naturally adapted to high altitudes and have nutritional value.

3.8.3 **Facilitate market access and price realization**. There is a need to improve cold chain infrastructure in the region. For this, investment in cold storage facilities and refrigerated transportation will minimize post-harvest losses of perishable goods like fruits and vegetables. Encourage farmers to form collectives and cooperatives and strengthen them to aggregate produce, negotiate better prices, and access wider markets. E-commerce platforms must be explored by which access to online platforms could be facilitated for direct marketing of Ladakhi agricultural products to national and international markets.

3.8.4 **Prioritize sustainable practices in agriculture**. Towards this, organic farming must be promoted. Encourage organic farming practices would also preserve the fragile ecosystem and cater to the growing demand for organic products. In Ladakh, the vegetables were first successfully produced at the Model Ladakh Winter Greenhouse at Gupuk Farm in the harsh winter months at -20^{o} C, using natural/solar energy (carbon neutral) under Mission Organic Development Initiative (MODI). Under this organic mission, Ladakh is planning to build around 900 greenhouses, out of which 150 have already been completed. By adopting water conservation techniques with utilization of drip irrigation, mulching, and rainwater harvesting water usage in the arid climate could be minimized. To add to these measuresImplement soil health management: Advocate for composting, biofertilizers, and cover cropping to maintain soil fertility and reduce reliance on chemical inputs.

3.8.5 Certain additional considerations as follows will give the much needed push to deal with the unique challenges and opportunities of Ladakh's cold regions which could potentially enhance farmers income, improve their livelihoods and contribute to the sustainable development of the region's agriculture sector:-

(a) **Skill development and training**. Provide training programs on greenhouse management, organic farming, livestock rearing, and value-addition techniques to enhance farmers' skills and knowledge.

(b) **Financial support and subsidies**. Offer financial assistance, subsidies, and access to credit for farmers to invest in new technologies, infrastructure, and processing units.

(c) **Research and development**. Support research efforts on cold-tolerant crops, improved livestock breeds, and sustainable agricultural practices specific to Ladakh's conditions.

CHAPTER-4

IMPACT AND CHALLENGES OF AGRICULTURE AND GREENHOUSE FARMING

4.1 Agriculture and Allied Services: a Sectoral Overview

Life in Ladakh revolves around agriculture, with nearly 70% of the community relying on it directly or indirectly. But harsh winters cut the growing season to just 4-5 months, forcing reliance on single cropping. Irrigation is crucial, and double cropping is only possible below 3,000 meters. Landholdings are small, with half the families having less than 0.5 hectares. This, coupled with limited Leh's land of 0.2% allocated to agriculture (10,223 ha), makes self-sufficiency a major challenge.

The region imports a staggering 73% of its food grains, 67% of vegetables, and 85% of fruits. Winter intensifies this dependence, as snow shuts down the two main highways, leaving air travel as the only option – an expensive burden for locals. This significantly reduces their consumption of fresh produce during winter months.

In its fruit basket, Ladakh boasts apricots and apples. Both are renowned for their exceptional quality, nurtured by the region's unique climate. Extended fruiting seasons, clear skies, and dramatic day-night temperature swings during the growing months create the perfect recipe for these delicious fruits. In 2016-17, Ladakh proudly harvested 5,644 metric tonnes of apples, with a steady growth of 2.05% per year over the past decade. Apricot production, although declining slightly at -2.77% annually, reached a respectable 5,698 tonnes in the same year.

Seabuckthorn. Native to the region, seabuckthorn flourishes with minimal human intervention, growing wild across vast landscapes. Traditionally valued for its medicinal properties, recent discoveries about its health benefits have skyrocketed its price, even at its source. But cultivating this hardy plant on a larger scale holds immense potential for Ladakh's long-term development. Experts estimate planting seabuckthorn on 2,500 hectares could generate a staggering Rs 491 crore annually by 2030, just from harvesting and basic processing. Currently, Ladakh boasts 7184 hectares of pure seabuckthorn stands and 2083 hectares of mixed stands, accounting

for 70.9% of India's total seabuckthorn cultivation. However, this represents less than 5% of the region's potential.

Cultivation of Vegetables. Back in the 1960s, Ladakh's menu sported a mere four vegetable varieties. Today, a remarkable transformation has bloomed – researchers have proven the feasibility of growing a whopping 101 diverse vegetables in this region! What's even more exciting is that Ladakh's climate is perfect for nurturing "exotic" crops like bell peppers and broccoli, currently heavily imported by India. Considering India's 2019 fruit and vegetable import bill of USD 1.189 billion and the fact that only 629 hectares of Ladakh's vast land are currently used for vegetable cultivation, the potential for expansion is simply immense.[25].

Ladakh has varieties of fruits and vegetables that are unique to the region. Also the region has an environment favourable for production of exotic vegetables, coarse grains etc. However, their production remains low at present due to water scarcity, improper branding and poor market linkages.

4.2 Gaps in the Agri Sector

Ladakh's agricultural landscape is unique compared to other rural regions in India. Unlike most areas with year-round growing seasons, cultivation here is confined to a mere four months, posing a significant challenge. Additionally, the soil is loose and struggles with severe water stress, further complicating farming efforts. On top of these environmental hurdles, socioeconomic factors like fragmented landholdings, limited labor availability, and low productivity create further obstacles. Inefficient post-harvest management and limited access to fair markets for selling produce add to the complexities faced by Ladakhi farmers.

Certain major gaps identified in the sector include the following:-

(a) In Ladakh, the land-based food production is dipping with the emergence of a supply oriented food system.

[25] *Ladakh ASSOCHAM (2021). 'Unleasing Ladakh' cited at* https://www.assocham.org/uploads/files/Ladakh%20TL_%20Final%20Document.pdf

(b) Adverse climatic conditions leading to limited vegetable cultivation particularly in winter months resulting in high dependency on imported food grains.

(c) New generations of locals are shifting to occupation like tourism industry due to low returns from agriculture sector on account of lack of crop diversification, ample technology and poor market linkages.

(d) Low thrust on value chain development for key produces like apple, apricots, seabuckthorn etc. This not only includes limited capacity building of locals but also limited provision of crucial infrastructural inputs and low packaging, branding and marketing capacities of the region.

(e) High wastage of food resulting from inefficient yield and post-harvest technologies.

(f) Farmers shying away from taking up new techniques, technologies and high value crops because of lack of knowledge and access to infrastructure.

(g) The region also losing its competitive advantage to J&K, due to lack of distribution network.

4.3 Government interventions which could contribute immensely in unleashing the sector's economic potential

Once self-sufficient, Ladakhis cultivated their own grains, vegetables, and raised animals for food. They even produced their own seeds, manure, and other agricultural inputs, adapting seamlessly to the region's unique climate. However, due to low yields, limited growing seasons, and inefficient farming practices, reliance on imported food has increased. Further, younger generations are drawn to more prosperous sectors like tourism, leaving agriculture behind. Despite these challenges, hope remains. Concerted efforts by the government and private sector aim to revitalize Ladakh's agricultural sector. By boosting yields, implementing low-cost technologies for diversified vegetable production, securing winter food supplies, and adding value to horticultural products, Ladakh can potentially become self-sustaining once again.

4.3.1 Commercial Greenhouse. Ladakh has a harsh environment and it has a short agricultural season being a cold, dry, high-altitude area. Commercial greenhouses offer a solution, promising both economic prosperity and improved health for Ladakhis. Currently, fresh vegetables, rich in essential vitamins and minerals, are only available for eight months. Greenhouses provide a warm, sunlit haven for year-round vegetable production. They cleverly trap plant-emitted carbon dioxide (fueling photosynthesis), minimize water evaporation, and reduce irrigation costs. Inspired by successful greenhouse adaptations in the climatically similar Tibetan region, Ladakh's Agriculture Department has embraced the concept. However, scaling it up is crucial. Ideally, each village should have at least one or two greenhouses to maximize their impact.

Commercial cultivation of Indian/exotic vegetables/flowers in large greenhouses could be used to first meet the local demand. Then the produce can be supplied to local hotels and army bases on contractual basis after which these can be supplied to other parts of the country at a premium as most of the vegetables especially those like broccoli, bell pepper etc. which are relied on import to meet the demand by India.

4.3.2 Cold storage facilities. Ladakh's precious organic fruits and vegetables often face a tragic fate - rotting away due to a lack of proper storage. These losses are exacerbated by the region's power shortages, making traditional cold storage impractical. However, a solution exists namely solar-powered cold storages. Both investors and entrepreneurs recognize the potential of solar energy to unlock greater value for Ladakh's growers. Harnessing the sun's power can empower farmers to store and sell their produce for extended periods, drastically reducing post-harvest losses and boosting their income. Following the success of commercial greenhouses, implementing solar-powered cold storage units at scale holds immense promise. Imagine each village equipped with this technology, enabling a thriving agricultural ecosystem and a healthier, more prosperous Ladakh.

4.3.3 Trench Farming. While commercial greenhouses hold promise, their high cost limits accessibility for many Ladakhi farmers. Fortunately, low-tunnel technology offers a low-cost, portable alternative. Farmers can easily relocate these tunnels, making them perfect for diverse terrains and climates. Even in harsh regions like Changthang, they enable cultivation of a wider range of vegetables and herbs.

Early adopters have seen impressive results, increasing their vegetable variety from 10 to a remarkable 28, leading to higher income and access to diverse, healthy produce for the community. Therefore, promoting wider adoption of low-tunnel technology is crucial. Capacity building activities, in collaboration with organizations like DRDO, can ensure farmers understand and embrace this effective approach. Empowering Ladakhi farmers with this accessible technology paves the way for a more resilient and diverse agricultural sector.[26].

4.3.4 <u>Increased focus on horticulture products and value addition to local produce</u>. Food processing presents a golden opportunity for Ladakhi farmers, entrepreneurs, and the local economy. It addresses a crucial need gap and offers immediate, tangible benefits to all stakeholders. Imagine transforming Ladakhi fruits like sea buckthorn and apricots, along with vegetables like peas, tomatoes, and potatoes, into value-added products with extended shelf lives. This wouldn't just increase their availability throughout the year, within and beyond Ladakh, but also create new income streams and empower local businesses. The potential is already evident. Products like juices, jams, and oils made from local produce are starting to gain traction. Now, it's time to scale up and diversify..

(a) **<u>Seabuckthorn</u>**. Currently, primary processing of the berry for seabuckthorn is made in Ladakh. Components like pulp, seed and hull further value addition are sold to firms located outside the region. Opportunity exists to develop value-added products in this area. So, government needs to look for creation of a favourable environment for the investors by way of support which can be in the form of subsidies, training and skill development on value added product. It would be a great idea to make pulp extraction facilities as a part of food parks. Varities of value-added products could be created from the raw material. These could include beverages viz flavoured tea, juices, health drinks, wine, oil, creams, etc.

(b) **<u>Apricots and apples</u>**. Apricots and apples are the main fruit trees of Ladakh. These are abundantly produced in Ladakh especially in Sham, Nubra, and Kargil which are warmer and lower areas of the UT. Traditionally,

[26] *Ladakh ASSOCHAM (2021). 'Unleasing Ladakh' cited at* https://www.assocham.org/uploads/files/Ladakh%20TL_%20Final%20Document.pdf

apricots are sun-dried on the roofs of houses or on huge stones after which it is sold in markets of Leh and Kargil. Apricots and apples that are cultivated in Ladakh are highly perishable which spoils within the short time of summer season. Therefore, these fruits are necessarily to be transported to the markets immediately after their harvesting in July and August. Poor market linkages in the region give on to high wastage of these produce. Fruit processing units may be created in the food parks in accordance with Food Processing Order (FPO) standards. Self-help groups of local women may also be organised on a large scale, they be trained to extract pulp for producing jellies, jams, oil etc as well as look for potential buyers from the market.

4.3.5 High quality seed production. Ladakh's unique climate - intense sunlight, minimal rain, and long summer days - offers a natural greenhouse for diverse vegetable seed production. While disease and pests are rare, success relies on specific techniques for each crop. DIHAR has already developed systems for various temperate vegetables like onion, beetroot, cabbage, and radish. Grown on suitable soils with proper water and nutrients, these seeds have the potential to be exported worldwide. Imagine small-scale food parks (10-20 acres) scattered across villages, blocks, and zones. These "cluster idea" parks would feature start-up units with facilities leased to entrepreneurs and cooperatives. In collaboration with these groups and the private sector, the administration could upskill locals to maximize their produce. Imagine the benefits: shared infrastructure, streamlined procurement and logistics, expert guidance, and ultimately, maximizing value addition, boosting farmer income, minimizing waste, and creating rural employment.

4.3.6 Support in marketing and packaging. Push vigorously for fast tracking the Mission Organic Development Initiative, the five-year initiative launching Ladakh onto the global organic stage. This mission empowers local producers and creates a unified brand for their high-quality, organic products. Ladakh's exquisite vegetables, fruits, and other organic offerings must be marketed and branded under this umbrella. Through strategic e-commerce and targeted campaigns, the world will discover the unique taste and purity of Ladakh's bounty, fueling organic demand. But the mission goes beyond just sales. Achieving organic certification for the entire region, coupled with centralized branding, provides unparalleled exposure for local producers, many of whom lack the skills to navigate the global market. Furthermore, the mission

champions eco-friendly packaging, aligning with Ladakh's values and creating a distinctive brand image that resonates with environmentally conscious consumers. By empowering local producers, boosting demand, and promoting sustainability, the Mission Organic Development Initiative promises to be a transformative force for the region, propelling its organic offerings onto the global stage.

4.4 Envisaged role of private sector

4.4.1 Conducting research and development activities. Agricultural value chain involves various steps. These include supply, production, processing, transportation, trading, marketing and export. Most of these are linked with the output of one flowing into as input to the other. The entire sector in the region gets benefitted if R & D initiatives are undertaken in any point of the value chain. Certain research areas can be focussed towards development of less water intensive crops, bio-fortification, genetically modified crops, pest resistant crops, high yielding seed varieties, better storage, processing & supply chains and labour-saving technologies.

4.4.2 Additional investment in infrastructure. Private sector can be encouraged to invest in critical infrastructure for agriculture in the region. This will potentially transform the sector. Solar powered cold storage, Mini food parks, commercial greenhouses etc. are elements of such important infrastructure and these are necessary for the sector. Setting up of small units equipped with food processing facilities will also generate more jobs for locals.

4.4.3 Better market linkages. Private sector can emerge as an important player in providing market linkages to farmers in the region. Establishing farm-firm linkage could facilitate providing of credit, assured market, rewarding prices, quality check and extension services, mostly to small landholders.

4.5 Positive impact on climate

Agriculture sector has an important part in contributing towards carbon reduction as well as sequestration. Lowering of agriculture’s own carbon footprint by way of cover crops, reduced tillage, increased crop rotations, animal reintegration into agricultural production systems etc is a well documented fact. At the same time, it has shown to have been absorbing carbon from other industries as well. Among other things

development of Ladakh's agricultural and associated sectors would lessen the region's need on tourists for survival.

4.6 Benefits of Greenhouse Farming in Ladakh

Adopting to Greenhouse Farming in Ladakh has provided the region with its share of benefits over a range of aspects. These are analysed and discussed as follows:-

(a) **Increased Crop Yield and Diversity**. Greenhouses protect crops from harsh weather, leading to significantly higher yields compared to open fields. This is crucial in Ladakh's short growing season (5 months). Farmers can harvest up to 3 times more vegetables in the same space.

(b) **Extended season**. Greenhouses enable year-round cultivation, even during the frigid winters when outdoor farming is impossible. This increases crop diversity beyond traditional cold-tolerant vegetables like cabbage and cauliflower. Crops like tomatoes, broccoli, and even mushrooms can be grown, bringing more variety to the Ladakhi diet.

(c) **Economic Benefits to Farmers**. Increased yield and diverse crops translate to higher income for farmers. They can sell vegetables year-round, commanding premium prices during off-seasons. This improves livelihoods and reduces dependence on imported food.

(d) **Job creation**. Greenhouse farming requires more labor than traditional methods, creating jobs in rural areas and boosting the local economy.

(e) **Sustainability and Resource Conservation**. Benefit is accrued by way of water conservation. Greenhouses use drip irrigation, minimizing water waste compared to open field flooding. This is crucial in Ladakh's water-scarce environment. Also, protected from wind and rain, greenhouses experience less soil erosion, preserving precious topsoil. The controlled environment allows for reduced pesticide and fertilizer use, promoting organic farming practices.

4.7 Impacts of Greenhouse Farming in Ladakh

Following impacts are felt in the region due to adoption of greenhouse farming:-

(a) **Initial investment**: Setting up a greenhouse requires a significant initial investment, which can be a barrier for some farmers. Government subsidies and loans can help bridge this gap.

(b) **Energy use**. Depending on the greenhouse design and technology, some require heating systems, increasing energy consumption and associated costs. Exploring renewable energy sources like solar power can mitigate this.

(c) **Waste management**. Plastic used in greenhouse construction and covering needs proper waste management to prevent environmental pollution.

Overall, greenhouse farming in Ladakh offers significant benefits for crop yield, diversity, farmer income, and sustainability. However, careful planning, resource management, and addressing potential challenges are crucial for long-term success. The Ladakh Winter Greenhouse is a successful model designed specifically for the region's harsh climate. It utilizes passive solar heating and local materials for affordability and sustainability. Government initiatives and research are promoting adoption and innovation in greenhouse technologies suitable for Ladakh's unique conditions.

CHAPTER-5

PUBLIC INTERVENTIONS IN PROMOTING GREENHOUSE TECHNOLOGY IN AGRICULTURE

5.1 Introduction

The Government of Ladakh is taking a number of initiatives and schemes to promote greenhouse technology in agriculture amongst the farmers of Ladakh.

5.2 Schemes of Ladakh Agriculture Department

5.2.1 UT Ladakh has following eight Agriculture schemes for the farmers as reflected on its website[27]:-

(a) Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) Flagship scheme
(b) Rashtriya Krishi Vikas Yojana-RAFTAAR (RKVY–RAFTAAR)
(c) Rashtriya Krishi Vikas Yojana-RAFTAAR (RKVY–RAFTAAR)
(d) National Mission on Agricultural Extension and Technology (NMAET)
(e) National Mission on Sustainable Agriculture (NMSA)
(f) National Food Security Mission (NFSM)
(g) National Mission on Oilseed sand Oil-Palm (NMOOP)
(h) Pradhan Mantri Kisan Samman Nidhi(PM-KISAN)

5.2.2 **S**chemes of UT Ladakh that support greenhouses and organic farming are:-

(a) Mission Organic Development Initiative (MODI). It is aimed at embracing organic farming with the aim to realise carbon-neutral Ladakh. It seeks to transform agriculture in Ladakh into a sustainable, remunerative, respectable occupation and to enable the farmers to reap benefits of dynamic market opportunities while also providing fresh organic vegetables in winter.

[27] https://ladakh.gov.in/agriculture/#1663302008438-b908c780-4027

Ladakh Greenhouse Project, a project by UT Ladakh and DIHAR to improve food security and promote livelihood in Ladakh. This greenhouse is also a part of Mission Organic Development Initiative, which aims to make Ladakh an organic region by year 2025.

The project aims at establishing about 1,000 numbers of Ladakh Greenhouses in Leh and Kargil districts between 2021-23 with 75% subsidy by the Agriculture Department, UT Ladakh. A single Greenhouse can generate up to Rs 75,000 in a year for the farmer. Newspaper interview of one farmer Tashi Tundup of Thiksay village reveals that he has earned Rs 1.75 lakh from the crops grown and his income from farming has increased and doubled.. A Women Self-help Group Barba in Village Shey of Leh Ladakh claims generation of an income of approx. Rs.40,000 in just five months by installing greenhouses. The scheme has enabled reducing the cost of living index for local population, water and energy conservation through sustainable organic farming. women empowerment besides creating agricultural entrepreneurs[28], reports DARPG in its Abhinav Pahal portal on dissemination of best practices.

(b) Paramparagat Krishi Vikas Yojana (PKVY), the scheme launched in 2015 by central government as an extended component of Soil Health Management (SHM) under the Centrally Sponsored Scheme (CSS) of National Mission on Sustainable Agriculture (NMSA)

5.2.3 The initiatives of UT Ladakh aim at the following:-

(a) **Providing financial assistance**: The government provides financial assistance to farmers to help them purchase and install greenhouse kits. This assistance are in the form of subsidies, grants, or loans.

(b) **Providing technical training**: The government provides technical training to farmers on how to use and maintain greenhouse technology

[28] https://abhinavpahal.nic.in/uploads/BhWI5q061pAgriculture%20Department,%20Ladakh.pdf

effectively. This training covers topics such as greenhouse design, crop selection, and pest and disease management.

(c) **Establishing demonstration greenhouses**: The government has established demonstration greenhouses in various parts of Ladakh. These greenhouses allow farmers to see firsthand how greenhouse technology works and to learn from the experience of other farmers.

(d) **Promoting greenhouse technology**: The government is actively promoting greenhouse technology among farmers through various outreach programs and campaigns. These programs and campaigns highlight the benefits of greenhouse technology and encourage farmers to adopt it.

5.2.4 Some specific examples of the various initiatives by which the Government of Ladakh is enabling the farmers to adopt and thus promote greenhouse technology in agriculture are as below:-

(a) The Ladakh Autonomous Hill Development Council (LAHDC) provides a subsidy of up to 50% of the cost of greenhouse kits to eligible farmers.

(b) The Krishi Vigyan Kendra (KVK) in Leh provides technical training to farmers on greenhouse technology. The KVK also organizes field visits to demonstration greenhouses so that farmers can see firsthand how greenhouse technology works.

(c) The Department of Agriculture and Horticulture in Ladakh has established demonstration greenhouses in various parts of the region. These greenhouses serve as a learning resource for farmers and help to promote the adoption of greenhouse technology.

(d) The Government of Ladakh is also working to promote greenhouse technology through various outreach programs and campaigns. For example, the government has launched a campaign called "Greenhouse Mission

Ladakh" to raise awareness of the benefits of greenhouse technology and to encourage farmers to adopt it.

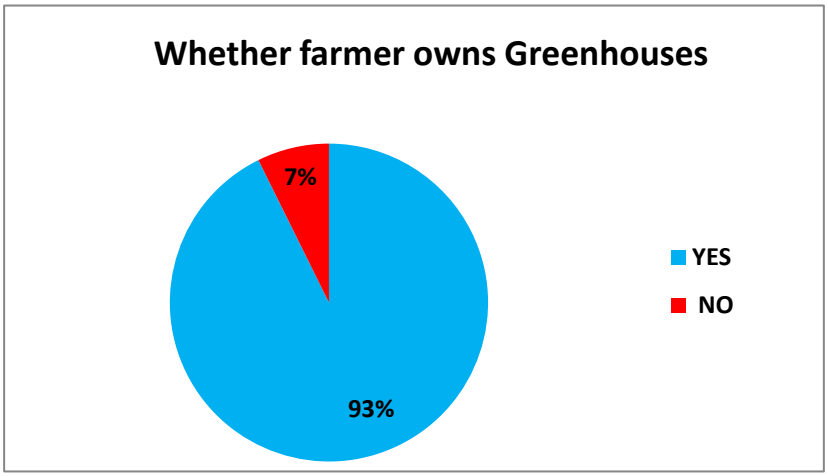
In addition to the above initiatives, UT Ladakh is also working to develop new and innovative ways to promote greenhouse technology among farmers. For example, the government is working to develop low-cost greenhouse kits that are suitable for use in the harsh Ladakh conditions. The government is also working to develop greenhouse technologies that are specifically adapted to the needs of Ladakhi farmers.

5.3 Primary Data Sources

A questionnaire is circulated amongst farmers in Leh, Ladakh who are engaged in farming in greenhouses. The questionnaire was framed in two parts. Part 1 consisting of 11 questions was intended to assess the greenhouse technology adoption amongst the farmers of the region and Part 2 of 15 questions to gauge the economic well-being of the farmers. Of the total 26 questions posed, one question was not responded by anyone and the same is therefore omitted in following analysis of the responses received. The questionnaire is placed as *Annexure A*. A total of 41 responses were received. Farmers' responses are analysed as detailed below:-

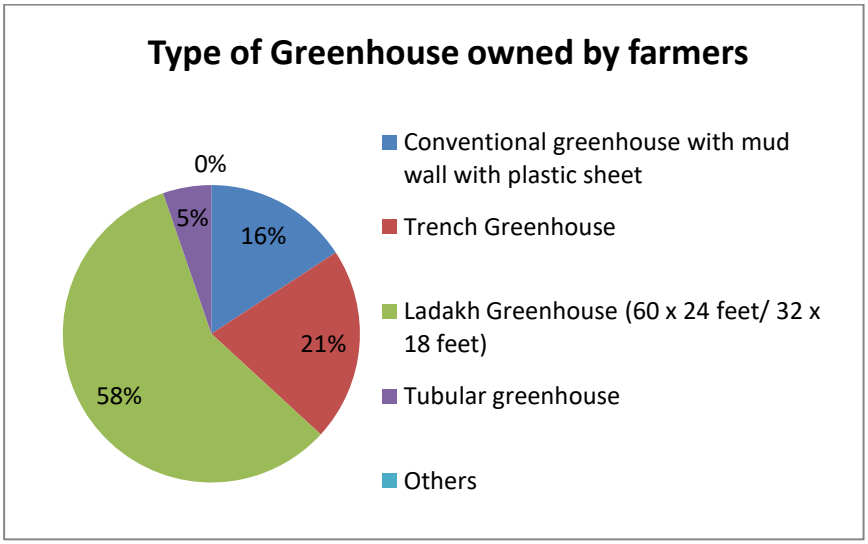
5.3.1 Greenhouse Technology Adoption

(a) Question 1: Whether the farmer owns a Greenhouse.



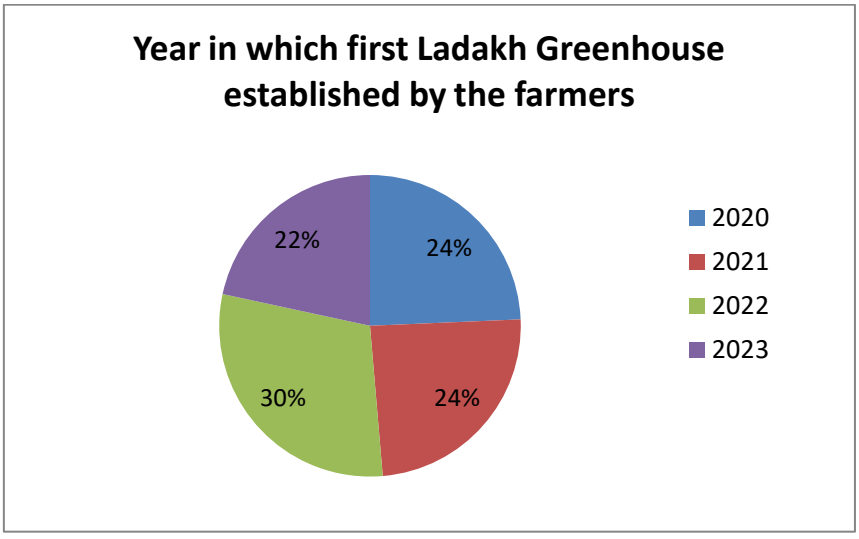
Of the 41 respondents, 95% (38) owned a greenhouse in some form or the other. 22 farmers do their farming under own Ladakh Greenhouse while the rest did in traditional greenhouses.

(b) Question 2: If yes, the type of greenhouse owned.



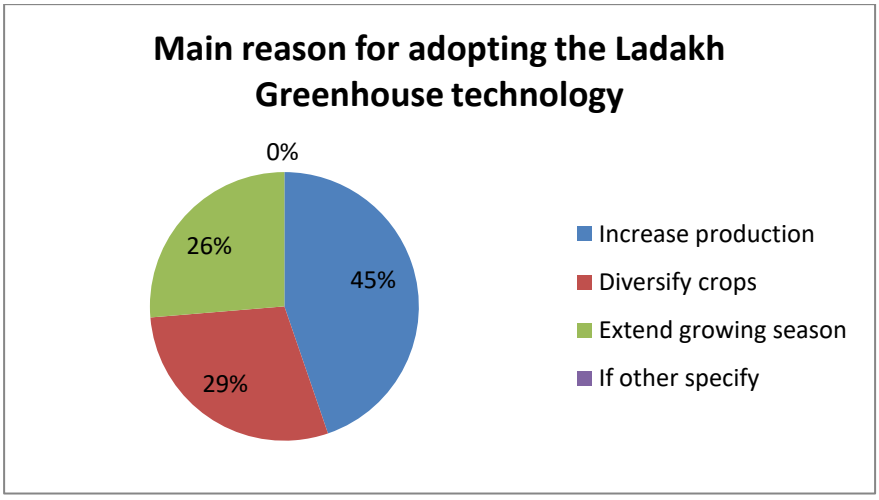
58% of the farmers owned a Ladakh Greenhouse while the remaining 42% had some form of greenhouses.

(c) Question 3: Year in which the first Ladakh Greenhouse established by the farmer.



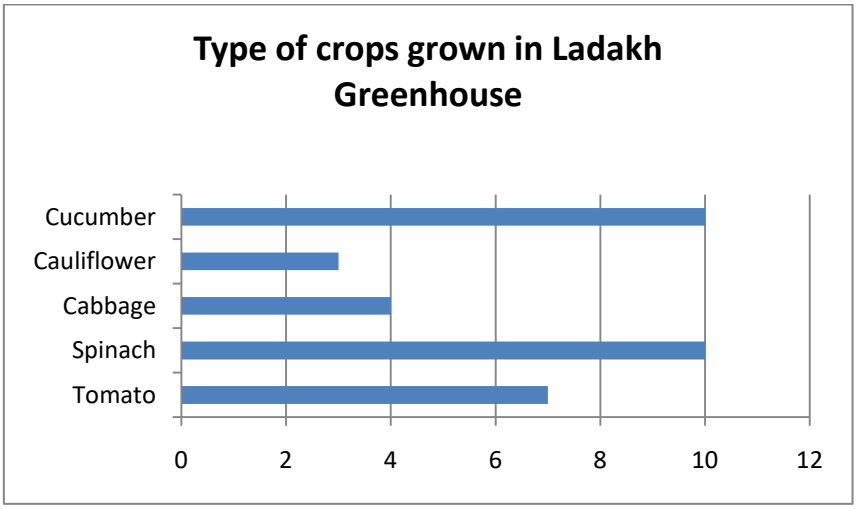
Respondents had adopted the greenhouse technology and established the first greenhouse since year 2020.

(d) Question 4: Main reason for adopting the Ladakh Greenhouse technology.



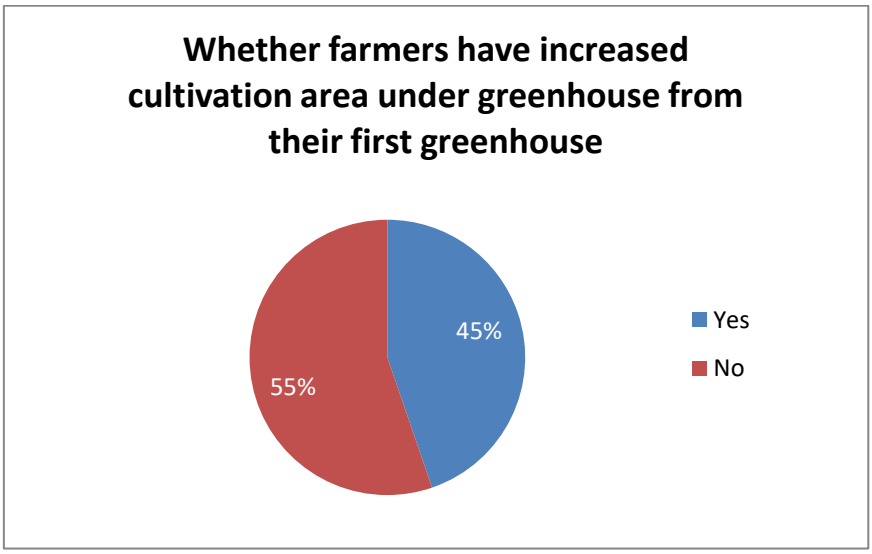
45% of respondents opted for technology due to its potential to provide increased farm output while the other two reasons were to diversify crops and to extend the growing season.

(e) Question 5: Type of crops grown in by the farmer in his Ladakh Greenhouse.



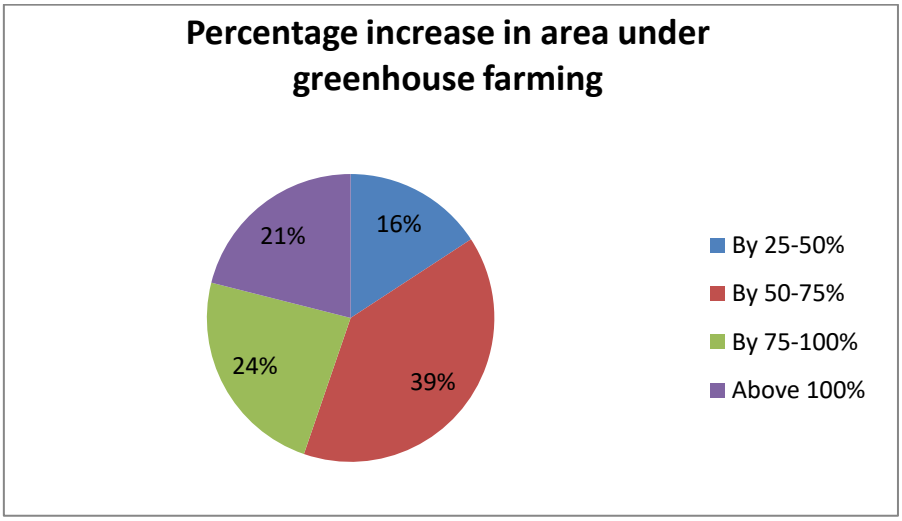
Farmers grow multiple crops in the greenhouse. Cucumber, Spinach, Tomato had higher number growers.

(f) Question 6: Whether farmer has increased his area of cultivation under greenhouse from his first greenhouse.



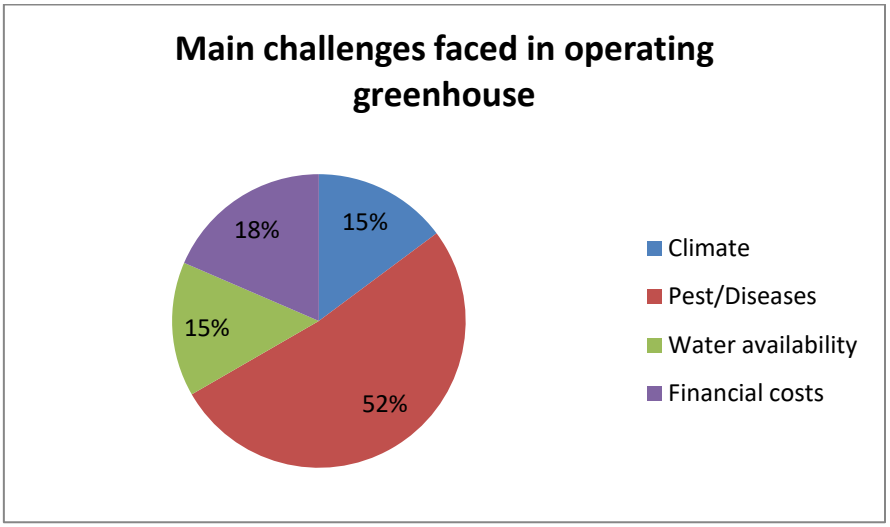
45% of respondents have increased the area of cultivation under new greenhouse from their first traditional greenhouse.

(g) Question 7: Percentage increase in area under greenhouse farming by farmers.



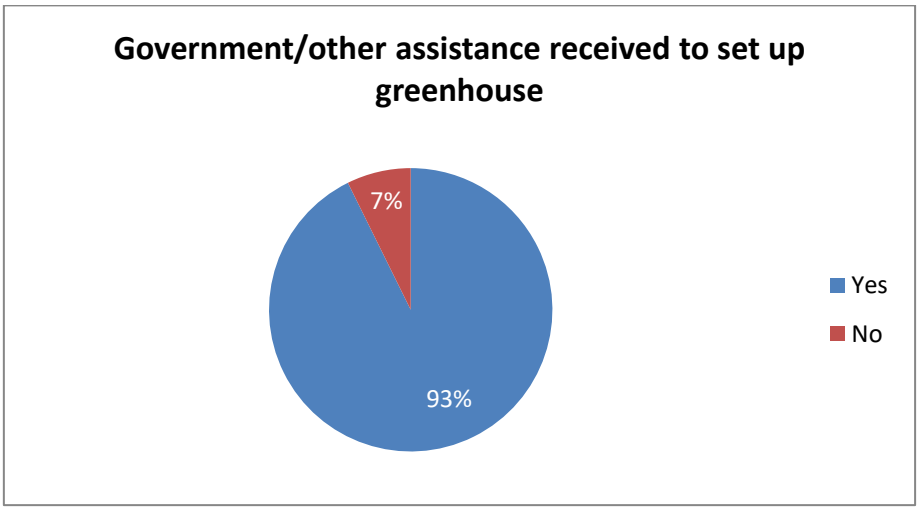
In addition to their traditional greenhouses, 39% of respondents have increased the area under farming by 50-75%

(h) Question 8: Main challenges faced by farmers in operating their greenhouse.



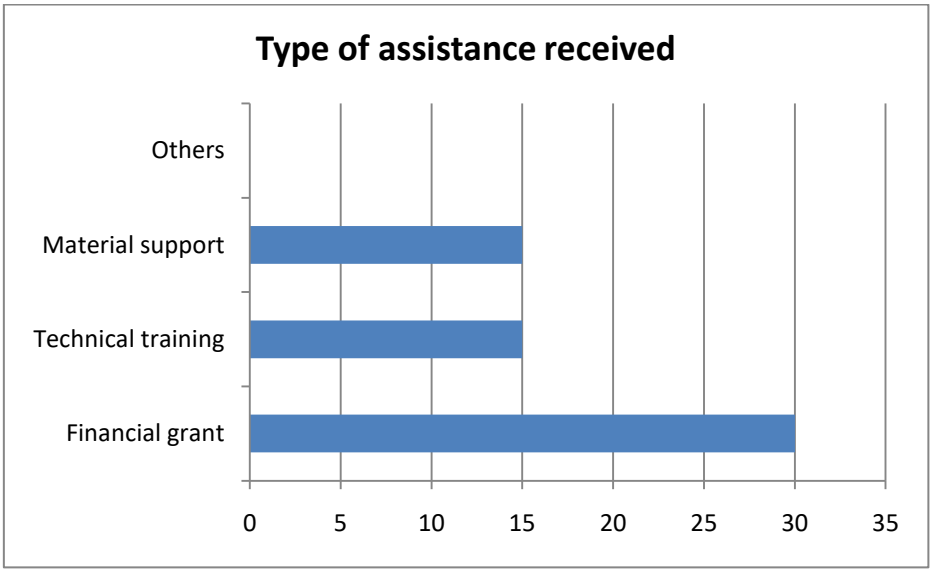
52% of the respondents faced the issue of pests/diseases under greenhouse cultivation. Financial costs are an issue with farmers who have difficulty in arranging the 25% of installation costs over the subsidy of 75% provided by the UT. This indicates the delay in achieving the break-even.

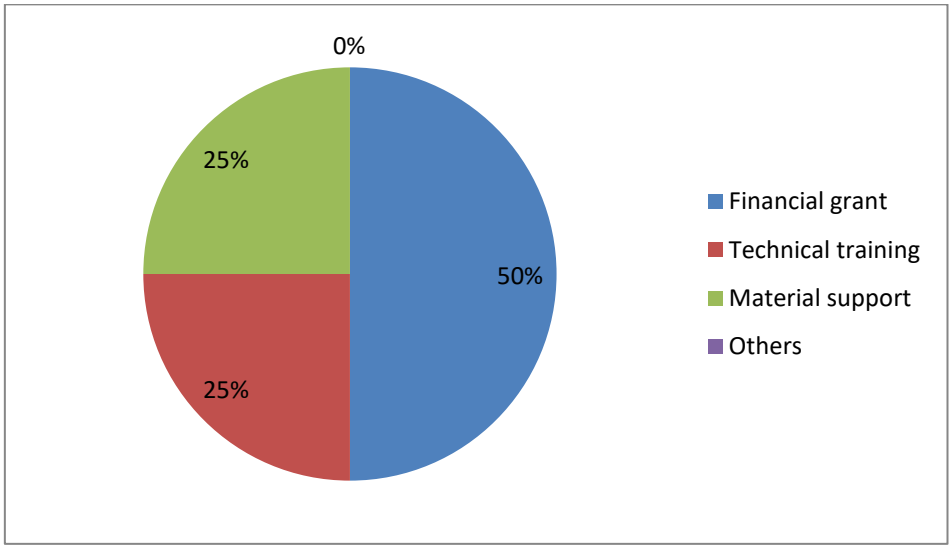
(i) Question 9: Any government or other assistance received by farmer to set up his greenhouse.



Majority of respondents (93%) had received assistance from government or other agencies to establish in the greenhouse farming. The remaining respondents who responded 'No' is presumed are those who have not pursued to own greenhouses.

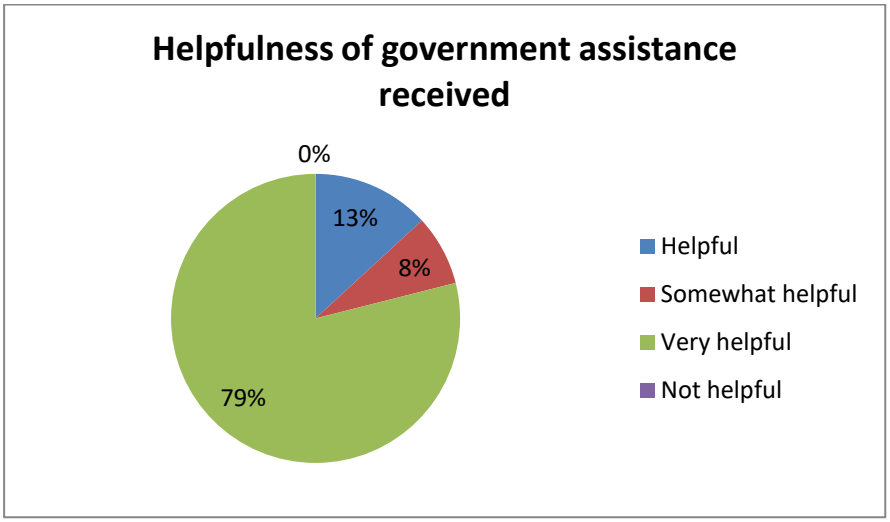
(k) Question 10: If yes, the type of assistance received.





Of the 41 respondents 50% received financial support in the form of subsidy/grant from government or other agencies. 25% got material support in the form of vermicompost pits, seed, and seedlings. 25% got formal technical training on greenhouse technology.

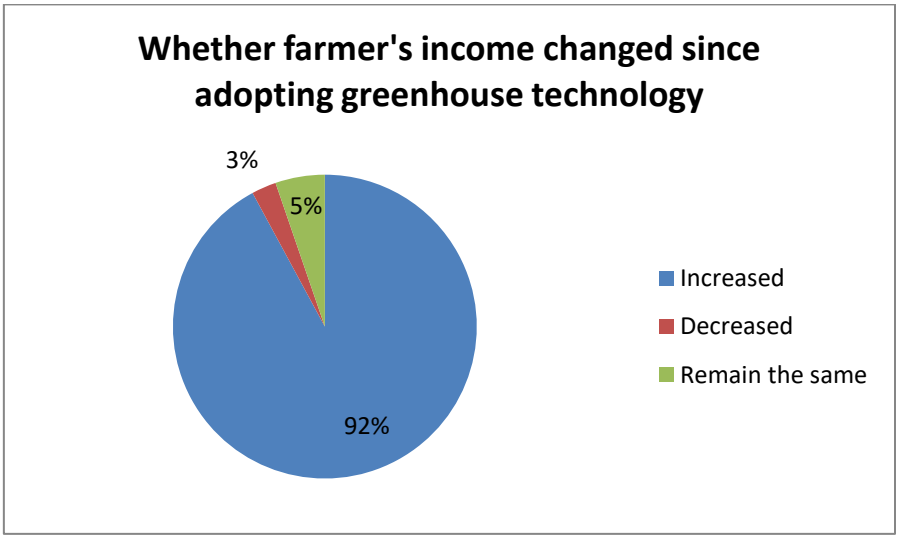
(l) Question 11: Helpfulness of government assistance received to farmer.



Most respondents found the government assistance as helpful to establish their own greenhouse farming in some manner or other.

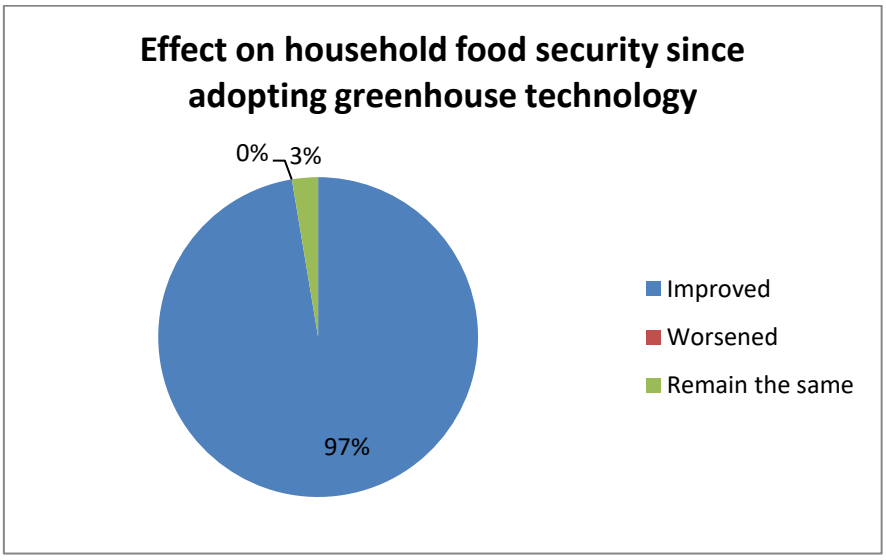
5.3.2 Assessing Economic Well-being

(a) Question 12: Whether income of farmer changed since adopting greenhouse technology.



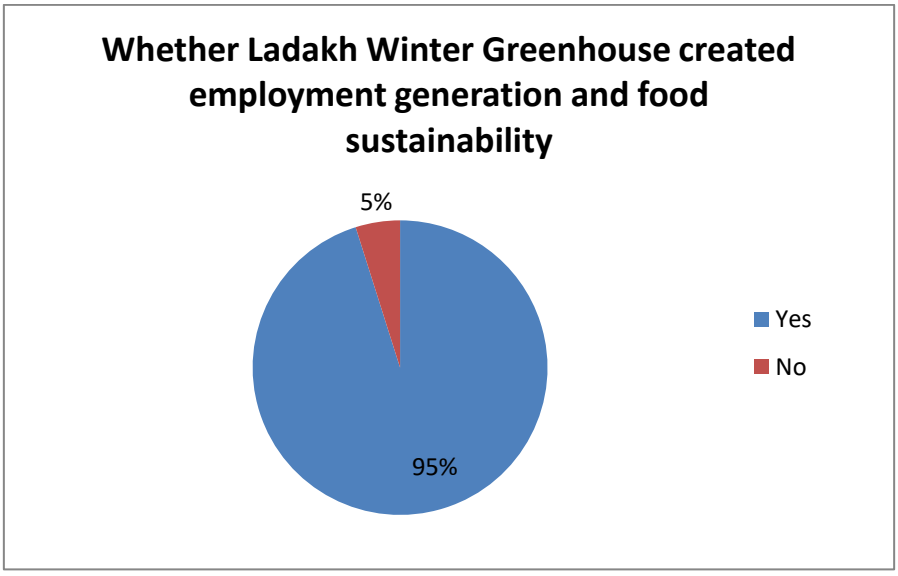
92% of the respondents experienced an increase in agricultural income by adopting to greenhouse technology.

(b) Question 13: Effect on farmer's household food security since adopting greenhouse technology by him.



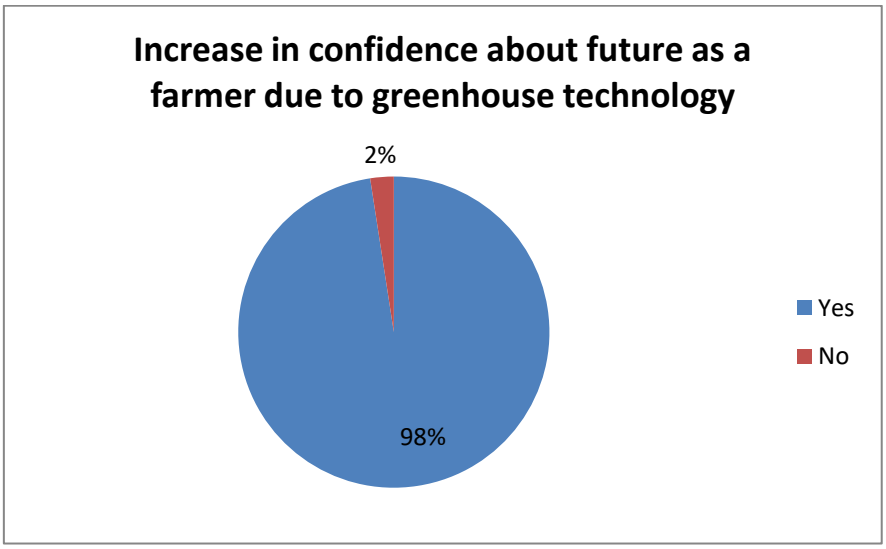
Almost all have agreed to the fact that their household food requirements are being met since they have adopted greenhouse technology for farming.

(c) Question 14: Whether the Ladakh Winter Greenhouse created employment generation and food sustainability.



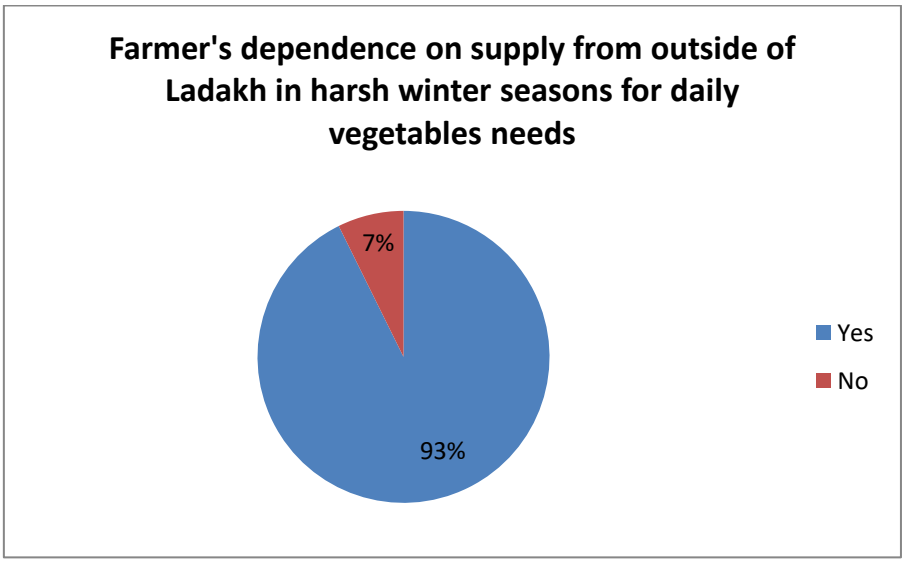
95% respondents agree that greenhouse technology has created employment and availability of food in a sustained manner.

(d) Question 15: Whether there is an increase in confidence in the farmer about his future as a farmer due to greenhouse technology.



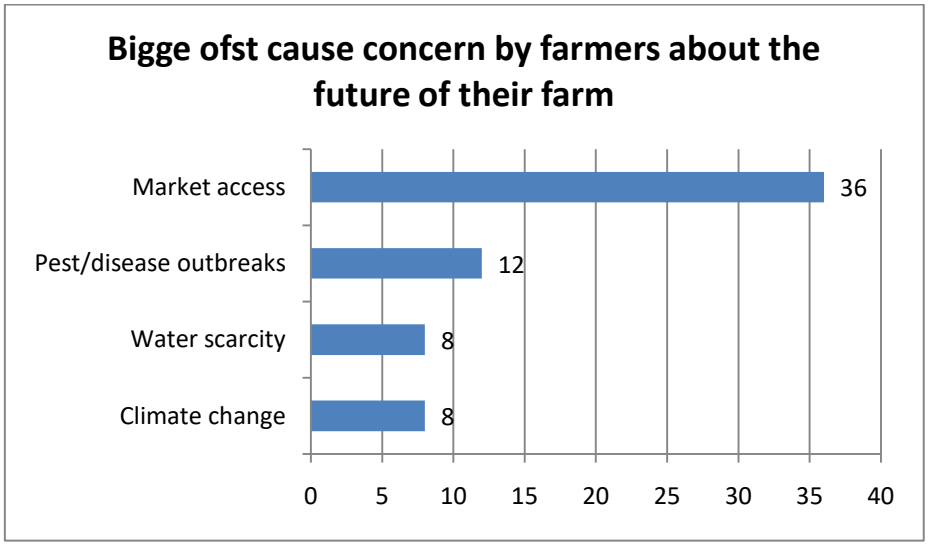
The greenhouse technology adoption has given confidence to 98% of the respondents. Targeted skill development initiatives by UT on the technology can sustain this.

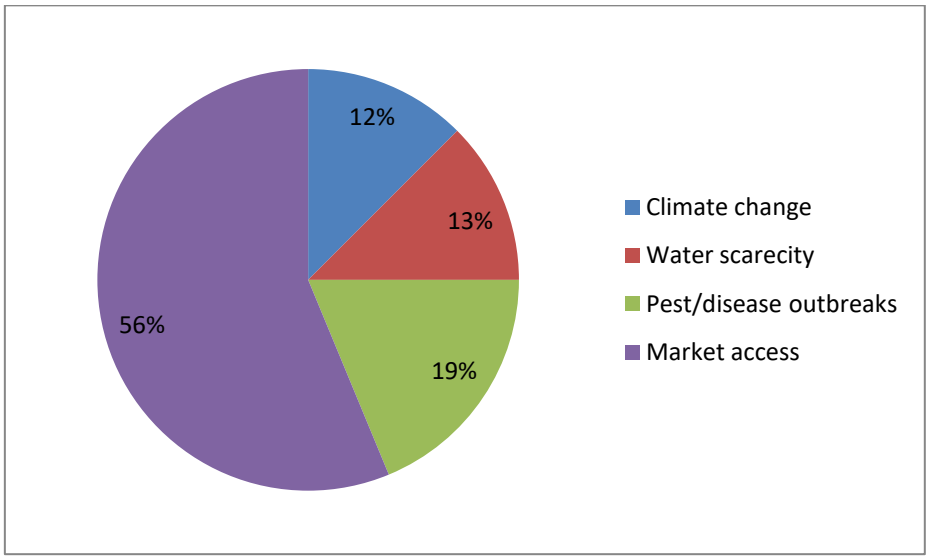
(e) Question 16: Whether farmer still ddependent on supply from outside of Ladakh in harsh winter seasons for daily vegetables needs.



The 93% response indicates that local farmers and populace are now increasingly benefitted with local farm produce as their dependence to outside supply has reduced.

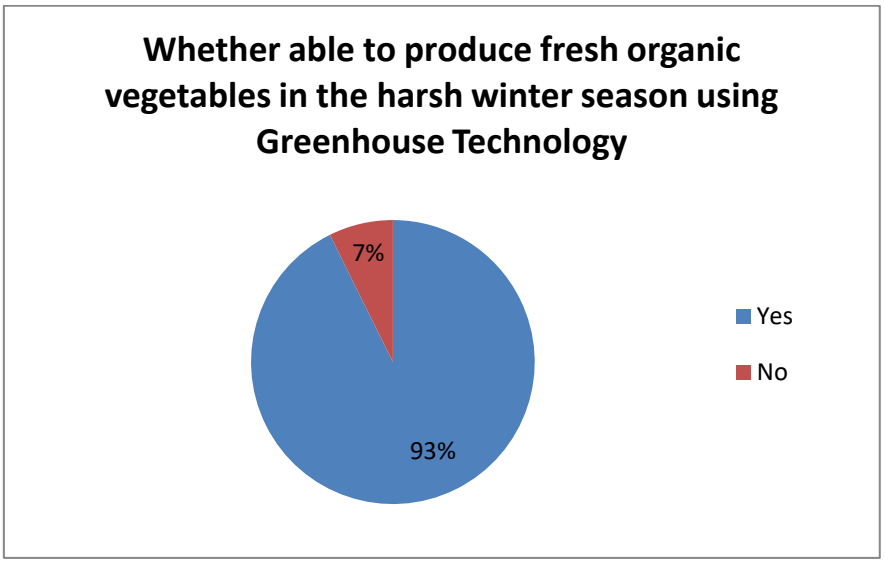
(f) Question 17: Biggest cause of concerns by farmers about future of their farm.





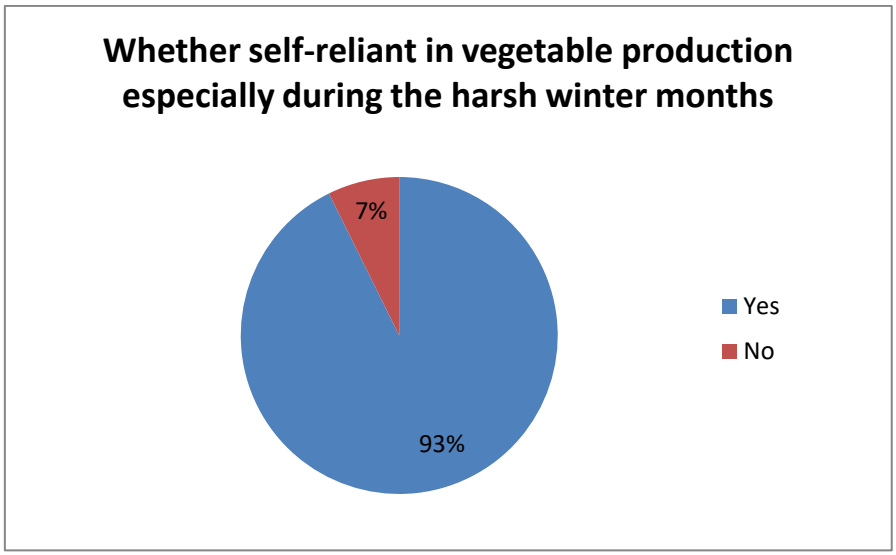
This question generated multiple responses. 36 respondents (56%) were of the view that market access is the biggest concern for them to sell out their produces in time. 12 farmers (19%) perceived issues of pest/diseases due to an increase in aphid infestation in the greenhouse in the all-year-round use of the greenhouse.

(g) Question 18: Whether farmer is able to produce fresh organic vegetables in the harsh winter season using Greenhouse Technology.



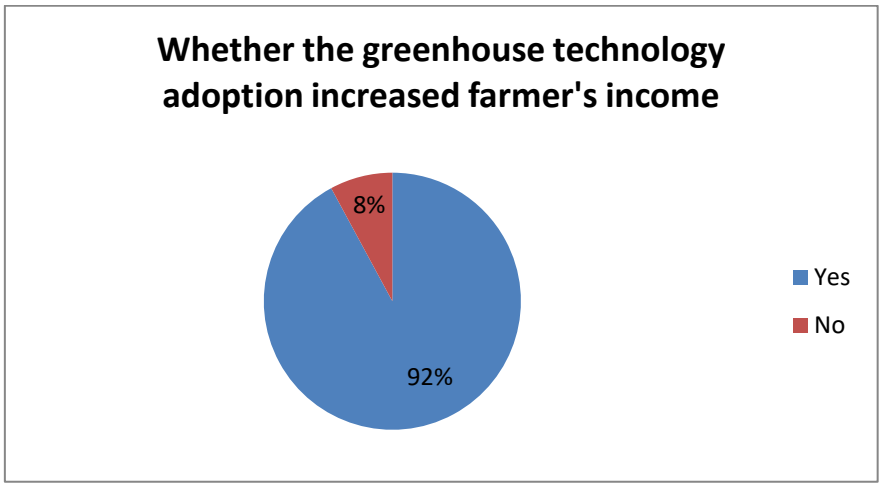
This response brings out that 93% of the farmers who have responded are able to produce fresh organic vegetables in their greenhouses in harsh winter season. The remaining 8% are those not yet adopted the technology in their farm.

(h) Question 19: Whether self-reliant in vegetable production especially during the harsh winter months.



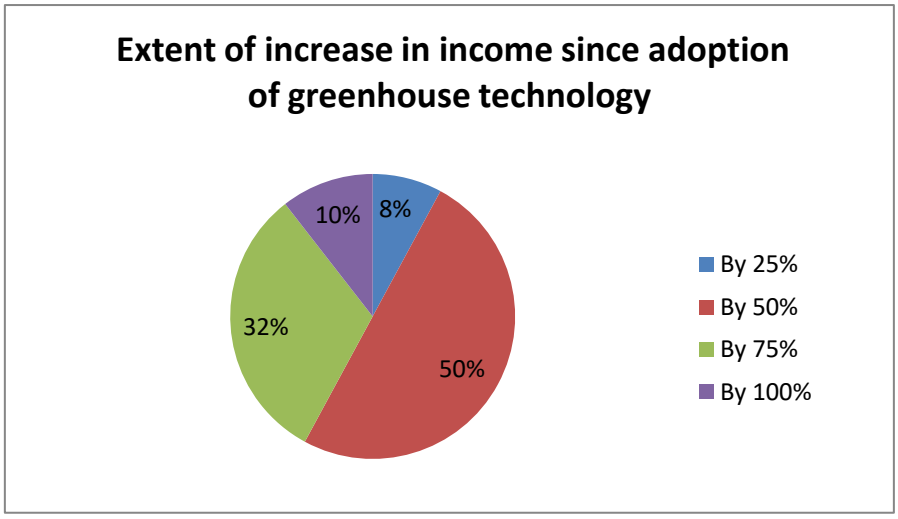
This question generated similar response as Q18 and hence reaffirming the effect of greenhouse technology adoption.

(i) Question 20: Whether the greenhouse technology adoption increased farmer's income.



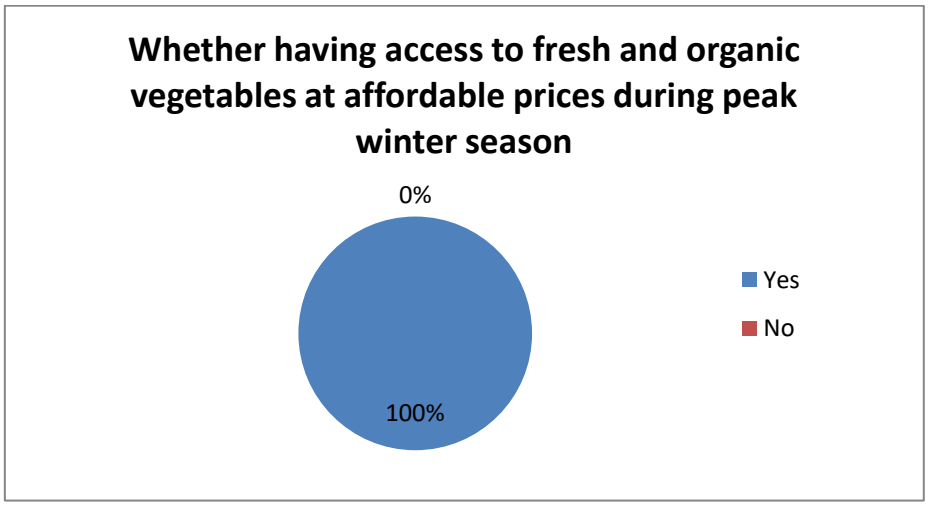
All respondents who adopted greenhouse technology (92%) have agreed that their income has increased. 8% of the respondents are those who have not yet adopted the technology.

(j) Question 21: Extent of increase in income of farmer since adoption of greenhouse technology



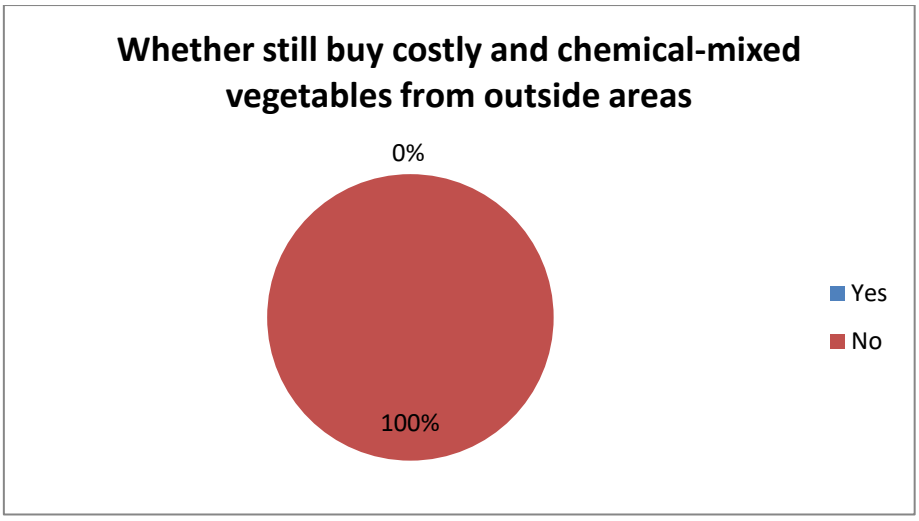
10% of respondents have doubled their income due to technology adoption. 50% of the respondents have had a 50% increase in their income.

(k) Question 22: Whether farmer have access to fresh and organic vegetables at affordable prices during peak winter season



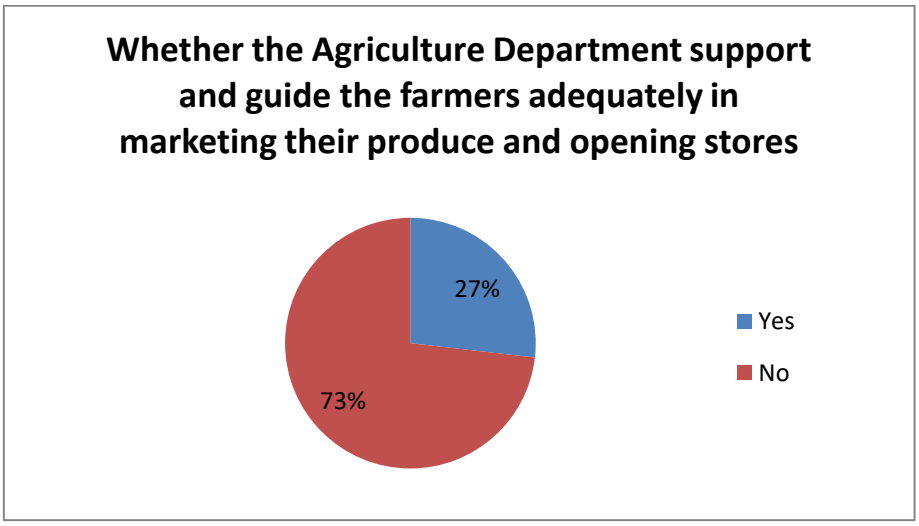
All agreed that they have now access to fresh and organic vegetables at affordable prices even during peak winter seasons. This availability of farm produces is attributable to the more greenhouses being adopted by the farmers in the region.

(l) Question 23: Whether still buy costly and chemical-mixed vegetables from outside areas.



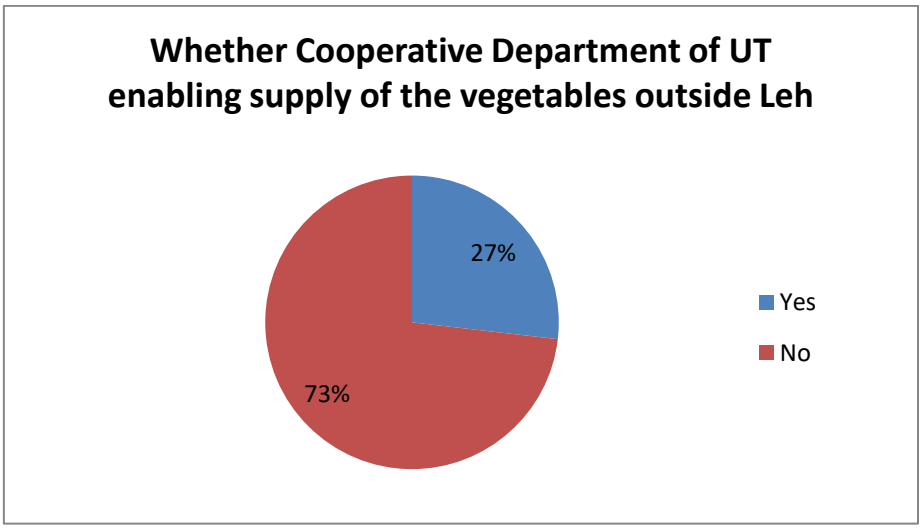
This question generated a similar response as Q22 wherein it reveals that the farmers now have access to local organic produces and are not dependent on produces from outside.

(m) Question 24: Whether the Agriculture Department support and guide the farmers adequately in marketing their produce and opening stores.



73% respondents agreed that the Ladakh Agriculture Department extended support and guided them in marketing their produce.27% are not satisfied with the inadequacy of market access for their farm produces.

(n) Question 25: Whether Cooperative Department of UT enabling supply of the vegetables outside Leh.



This question is directly linked to Q24. 73% wants the Cooperative Department of UT to do more for enabling them to supply their produces outside Leh while 27% agree that Cooperative Department has enabled them in supplying vegetables outside Leh.

5.3.2 A second questionnaire was designed for seeking direct inputs on the extent of progress made post receipt of PM's Award of Excellence in Public Administration (under the Innovation-States category) 2021 for the initiative of UT Ladakh. Inputs was obtained from Mr Ravinder Kumar, IAS the Champion-of-Change and Mr Thinles Dawa, the Chief Agriculture Officer Leh. The questionnaire is placed as *Annexure B.* The critical inputs gleaned out of the response received are as follows:-

(a) 695, 1122 and 205 greenhouses have been established on the farmers fields by the Administration of UT of Ladakh in 2021-22, 2022-23 and 2023-24 respectively. Thus, more than 2000 Ladakh Greenhouses have been established on farmers' fields after receiving the Prime Minister's Award for Excellence (2021). More women farmers are becoming part of the farming community. Given the increasing demand for Ladakh Greenhouses, UT Ladakh plans to construct an additional 6457 greenhouses in the next five years.

(b) The UT Ladakh has spent ₹ 14.361 Cr in 2021-22 and ₹ 29.361 Cr in 2022-23 towards promotion of Ladakh Greenhouse technology amongst the farmers in Ladakh. In the year 2023-24, this amount is ₹ 13.88 so far.

(c) UT Administration is providing incentives to the farmers for establishing Ladakh Greenhouses. 75% of the construction cost is borne by the UT Administration through subsidies, and the farmers bear the remaining 25%.

(d) Cultivation in Ladakh region has become possible for extended period throughout the year with the adoption of Ladakh Greenhouse technology. Farmers are now able to undertake three cycles of crops. Cycle 1 from mid October to early March is largely with Tomato, Cole crops and leafy vegetables and Cycle 2 from late March to early May is predominantly to develop and cultivate Vegetable nursery. Summer vegetables are grown during Cycle 3 from mid May to early October. This is a great achievement and boon for the farmers as only one or two cycles were possible in the conventional greenhouses and only single crop under open fields conditions. Therefore, cultivation for an extended period has become possible due to the Ladakh Greenhouse.

(e) There is an increase in income from farming for farmers. Besides meeting household requirements of fresh vegetables, the farmers are able to generate Rs 60,000-80,000 income in a year from a single greenhouse (60 feet x 24 feet).

5.4 Secondary Data Sources

Village Square, a public-interest communications initiative that focus on rural India, reports that farmers in Ladakh have adapted to the concept of greenhouses in the region promoted by the Agriculture Department. It cites examples of many successful farmers. Its reports "One farmer (Tsering Angchok) from Saboo village had set up a greenhouse about eight years ago. Earlier, he used to cover the crops with plastic sheets or even blankets and logs. He received 50% subsidy from government to set up a greenhouse. He spent Rs 1.5 lakh, and got a subsidy of Rs 80,000 from the government. He is now able to produce more vegetables, and sell more. Low cost alternatives like low tunnel technology to grow vegetables require the farmers to spend only Rs 2,000 for this. This technology is not only low-cost, but also portable. The farmers can shift the tunnel anywhere. Krishi Vigyan Kendra (KVKs) has been actively promoting this technology among villagers"[29]. Trench farms, known as poor man's greenhouse, are also used to grow herbs and vegetables in high mountain areas like Changthang[30]. Changthang's farming has been successfully built around the Ladakhi-style greenhouses, which are structurally and design-wise different from those in the plains.

Nyoma[31], in Ladakh which is one of the highest villages in the world has an array of agricultural tunnels, trenches and greenhouses where farmers mostly women grow a variety of vegetables. KVK Nyoma has brought in agricultural reforms through awareness campaign about modern farming for the region's people, most of whom lead a nomadic life. The women farmers are taking lead and able to grow more vegetables like tomato, aubergine, and mushrooms in greenhouses. These sturdy structures are easy to build and the use of locally sourced material keeps the costs

[29] https://www.villagesquare.in/winter-farming-technologies-boost-incomes-cold-desert-2/
[30] https://www.villagesquare.in/modern-farming-growing-potatoes-on-mars-ask-these-ladakhi-women-farmers/
[31] https://www.villagesquare.in/modern-farming-growing-potatoes-on-mars-ask-these-ladakhi-women-farmers/

down to a minimum. Plus, they blend with the landscape. Nyoma's Krishi Vigyan Kendra show about 500 farmers in the area and around 2,200 in the Changthang region engaged in modern farming. With KVK's intervention farmers, largely women here who used to grow only barley and occasionally turnips on their land are now growing cash crops like mushroom, cucumbers etc some of them even growing around six varieties of tomatoes and a type of brinjal, Modern farming techniques, women in Ladakh grow vegetables and earn a good income. It has given financial independence and enabled to earn in lakhs now as claimed by farmer Sona. She gets pre-orders for fresh cucumber, tomato and other greens from military units stationed in the region, earning around Rs 2 lakh a year. Changthang's women farmers are gradually basking in success.

5.4.1 Ladakh Greenhouse: A Status Update

Many passive solar greenhouses have been established in the region since the 1980s. However, given the limitations of the traditional greenhouses, DIHAR had developed the improvised passive solar 'Ladakh Greenhouse' technology, wherein growing cauliflower, cabbage, broccoli, tomato, chili, cucumber, and mushroom in sub-zero temperatures was demonstrated, which otherwise is not possible in the traditional passive solar greenhouses.

The greenhouse works all year round without a supplementary heating or cooling system.

The first trial of the greenhouse on farmers' fields began in 2020. Initially, five greenhouses were established by DIHAR in Thiksey village to demonstrate the working of the new technology on farmers' fields. On successful demonstration of the technology, the UT adopted the Ladakh Greenhouse technology for large-scale establishment on farmers' fields. Over 1500 Ladakh Greenhouses have been established in 120 villages within two years, and more greenhouse construction is underway. Due to its uniqueness and impact on the grassroots level, the Ladakh Greenhouse technology received the Prime Minister Award for Excellence in Public Administration (under the Innovation category) on 21 April 2022.

Presently, farmers in Ladakh grow cauliflower, cabbage, broccoli, tomato, chili, and cucumber in peak winter months, which is otherwise impossible in the traditional passive solar greenhouses. Besides alleviating hidden hunger, a farmer earns Rs 60,000–80,000 per year from a single greenhouse.

The UT administration provides 75 percent financial assistance to farmers to establish Ladakh Greenhouse. Even though farmers have to spend Rs one to two lakhs to cover the 25 percent cost of establishing one greenhouse, the greenhouse is in high demand. Therefore, the widespread use of Ladakh Greenhouse technology demonstrated the receptiveness of the Ladakhi farmers to adopting new technologies.

5.4.2 The Organic Aspiration of Ladakh

Ladakh Autonomous Hill Development Council (LAHDC) has declared to make Ladakh a fully organic UT by 2025 in accordance with the policy document "Mission Organic Development Initiative of Ladakh: Policy, Strategy, and Action Plan" after Ladakh became a Union Territory Oct 2019. The Rs 500-crore organic farming project named "Mission Organic Development Initiative of Ladakh" was launched by then Lieutenant governor, Shri R.K. Mathur on 4 July 2020 to be accomplished in three phases. Significant progress has been made with due to the farmers and government's strong support and political will. Under Phase-1, an area of 5342 hectares covering 34 villages as per plan is organically certified wherein these villages do not use any pesticides or herbicides. By 2025, the 40 villages in Phase-2 is expected to be certified. Certifications of Phase-3 villages are likely to be achieved in the next two more years at its current pace of development to make the UT Ladakh fully organic by 2027[32].

5.4.3 More success stories of greenhouses in Ladakh

The Better India News, an Indian digital media platform focused on positive stories and best practices, reports about certain farmers in Ladakh that "During the winter season, after taking into account the vegetables consumed in-house, some farmers

[32] Stobdan T (2023). Agriculture in Ladakh: A Step Towards Sustainable Mountain Development. Beeja House, New Delhi, India.

have earned around Rs 75,000 from all the crops grown inside the Ladakh Greenhouse. During the summer months, leafy vegetables like coriander, spinach and radish don't grow very well. Instead, they grew tomatoes, okra, capsicum, brinjal, chilies, etc. Since they started using this greenhouse, the farmers have cumulatively earned about Rs 1.75 lakh from all the crops grown inside excluding the items they consume in-house. Their income from farming has increased due to use of greenhouse. Now farmers are able to grow vegetables easily during peak winter months in their greenhouse where polycarbonate sheets are used. In summer, cauliflower sells for Rs 50 per kg, but by winter (January) they get about Rs 110 per kg,"[33]

Senior Scientist Dr Stobdan of DIHAR reports that "A variety of crops like broccoli, cauliflower, cabbage, knol-khol, mushroom, and tomato are being successfully grown inside the greenhouse during winter months. A medium greenhouse generates upto 325 kg of cauliflower/ greenhouse; 398 kg cabbage/ greenhouse, and 231 kg knol-khol/ greenhouse in Leh. These crops cannot grow well in traditional greenhouses. In the winter months, a variety of crops can be grown, which otherwise is not possible in a traditional greenhouse. During the summer months, a crop like cucumber would ordinarily enjoy a harvest from August onwards in the open field. Growing inside this greenhouse gives harvest by early June, and the farmers enjoy a higher crop yield of 4.5 kg per plant as opposed to 1.6 kg per plant on the open field, which is a 3-fold increase in crop productivity"[34].

UT Ladakh, in its response in the Questionnaire substantiates the above claims. It has stated that "locals have access to green vegetables during the peak winter season. Besides farmers, entrepreneurs and other residents who can't find work during the winter season, can also earn well during the winter season by growing and selling all these vegetables which have a ready market. We have even made a crop calendar for farmers, helping them navigate what they can grow throughout the year in the greenhouse. Besides installation, the administration also gives them some training about what crops they can grow during spring, summer and winter seasons. In the

[33] https://www.thebetterindia.com/266439/this-innovative-ladakhi-greenhouse-is-letting-farmers-grow-tomatoes-in-freezing-winter/
[34] https://www.thebetterindia.com/266439/this-innovative-ladakhi-greenhouse-is-letting-farmers-grow-tomatoes-in-freezing-winter/

long run, the objective is to reduce dependence on fresh vegetables from outside the region, both during summer and winter. For this, the Ladakh UT administration's target is to establish more greenhouses in Ladakh in the next two years".

5.4.5 Doubling of Farmers Income

The Government of India in its annual budget of 2016-17 set a policy target of doubling farmer's income by 2022. Agriculture sustains livelihood for more than half of the country's population. Doubling farmers' income in such a short period is a daunting task. Ladakh Greenhouse is vital for employment generation and food sustainability in the region[35]. Agriculture Department of Ladakh in close association with DIHAR has ensured making model Ladakh Greenhouse for demonstration for farmers and unemployed youth and subsequently operationalising it by adoption by farmers through its schemes. The Ladakh Greenhouse can produce fresh organic vegetables in the harsh winter season through polycarbonate greenhouse technology and also emphasised the technical/scientific use of the greenhouses to make Ladakh self-reliant in vegetable production especially during the harsh winter months and doubling the farmer income. The project will support young agri-entrepreneurs for commercial cultivation and thereby employment generation on a large scale. The sale of vegetables will enable locals to get fresh vegetables at an affordable price.

[35] https://ladakh.nic.in/ladakh-winter-greenhouse-will-be-vital-for-employment-generation-and-foodsustainability/#:~:text=This%20Greenhouse%20can%20produce%20fresh,and%20doubling%20the%20farmer%20income.

CHAPTER-6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Ladakh region has faced with vagaries of extreme long winters due to which the local populace especially the farmers were facing acute problems to generate adequate produce in open field environment to cater for their nutritional requirement and economic well being. The farmers are engaged in agriculture under various forms of traditional greenhouse infrastructure. The successful design, development and implementation of Ladakh Greenhouse technology in the region by DIHAR and Agriculture department of UT Ladakh in 2021 is a landmark achievement. For its uniqueness and impact in the region, this initiative the UT received Prime Minister's Award of Excellence in Public Administration in the year 2022.

Farmers of the region are adopting this greenhouse technology and this has enabled cultivation of crops all the year around. This study confirms the following:-

(a) The farmers of the Ladakh region are using the greenhouse technology in various traditional forms. With the success of Ladakh Greenhouse developed by DIHAR, farmers have started adopting this technology with involvement of the UT Administration.

(b) After the greenhouse technology transfer from DIHAR, Ladakh's Agriculture Departmenthas vigorously gone ahead to promote its adoption amongst the farmers. Since the technology adoption, 111 Ladakh Greenhouses were established on farmers' field till Dec 2021.

(c) The Administration of UT Ladakh has established 695, 1122 and 205 greenhouses on the farmers fields by in 2021-22, 2022-23 and 2023-24 respectively. More women farmers are becoming part of the farming community.

(d) The UT Ladakh has spent ₹ 14.361 Cr in 2021-22 and ₹ 29.361 Cr in 2022-23 towards promotion of Ladakh Greenhouse technology amongst the farmers in Ladakh.

In the year 2023-24, this amount is ₹ 13.88 so far. UT Ladakh plans to construct an additional 6457 greenhouses in the next five years citing the increasing demand for Ladakh Greenhouses.

(e) UT Administration is providing incentives to the farmers for establishing Ladakh Greenhouses. 75% of the construction cost is borne by the UT Administration through subsidies, and the farmers bear the remaining 25%. Besides this, the Agriculture Department provides quality seed and seedlings to farmers, and also composting units to promote the organic package of practices.

(f) Cultivation in Ladakh region has become possible for extended period throughout the year with the adoption of Ladakh Greenhouse technology. Farmers are now able to undertake three cycles of crops. This is a great achievement and boon for the farmers as only one or two cycles were possible in the conventional greenhouses and only single crop under open fields conditions. Therefore, cultivation for an extended period has become possible due to the Ladakh Greenhouse.

(g) Moreover, there is an increase in the variety of vegetables farmers in Ladakh are now able to grow such as cauliflower, cabbage, broccoli, tomato, chili, and cucumber in peak winter months, which is otherwise impossible in conventional passive solar greenhouses.

(h) Farmers are able to harvest crops in peak winter months (Dec-Jan), which is otherwise not possible in traditional greenhouses. Greenhouse vegetables are now sold in the market even in peak winter months.

(i) With the greenhouse technology, farmers are able to harvest warm season crops early in the season, i.e., May-June onwards, which otherwise is not possible earlier. Farmers are able to harvest cucumber within 40 days after sowing in Ladakh Greenhouse compared to 80-90 days in open fields. Similarly, farmers are able to extend the harvest season of warm season crops up to Nov-Dec. This translates to earlier availability and a longer period of fresh, local produce for the community.

(j) Besides cultivating three crops a year, farmers are getting three times more harvest from Ladakh Greenhouse as compared to the open field. The per plant harvest of cucumber was 4.56 kg in Ladakh Greenhouse compared to 1.76 kg in the open field.

(k) There is an increase in income from farming for farmers. They are now able to generate Rs 60,000-80,000 income in a year from a single greenhouse (60 feet x 24 feet) over and above meeting household requirements of fresh vegetables.

(l) The consumption of fresh vegetables has increased, especially in winter, due to the Ladakh Greenhouse. The all year round production of vegetables would make a positive effect to reduce the hidden hunger in the region.

(m) UT is vigorously pursuing for all the farmers to adopt an organic package of practices for growing vegetables in the Ladakh Greenhouse. This is in line with the 'Mission Organic Development Initiative' launched by the Administration in 2020 to make the region fully organic by then.

(n) With the Ladakh Greenhouse technology adoption, now vegetables are reaching remote and border villages. People in extreme altitudes are able to get leafy vegetables in peak winter months, which was otherwise not possible earlier.

(o) Average annual income over the last three years is evaluate as Rs 60,000-80,000 from a from a single Ladakh Greenhouse of 60 x 24 ft with average savings 40,000-50,000. This clearly indicates increase in the disposable income of farmers adopting the technology.

(p) The initiative has resulted in food security and to be vocal for local. Farmer income has increased and it resulted in women empowerment.

(q) A carbon neutral Ladakh is not far away with the UT Ladakh's twin pursuit of 'Mission Organic Development Initiative' and 'Ladakh Greenhouse Project and also to realise more crop per inch/per drop/water conservation.

6.1.1 Challenges/constraints and Measures Adopted

Certain challenges/constraints still exist for the farmers and administration of UT Ladakh. Proactive measures are adopted by the administration to address them. These involve the following:-

(a) 56% of the farmers who responded to the questionnaire face the issue of appropriate access to market to sell their produces. Agriculture Department of Ladakh is silent on this aspect in their response to the questionnaire under challenges and constraints of greenhouse farming.

(b) Many farmers (19% of respondents) are experiencing an increase in aphid infestation in their crops under greenhouse due to the all-year-round use of the greenhouse. The Agriculture Department is advocating good farming practices to reduce this. DIHAR is working on a farmer-friendly practice to reduce insect infestation, which is being followed-up by the administration.

(c) Few farmers (13% of respondents) are facing non-availability of water for irrigation purposes in winter months. To deal with this, the Agriculture Department is encouraging the farmers to establish Ladakh Greenhouse near water sources. Besides this, the UT Administration is providing bore wells to the farmers on subsidized rates.

(d) The Administration is being faced with an increased demand for Ladakh Greenhouse by the farmers. To meet this demand, the UT Ladakh plans to construct an additional 6457 greenhouses in the next five years. This is over and above the plans to continue with providing of incentives to the farmers so that every house in Ladakh benefits from the innovative technology.

(e) A small section of farmers finds it difficult to bear the 25% of the construction cost of Ladakh Greenhouse. The Agriculture Department is promoting Polytrench Greenhouse, a low-cost passive solar greenhouse developed by DIHAR, from 2023 onwards.

6.2 Recommendations

The UT Ladakh has successfully implemented the greenhouse technology in the region. Following are recommended to ensure enhanced sustained interest in the technology by the local farmers. This would further enhance the economic return and realise the dreams of doubling the farmers' income besides taking care of nutritional reuiewmwnt and food security of the local community in Ladakh.

(a) The UT administration needs to continue actively pursuing for enhanced promotion of Ladakh Greenhouse technology among more farmers in the region. It should stay its course with the plans of creating around 6457 greenhouses in the next five years.

(b) Presently, the farmers bear 25% of the construction cost of a greenhouse. To make it more attractive for farmers and early break-even, administration should involve cooperative department to aid pick up/take their farm produce and facilitate marketing.

(c) The Mission Organic Development Initiative be pursued with all its verve alongwith the plans for more Ladakh Greenhouses for its farmers to make its march towards enhanced food security and socio-economic benefits.

(d) Agriculture department must focus to diversify and promote high value cropson commercial and high technology greenhouses.

(e) The problems related to irrigation and pest/diseases must be addressed with persistent engagement with the farmers and DIHAR to ensure that such nagging issues are not a obstacle for farmers in continuing with agriculture and wean them away to other jobs with more economic benefits like tourism etc.

(f) Skill development programmes may be arranged to facilitate more awareness and interest and faster technology adoption.

(g) More schemes of government interventions be designed to aid the youth of Ladakh to

Enter into agriculture profession which is now possible throughout the year unlike the inconsistent industries like tourism.

(h) Digital recording of crop cultivation and success stories of farmers using greenhouse technology could be disseminated for the benefit of populace in local language and motivate to get into greenhouse agriculture.

(i) This has benefitted the small and marginal farmers, young agri-entrepreneurs of Leh and Kargil districts with special focus on women farmers and SHG’s.

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Annexure A

Questionnaire 1 (To Farmers)

Greenhouse Technology: Agriculture Reality in Cold Arid Ladakh

(The study seeks to evaluate the UT Ladakh's initiative of 'Building of Efficient Greenhouse to Grow Crops: Ladakh' for which the Department of Agriculture, UT Ladakh was awarded the Prime Minister's Award for Excellence in Public Administration in 2021 under Category : Innovation State).

Introduction. Thank you for participating in this survey! Your responses will help us understand the adoption of greenhouse technology in Ladakhi agriculture and its impact on your well-being. All information will be kept anonymous and confidential.

Part 1: Background Information

1. Name : (Optional)
2. Village/Town :
3. Age :
4. Gender :
5. Main source of income: (Choose one or multiple)
   (a) Farming
   (b) Livestock rearing
   (c) Wage labor
   (d) Other (please specify):
   (e) How many years have you been involved in agriculture?

Part 2: Greenhouse Technology Adoption

1. Do you have a greenhouse on your farm?

   (a) Yes (b) No

2. If yes, what type of greenhouse do you have?

   (a) Ladakh Greenhouse (b) Trench Greenhouse
   (c) Polytrench Glasshouse (d) Polynet Greenhouse
   (e) If other, please specify

3. In which year did you establish your first greenhouse?

   (a) 2020 (b) 2021 (c) 2022 (d) 2023

4. What was the main reason for adopting greenhouse technology?

(a) Increase production (b) Diversify crops
(c) Extend growing season (d) If other reason, please specify

5. What crops do you grow in your greenhouse? Please specify.

(a) (b) (c) (d)

6. Have your increased your area of cultivation under greenhouse from your first greenhouse?

(a) Yes (b) No

7. Area under your greenhouse farming has increased by how much?

(a) by 25-50% (b) by 50-75%
(c) by 75-100% (d) 100% and above

8. What are the main challenges you face in operating your greenhouse?

(a) Climate (b) Pests/ Diseases
(c) Water availability (d) Financial costs
(e) Other

9. Did you receive any government or other assistance to set up your greenhouse?

(a) Yes (b) No

10. If yes, what type of assistance did you receive?

(a) Financial grant (b) Technical training
(c) Materials support (d) Other

11. How helpful was the assistance you received?

(a) Helpful (b) Somewhat helpful
(c) Very helpful (d) Not helpful

12. Which governmental schemes of UT Ladakh have provided you financial assistance for greenhouse farming (Select from schemes like Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) Flagship scheme, Rashtriya Krishi Vikas Yojana-RAFTAAR(RKVY–RAFTAAR), Rashtriya Krishi Vikas Yojana-

RAFTAAR(RKVY–RAFTAAR), National Mission on Agricultural Extension and Technology(NMAET), National Mission on Sustainable Agriculture (NMSA), National Food Security Mission(NFSM), National Mission on Oilseed sand Oil-Palm(NMOOP), Pradhan Mantri Kisan Samman Nidhi(PM-KISAN)

(a) (b)
(c) (d)

Part 3: Assessing Economic Well-being

1. How has your income changed since adopting greenhouse technology?

(a) Increased (b) Decreased (c) Remained the same

2. How has your household food security changed since adopting greenhouse technology?

(a) Improved (b) Worsened (c) Remained the same

3. Has the Ladakh Winter Greenhouse created Employment generation and food sustainability?

(a) Yes (b) No

4. Do you feel more confident about your future as a farmer due to greenhouse technology?

(a) Yes (b) No

5. Do you still depend on supply from outside of Ladakh in harsh winter seasons for your daily vegetables needs?

(a) Yes (b) No

6. What are your biggest concerns about the future of your farm?

(a) Climate change (b) Water scarcity
(c) Pest/disease outbreaks (d) Market access
(e) Other

7. Are you able to produce fresh organic vegetables in the harsh winter season using Greenhouse Technology?

(a) Yes (b) No

8. Are you self-reliant in vegetable production especially during the harsh winter months?

(a) Yes (b) No

9. Has the greenhouse technology adoption increased your income?

(a) Yes (b) No

10. How much has your income increased since adoption of greenhouse technology?

(a) No change (b) by 50%
(c) by 75% (d) by 100%

11. Do you have access to fresh and organic vegetables at affordable prices during the peak winter season.

(a) Yes (b) No

12. Do you still buy costly and chemical-mixed vegetables from outside areas.

(a) Yes (b) No

13. Is the Agriculture Department supporting and guiding the farmers adequately in marketing their produce and opening stores.

(a) Yes (b) No

14. Is the Cooperative Department of UT enabling the supply of the vegetables outside Leh.

(a) Yes (b) No

Part 4: Additional Comments (Please share any additional thoughts or comments you have about greenhouse technology adoption in Ladakh and its impact on your well-being).

Thank you for your participation!

Annexure B

Questionnaire 2 (To the Administration of UT Ladakh)

Ladakh Greenhouse Technology: Agriculture Reality in Cold Arid Ladakh

(The study seeks to evaluate the UT Ladakh's initiative of 'Building of Efficient Greenhouse to Grow Crops: Ladakh' for which the Department of Agriculture, UT Ladakh was awarded the Prime Minister's Award for Excellence in Public Administration in 2021 under Category : Innovation State).

1. What is the extent of adoption of greenhouse technology by the farming households of Ladakh since the receipt of Prime Minister's Award for Excellence (2021) by UT Ladakh?

Reply: More than 2000 Ladakh Greenhouses have been established on farmers' fields by the Administration of Union Territory of Ladakh after receiving the Prime Minister's Award for Excellence (2021). Given the increasing demand for Ladakh Greenhouses, UT Ladakh plans to construct an additional 6457 greenhouses in the next five years.

2. Please indicate the types and number of greenhouses that are functioning in the region? What is the progressive number of different types of greenhouses added in the Ladakh region in each year over the last five years.

Reply:

Year	Sl No.	Type of Greenhouse	No. of Greenhouses added during the year
2018-19	(a)	Traditional Greenhouse with mud wall and plastic sheet	
	(b)	Trench Greenhouse	
	(c)	Polytrench Greenhouse	0
	(d)	Ladakh Greenhouse	0
	(e)	FRP Greenhouse	0
2019-20	(a)	Traditional Greenhouse with mud wall and plastic sheet	
	(b)	Trench Greenhouse	
	(c)	Polytrench Greenhouse	0
	(d)	Ladakh Greenhouse	0
	(e)	FRP Greenhouse	0
2020-21	(a)	Traditional Greenhouse with mud wall and plastic sheet	
	(b)	Trench Greenhouse	
	(c)	Polytrench Greenhouse	0

	(d)	Ladakh Greenhouse	5
	(e)	FRP Greenhouse	0
2021-22	(a)	Traditional Greenhouse with mud wall and plastic sheet	
	(b)	Trench Greenhouse	
	(c)	Polytrench Greenhouse	0
	(d)	FRP Greenhouse	0
	(e)	Ladakh Greenhouse	695
2022-23	(a)	Traditional Greenhouse with mud wall and plastic sheet	0
	(b)	Trench Greenhouse	0
	(c)	Polytrench Greenhouse	0
	(d)	Ladakh Greenhouse	1122
	(e)	FRP Greenhouse	0
2023-24	(a)	Traditional Greenhouse with mud wall and plastic sheet	
	(b)	Trench Greenhouse	
	(c)	Polytrench Greenhouse	40
	(d)	Ladakh Greenhouse	205
	(e)	FRP Greenhouse	0

3. Has the cultivation become possible in Ladakh for extended period (duration) with the adoption of Ladakh Greenhouse technology? If yes, since which year?

Reply: Three cycles of crops are grown in Ladakh Greenhouse (Cycle 1: Tomato, Cole crops and leafy vegetable-mid October to early March; Cycle 2: Vegetable nursery-late March to early May; Cycle 3: Summer vegetables-mid May to early October), as compared to one to two cycles in the conventional greenhouses. Under open fields, farmers in the region are able to grow a single crop. Therefore, cultivation for an extended period has become possible due to the Ladakh Greenhouse. Besides, farmers in Ladakh are now able to grow a variety of vegetables such as cauliflower, cabbage, broccoli, tomato, chili, and cucumber in peak winter months, which is otherwise impossible in conventional passive solar greenhouses.

4. What are the improvements that the Ladakh Greenhouse technology adoption has brought to the people of Ladakh?

(a) **Increased variety of vegetables:** Farmers are now able to grow a variety of vegetables, which is not possible otherwise, especially in autumn, winter, and spring in the traditional Ladakh Greenhouse.

(b) **Vegetable harvest in peak winter:** Farmers are able to harvest crops in peak winter months (Dec-Jan), which is otherwise not possible in traditional greenhouses. Greenhouse vegetables are now sold in the market even in peak winter months.

(c) **Early harvest and extended crop harvest:** With the Ladakh Greenhouse technology, farmers are able to harvest warm season crops early in the season, i.e., May-June onwards, which otherwise is not possible earlier. Farmers are able to harvest cucumber within 40 days after sowing in Ladakh Greenhouse compared to 80-90 days in open fields. Similarly, farmers are able to extend the harvest season of warm season crops up to Nov-Dec.

(d) **Increase crop productivity:** Besides getting three crops a year, farmers are getting three times more harvest from Ladakh Greenhouse as compared to the open field. The per plant harvest of cucumber was 4.56 kg in Ladakh Greenhouse compared to 1.76 kg in the open field.

(e) **Farm income:** Besides meeting household requirements of fresh vegetables, the farmers are able to generate Rs 60,000-80,000 income in a year from a single greenhouse (60 feet x 24 feet).

(f) **Hidden hunger:** The consumption of fresh vegetables has increased, especially in winter, due to the Ladakh Greenhouse.

(g) **Organic harvest:** All the farmers adopt an organic package of practices for growing vegetables in the Ladakh Greenhouse.

(h) **Vegetables in remote and border villages:** The Ladakh Greenhouse technology has reached remote and border villages. Due to the benefit of the technology, people in extreme altitudes are able to get leafy vegetables in peak winter months, which is otherwise not possible earlier.

5. What is the average annual income and savings from a Ladakh Greenhouse? If yes, please furnish approximate figures.

Year	**Average income per Ladakh Greenhouse (60 x 24 feet)**	**Average saving due to single Ladakh Greenhouse (60 x 24 feet)**
2020-21	Rs 60,000-80,000	40,000-50,000
2021-22	Rs 60,000-80,000	40,000-50,000
2022-23	Rs 60,000-80,000	40,000-50,000

6. What are the public interventions / governmental schemes implemented by the UT to promote Ladakh Greenhouse technology among farmers in Ladakh in the last five years from 2018-19 to 2022-23? Please indicate in the table below. What is the amount of public money allocated and spent under each such scheme for these corresponding years?

Year	Sl No.	Name of Public interventions / Governmental schemes	Amount Spent (in Crore)
2018-19	1.	-	
	2.	-	
	3.	-	
2019-20	1.	-	
	2.	-	
	3.	-	
2020-21	1.	Ladakh Greenhouse (trial)	
	2.	-	
	3.	-	
2021-22	1.	Ladakh Greenhouse	14.361
	2.	-	
	3.	-	
2022-23	1.	Ladakh Greenhouse	29.361
	2.	-	
	3.	-	
2023-24	1.	Ladakh Greenhouse	13.88 (till date)
	2.	-	
	3.	-	

7. What are the support and incentives provided by the UT to farmers adopting Ladakh Greenhouse farming in the Ladakh region? Please list them below.

(a) UT Administration is providing incentives to the farmers for establishing Ladakh Greenhouses. Approx. 75% of the construction cost is borne by the UT Administration through the Agriculture Department, and the farmers bear the remaining 25%.
(b) The Agriculture Department provides quality seed and seedlings to the farmers.
(c) To promote the organic package of practices, the Agriculture Department provides composting units to farmers.

8. What are the measured economic benefits and impacts of adopting Ladakh Greenhouse technology to the farmer households, people in the region and the UT? Please list them.

(a) Locally grown vegetables are now available all year round. However, the quantity needs to increase by establishing more Ladakh Greenhouses.
(b) The Ladakh Greenhouse technology has reached remote and border villages. Due to the benefit of the technology, people in extreme altitudes are able to

get leafy vegetables in peak winter months, which is otherwise not possible earlier.

(c) Farmers in the region are willing to bear 25% of the construction cost due to the benefit of the new technology.

(d) Besides meeting the household requirement for fresh vegetables, the farmers are able to generate Rs 60,0000 to 80,000 in income in a year from a single greenhouse (60 feet x 24 feet)

(e) Household expenditure on fresh vegetables has reduced significantly.

9. List the challenges and constraints of greenhouse farming that are being faced by the region despite various schemes by the government? Please indicate the measures being undertaken by the Department of Agriculture, UT Ladakh to deal with these challenges and constraints?

Sl No.	Challenges and Constraints	Measures adopted by UT
(a)	Many farmers perceived an increase in aphid infestation in the greenhouse due to the all-year-round use of the greenhouse.	The Agriculture Department is advocating good farming practices to reduce the aphid infestation. DRDO-DIHAR is working on a farmer-friendly practice to reduce insect infestation.
(b)	Non-availability of water for irrigation purposes in winter months	The Agriculture Department is encouraging farmers to establish Ladakh Greenhouse near water sources. The UT Administration is providing bore wells to the farmers on subsidized rates.
(c)	Increase demand for Ladakh Greenhouse by the farmers	The Agriculture Department plans to continue giving incentives to the farmers so that every house in Ladakh benefits from the innovative technology. Given the increasing demand for Ladakh Greenhouses, UT Ladakh plans to construct an additional 6457 greenhouses in the next five years.
(d)	A small section of farmers finds it difficult to bear the 25% of the construction cost of Ladakh Greenhouse.	The Agriculture Department is promoting Polytrench Greenhouse, a low-cost passive solar greenhouse developed by DRDO-DIHAR, from 2023 onwards.