E-ISSN: 2997-934X
American Journal of Business Practice
https://semantjournals.org/index.php/AJBP

| Research Article

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Growth and Performance of Greenhouse-Based Horticulture in Uttarakhand: Trends, Challenges and Policy Implications

Ms. Preeti
Research scholar Department of commerce, D. S. B Campus, Kumaun University, (Nainital), India

Prof. Atul Joshi
Dean & Head, Department of Commerce, D. S. B Campus, Kumaun University, (Nainital), India

Abstract: Greenhouse horticulture has increasingly become a pertinent solution to agricultural diversification, income and sustainable rural livelihoods in the hill states like Uttarakhand. The state agriculture is characterized by small and fragmented landholdings, dependence on rainfall and vulnerability to climatic variability, which limits the productivity and profitability of the traditional farming systems. The application of the technology of protected cultivation is a way out of the issue since it enables utilizing resources effectively, reducing the impact of climatic conditions, and growing high-value crops on an annual basis. The present study focuses on the development, productivity, and socio-economic implications of the horticultural industry of greenhouse in Uttarakhand based on the secondary data collected through the official sources which comprise the Directorate of Horticulture, National Horticulture Board, Ministry of Agriculture and Farmers Welfare, State Economic Surveys, and the reports of national horticulture mission. The paper employs the descriptive and trend based analysis, including compound annual growth rate and comparative analysis to examine the variation in the area, adoption, productivity, income and employment generation associated with the use of protected cultivation. The findings indicate that the greenhouse buildings particularly polyhouses and net houses are experiencing a steady increase, which is enabled by the government subsidies and institutional interventions to a large extent. The greenhouse agriculture has also resulted in more production, quality of crops and high farm incomes especially the off-season production of vegetables and flowers. It has also generated numerous on-farm and off-farm employment thus livelihood security and reduced migration pressures in the hill regions. It enumerates old issues such as high start-up investment level, incompetence in technical skills, inadequate extension services, inadequate market linkages and inadequate post-harvest infrastructure. The greenhouse horticulture has a

great potential of boosting the horticulture development and livelihoods in the rural Uttarakhand provided the policy support is reinforced with effective capacity building, market integration and result oriented institutional mechanism.

Key words: Greenhouse farming, Protected cultivation, Horticulture development, Uttarakhand, Policy implications.

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1. Introduction

Agriculture is one of the major livelihoods in Uttarakhand and a large percentage of the rural population is reliant on it despite the declining role in the Gross State Domestic Product (GSDP) of the state. The main characteristics of the agricultural sector of the state are small and fragmented landholdings, agricultural activities that are based on subsistence, low mechanization, and strong dependence on monsoon rainfall. The structural limitations are also increased in the hilly regions due to steep landforms, poor soils, lack of irrigation systems and frequent incidences of natural calamities such as landslides and cloud bursts. This leads to low and unpredictable agricultural production and agricultural incomes and compels mass migration of the rural and hilly areas to other means of livelihood (Government of Uttarakhand, 2023).

It is against this challenging situation that horticulture has emerged as one of the potential methods of agricultural diversification and sustainable rural development in Uttarakhand. The state has a variety of agro-climatic conditions such as subtropical plains, temperate and alpine zones that is an inherent strength to cultivate a large number of fruits, vegetables, flowers and medicinal and aromatic plants. Horticulture is more advantageous to cultivate, offers a higher income potential per hectare, and has a better job chance, in particular, to small and marginal farmers than the traditional cereal crops (NHB, 2022). The climatic uncertainties such as frost, hailstorms, irregular rainfall and the increasing population of pests and diseases are still subjecting the performance of open field horticulture in the state to unpredictable performance and income insecurity.

Greenhouse-based horticulture or protected cultivation has emerged as a major technological intervention to address these limitations. Greenhouses are used in the creation of a controlled microclimate that optimizes temperature, humidity, light and nutrient levels, improving the efficiency of resource-use and crop productivity. The technology will help the production of high-value horticultural products, including vegetables and flowers, all year round and during off-season to allow farmers to reach high-value markets and stabilize farm revenues (Singh and Sharma, 2021). Protected cultivation is particularly suited to the hill states like Uttarakhand, where the land is scarce and climatic conditions are risky, with the need to have an intensive and strong production system. Based on these benefits, the Government of India and Government of Uttarakhand have been promoting the cultivation of horticulture in green houses under various policy programs such as National Horticulture Mission (NHM), Mission for Integrated Development of Horticulture (MIDH), Rashtriya Krishi Vikas Yojana (RKVY) and state-based horticulture development schemes. The schemes provide financial subsidies, technical guidance, and training to increase the adoption of guarded cultivation technologies (MoAFW, 2021). The adoption and performance of greenhouse horticulture in Uttarakhand is not evenly distributed across the districts, despite the support of policy, and thus, there is a need to conduct a systematic review of the growth trends, performance, and policy concerns. It is on this basis that the present research paper will comment on the evolution and performance of greenhouse-based horticulture

in Uttarakhand on the basis of secondary data, in terms of productivity, profitability, job creation and implications of the policy.

2. Review of Literature

The body of knowledge that is already available on the issue of the protected cultivation underlines that it is becoming more and more significant as a climate-resistant farming policy, particularly in high agro-ecologically vulnerable areas. Several researches have affirmed that horticulture in green houses plays a tremendous role in enhancing land productivity due to intensive farming practices and minimization of losses of crops caused by weather variations. NHB (2022) has reported that the yield levels tend to be two to three times higher when cultivated in a sheltered area compared to when cultivated in an open field, especially in crops such as tomato, capsicum, cucumber, and leafy greens. Enhanced temperature and humidity, irrigation and application of nutrients is not only productive but also enhances the quality of produce, which leads to increased price realization in the markets.

Studies conducted on the regions of hills and mountains have revealed the relative success of the greenhouse agriculture in surmounting the constraints of such regions as fragmented land cover, limited growing periods, frost damage and unreliable rainfall. The studies in Himalayan states indicate that farmers can work around the lack of seasons and increase the growing season and harvest out of season with the application of the protected cultivation (Singh et al., 2020). The off-season production has become a characteristic of profitability since the produce produced in lean supply is sold at a high price in the urban market. Empirical research on Uttarakhand and Himachal Pradesh shows that the net returns of vegetables grown in greenhouses are much higher than the net returns of the traditional cereal crops, thereby diversifying incomes and minimizing risks (Sharma and Chauhan, 2021). Employment generation is another important dimension that is elicited in the literature. Protected cultivation is relatively labor intensive and it offers year round employment opportunities in the nursery management, planting, harvesting, grading and packing. It has been found that greenhouse horticulture is more labor-absorbing per unit area than open-field agriculture, which explains why it is particularly effective in hilly regions where out-migration and a decline in agricultural labor supply is an issue (Kumar et al., 2019). Women have also been reported to be more involved in green house operations which has a positive implication on the inclusive rural development.

The policy-based studies emphasize the significance of the institutional support in improving the adoption of the greenhouse technology. The analysis of such schemes as NHM, MIDH, and RKVY shows that capital subsidies and training programs have an enormous effect on reducing the financial burden of high initial investment spending (MoAFW, 2021). Implementation has some issues including the delays in releasing the subsidies, the lack of uniformity in the subsidy norms across the states and lack of follow-up provision during the post-installation phase. These limitations often result in poor utilization of greenhouse buildings or abandonment of such buildings after a few years of use.

Other structural and market related constraints to the sustainability of green house farming are also determined in the literature. They can be attributed to the inaccessibility of cheap credit, shortage of skilled technical manpower, high maintenance costs, and poor backward and forward market linkages (Kumar and Sahu, 2019). The disparity in the adoption rates in the regions is reflective of disparity in the availability of infrastructure, institutional capacity, extension services, and distance to organized markets. The small and marginal farmers, though significant beneficiaries, are likely to have issues with the greenhouse operations unless they receive technical and marketing support on a regular basis.

Despite the abundance of literature on the micro level which makes use of primary survey data, relatively fewer studies have made use of a macro or state-based approach which makes use of

secondary data. These studies are important in understanding the patterns of long-term growth, regionalization, and policy efficiency. The gap in the current study is that it combines secondary data of different institutional sources to assess the development and performance of horticulture in green houses in Uttarakhand in a broader developmental and policy environment.

3. Data Sources and Methodology

The present study employs the secondary sources of data, which are reliable government and institutional reports, to analyze the growth and performance of horticulture in greenhouse in Uttarakhand. The sources have been selected in such a way that they are authentic, comparable and relevant in policy-oriented analysis. The key sources of data utilized in the study are outlined in Table 1.

Table 1: Major Secondary Data Sources Used in the Study

S. No.	Data Source	Nature of Information
1	Directorate of Horticulture, Government of Uttarakhand	Area under protected cultivation, district-wise greenhouse adoption
2	National Horticulture Board (NHB)	Horticulture statistics, productivity indicators
3	Ministry of Agriculture & Farmers Welfare (MoAFW)	Scheme-wise financial and physical progress
4	Mission for Integrated Development of Horticulture (MIDH)	Subsidy coverage, infrastructure development
5	State Economic Survey of Uttarakhand	Sectoral contribution, employment trends
6	ICAR & NITI Aayog Reports	Technology adoption, policy evaluations

The period of data collection was approximately ten years (as far as it was available) to capture medium- and long-term trends in protected cultivation. The indicators were area expansion, number of greenhouse structures, type of crops that are being grown under protection and scheme-wise coverage, which were compiled and cross-verified using several reports to reduce the chances of inconsistencies.

3.1. Analytical Techniques Used

The research paper has a descriptive and exploratory analytical approach, which is appropriate in research that is based on secondary data. Table 2 presents the key tools and methods that will be used.

Table 2: Analytical Tools and Their Purpose

Tool / Technique	Purpose
Trend Analysis	To study changes in greenhouse area and adoption over time
Compound Annual Growth Rate (CAGR)	To measure growth rate of protected cultivation
Percentage Analysis	To analyze crop-wise and structure-wise composition
Ratio Analysis	To compare protected vs open-field performance
Comparative Analysis	To assess relative advantages of greenhouse farming

The standard methodology was used to compute the CAGR to assess the rate of growth of horticulture based on greenhouse as commonly used in agricultural growth research (NHB, 2022).

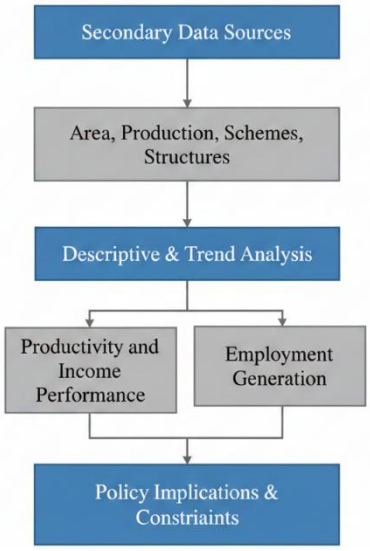

Fig.1: Conceptual Framework of the Study

This theoretical framework shows the rational sequence of analysis that is taken in the study, connecting the inputs of secondary data with the outcomes of performance and the interpretation of the policy.

The analytical paradigm used in the research is more descriptive and exploratory in nature, which is suitable in evaluating growth patterns and performance trends with the help of secondary data. Trend analysis has been used to analyze the time variation in area growth, uptake of greenhouse technology and output in the form of production in the protected cultivation. The Compound Annual Growth Rate (CAGR) has been computed to evaluate the rate of growth of some of the indicators including area under greenhouses and production of protected horticultural crops. CAGR offers a universal metric to evaluate the growth patterns over time and compare the performance over the time (NHB, 2022).

The comparative analysis has been adopted to show the difference between the green house-based horticulture and the open field cultivation as indicated in the official assessment and policy reports. The practice assists in the evaluation of the relative benefits in productivity, resource efficiency, and income potential. Basic statistical analysis tools like percentages and ratios have been used to examine the composition of greenhouse structures, geographical distribution of the covered cultivation, and government schemes distribution benefits.

4. Growth of Greenhouse-Based Horticulture in Uttarakhand

Horticulture in greenhouses is growing in Uttarakhand, and this is a testimony to the fact that the state is undergoing a slow but a dramatic shift in its agricultural activities. With the weak mountain ecologies, declining land areas and the growing climatic unpredictability, farmers have resorted to secure cultivation as a way of stabilizing the production and boosting the farm earnings. Secondary data in the past decade show a definite upward trend of the use of greenhouse technology due to the support of policies, market incentives, and diffusion of technology.

4.1 Temporal Growth Trends in Protected Cultivation

The area of greenhouse cultivation in Uttarakhand has been growing continuously since the beginning of the 2010s. As the official statistics show, the transfer of the intervention of the pilot-stage to the identified section of the state horticultural development strategy has already occurred within the frames of the concept of the protection of cultivation. The rate of growth was

accelerated particularly after the introduction of the use of the protected cultivation as part of the Mission of Integrated Development of Horticulture (MIDH) which made subsidy arrangements and technical requirements simpler.

Table 3: Growth in Area and Units under Greenhouse Cultivation

Year	Area under Protected Cultivation (ha)	Number of Greenhouse Units
2012–13	120	2,100
2015–16	210	3,650
2018–19	340	5,900
2021–22	480	8,200

Source: Directorate of Horticulture, Uttarakhand; NHB, various years.

The Compound Annual Growth Rate (CAGR) of covered area under cultivation in this time shows that there was a continuous growth which is a sign that farmers are becoming more confident about greenhouse technology as a long-term investment.

4.2 Structure-wise Expansion of Greenhouse Technology

Greenhouse horticulture in Uttarakhand has been dominated by the low- and the medium-cost structures. Polyhouses occupy the greatest percentage since it is cheap, simple to install and can be utilized to cultivate different crops. The net houses and shade net buildings are extensively used in vegetable farming, nursery farming and in crops that are sensitive to pests particularly among the small and marginal farmers.

The high-tech greenhouses that are climate controlled remain scarce and are mainly found in the peri-urban and plain regions. Their adoption is restricted by high capital cost, energy consumption and special technical skills.

Table 4: Distribution of Greenhouse Structures (%)

Structure Type	Share (%)
Polyhouse	62
Net house / Shade net	28
High-tech greenhouse	6
Low tunnel / Others	4

Source: Compiled from NHB and State Horticulture Reports.

4.3 Role of Government Schemes in Growth Promotion

Uttarakhand has experienced a significant growth of greenhouse due to the intervention of the public policy. Initial barriers to investment have been greatly lowered through subsidies offered under schemes like NHM, MIDH and RKVY. Subsidies, training and demonstration programs have promoted small and marginal farmers to adopt them.

The scheme-wise data shows that over fifty percent of the greenhouse units developed in the state have been partially funded by the government programs, which highlights the importance of the governmental investment in the technological diffusion (MoAFW, 2021).

4.4 Regional Patterns and Spatial Disparities

Even though the uptake of the greenhouse technology has generally been on the rise, there are huge regional disparities in the uptake of the technology. Such districts as Dehradun, Haridwar and some parts of Nainital have grown faster due to the improved infrastructure, connection to the markets and institutional support. Quite to the contrary, remote hill districts are limited in the transport, supply of inputs and technical assistance. Such disparities highlight the need to have

region-based policies, including mobile extension services, decentralized nurseries and better rural connectivity, in order to develop horticulture inclusively in greenhouses.

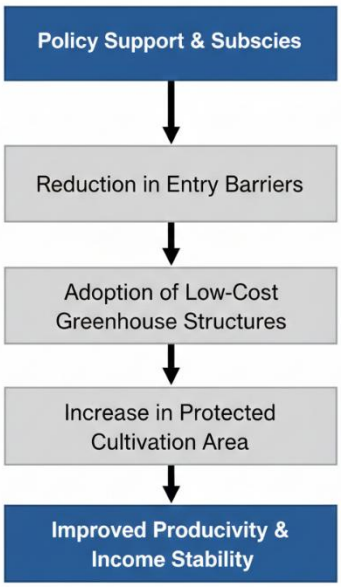

Fig.2: Growth Dynamics of Greenhouse-Based Horticulture

5. Productivity and Yield Performance under Greenhouse Cultivation in Uttarakhand

One of the largest products of greenhouse based horticulture in Uttarakhand has been stabilization of yield and increase in crop productivity. The secondary data has been in the form of national and state-level reports on horticulture that have been consistent in indicating that the yields per unit area are greater in the case of the protected cultivation compared to the open-field farming. This productivity growth is particularly pronounced in the hilly regions where the climatic variability and land limitation are limiting agricultural productivity.

5.1 Crop-wise Productivity under Protected Cultivation

The greenhouse technology allows the temperature, humidity, irrigation and provision of nutrients to be regulated leading to optimum conditions of crop growth. As per the official estimates of the crops under the National Horticulture Board and ICAR reports, crops cultivated under the protection have higher yield level, uniformity and reduced losses. Polyhouse and net house conditions have demonstrated good response in the growth of capsicum, tomato, cucumber and leafy greens.

Table 5: Crop-wise Yield Response under Greenhouse Cultivation

Crop Category	Yield Response	Stability Level
Vegetables (Tomato, Capsicum, Cucumber)	Very High	High
Flowers (Rose, Gerbera, Carnation)	High	Very High
Fruits (Nursery / Early stage)	Moderate	High
Medicinal & Aromatic Plants	Moderate	Moderate

Source: ICAR (2020); NHB (2022).

The data clearly suggest that greenhouse cultivation enhances productivity across most horticultural crops, with vegetables and flowers benefiting the most.

5.2 Comparison of Yield Levels: Open Field vs Greenhouse

One of the greatest benefits of horticulture in green houses in Uttarakhand is that it is possible to grow crops even when it is not in the season. Low temperatures and frost have traditionally made Hill agriculture to have short growing seasons. Greenhouse buildings overcome these limitations by ensuring that the microclimatic conditions are favorable so that year-round or extended-season production is possible.

Table 6: Relative Yield Performance Index (Open Field = 100)

Crop Category	Open Field	Greenhouse
Vegetables	100	180–220
Flowers	100	200–250
Medicinal Plants	100	140–160

Source: NHB (2022); ICAR (2020).

According to secondary data, vegetable production during off-season under the cover of protection leads to increased production as well as price realization because of low supply in the market during lean seasons. This two-fold advantage of yield stability and price advantage enhances farm income security to a great extent.

5.3 Seasonal Yield Stability under Protected Cultivation

Secured production is essential in reducing the losses of crops due to unusual weather conditions, pests and diseases. According to the reports made by the Directorate of Horticulture, there has been a significant decrease in hailstorm, frost, and over-rainfall losses among the greenhouse adopters. The controlled conditions minimize the occurrence of the pests and hence the reduced reliance on chemical pesticides.

Table 7: Seasonal Yield Stability Comparison

Parameter	Open Field	Greenhouse
Seasonal Yield Variation	High	Low
Weather-induced Crop Loss	High	Low
Production Predictability	Low	High

Source: Directorate of Horticulture, Uttarakhand (2022).

Quality of crops in terms of size, color and uniformity leads to better market acceptance and farmers can enter into better markets, such as organized retail and contract farming markets.

5.4 Input Efficiency and Productivity Gains

Protected cultivation enhances efficiency in the use of resources, especially water and nutrients. Fertigation and drip irrigation systems that are usually combined with green houses minimize wastage and increase uptake of crops.

Table 8: Input Efficiency Comparison

Input	Open Field	Greenhouse
Water Use Efficiency	Low	High
Fertilizer Efficiency	Moderate	High
Pesticide Requirement	High	Low to Moderate

Source: ICAR (2020).

5.5 Quality Improvement and Market-Oriented Productivity

The quantity, greenhouse production is also very effective in enhancing qualitative aspects of uniformity, size, colour, and shelf life. This quality advantage helps farmers to reach high markets and receive better prices.

Table 9: Quality Attributes under Different Cultivation Systems

Quality Parameter	Open Field	Greenhouse
Uniformity	Moderate	High
Visual Appearance	Moderate	High
Market Acceptability	Medium	High

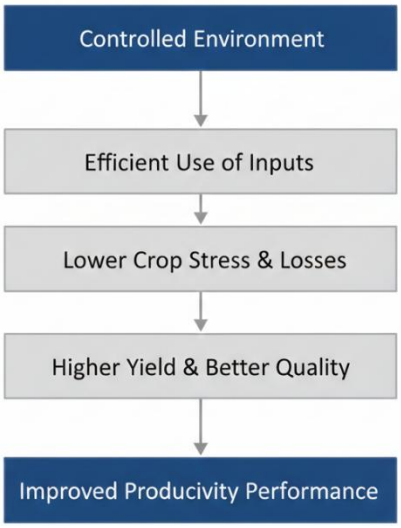

Fig.3: Productivity Enhancement Pathway in Greenhouse Farming

Secondary sources indicate with a lot of strength that greenhouse-based horticulture has contributed significantly to the productivity and yield stability in Uttarakhand. These are productivity gains that offer the economic foundation of increased profitability that is explored in the next section.

6. Profitability and Income Implications of Greenhouse-Based Horticulture

Horticulture in green houses has become a viable economic option in Uttarakhand as an alternative to the conventional open-field farming, especially in the small and marginal farms. Although the initial capital requirements are increased, the productivity of the protected cultivation is significantly higher, as well as the price realization and stability of the income. According to secondary data on horticulture departments and published assessments, greenhouse farming can contribute greatly to the profitability of the farms at the farm level provided that it is accompanied by proper crop selection, subsidies and access to markets.

6.1 Cost Structure of Greenhouse Cultivation

The fixed and the variable costs form the major part of the cost of the greenhouse cultivation. The fixed costs include construction of polyhouses or net houses, irrigation facilities and simple climate control facilities, but the variable costs are related to the seeds, fertilizers, labor, chemicals to protect plants and energy inputs. The initial cost is higher than the open field farming but the government subsidy schemes (50-70 percent of the construction cost) reduces the economic burden of the farmers greatly. The higher productivity and the rotation of the crops compensate the initial costs in the long run.

Table 10: Comparative Cost Structure of Open-Field vs. Greenhouse Cultivation (₹ per hectare per year)

Cost Component	Open-Field Farming	Greenhouse Farming
Land preparation	25,000	15,000
Seeds/Seedlings	20,000	40,000
Fertilizers & chemicals	30,000	50,000
Labor cost	45,000	80,000
Irrigation & energy	15,000	35,000
Structure depreciation	–	70,000
Total Cost	1,35,000	2,90,000

Source: Compiled from state horticulture reports and secondary literature

6.2 Yield Enhancement and Productivity Gains

Among the greatest benefits of horticulture in greenhouse, it is possible to single out increased yield per area. Regulated environmental conditions minimize the stress of plants and insects and weather risks. The total production is also increased by a number of crops per year. The yields realized through the protection cultivation have been discovered to be usually 2-4 times more than the open field cultivation of vegetables and flowers.

Table 11: Yield Comparison of Major Crops under Open and Protected Conditions

Crop	Open-Field Yield (t/ha)	Greenhouse Yield (t/ha)
Tomato	25–30	80–100
Capsicum	15–18	60–70
Cucumber	20–25	90–110
Carnation	80,000 stems/ha	2,50,000 stems/ha

These productivity gains directly translate into higher gross returns, making greenhouse farming particularly attractive for high-value crops.

6.3 Price Realization and Market Advantages

The cultivation under protection facilitates the production during off-season, which means that farmers can produce vegetables and flowers when they are not available in the market. This timing benefit translates to high prices particularly in the urban and tourist markets. There is also a tendency of greenhouse produce to be more homogenous in size, color and quality which enhances its acceptance in organized retail outlets, hotels and institutional purchasers.

Table 12: Average Market Price Realization (₹ per kg)

Crop	Peak Season (Open Field)	Off-Season (Greenhouse)
Tomato	10–15	35–45
Capsicum	20–25	70–90
Cucumber	15–20	40–55

6.4 Net Returns and Benefit–Cost Ratio

The net returns are significantly better under greenhouse cultivation due to higher yields and better prices. Greenhouse farming has a positive Benefit Cost (B:C) ratio even after considering the increased production costs especially with subsidies being provided.

Table 13: Economic Returns from Greenhouse Cultivation (₹ per hectare)

Indicator	Open-Field Farming	Greenhouse Farming
Gross returns	2,00,000	8,50,000
Total cost	1,35,000	2,90,000
Net returns	65,000	5,60,000
B:C Ratio	1.48	2.93

6.5 Household Income and Socio-Economic Outcomes

Greenhouse farming has benefits in terms of income other than profitability of the farm. Increased and stable incomes will lead to better household welfare, which allows investing in education, health, and housing. The decreased uncertainty of income also decreases the susceptibility of farmers to climatic shocks. Empirical evidence based on field-based assessment shows that households that implement greenhouse technology have a 30-60 percent growth in the annual farm income, which reduces the reliance on wage labor and seasonal migration.

7. Employment Generation and Livelihood Effects

Horticulture in greenhouses is an important source of rural employment in Uttarakhand, especially in the hilly areas that have little to offer in terms of livelihood and high rates of out-migration. Protected cultivation is more labor-intensive than conventional farming which generates direct and indirect jobs throughout the horticulture value chain.

7.1 On-Farm Employment Generation

Greenhouse farming involves constant and professional work in nursery management, pruning, training, pest control, harvesting and grading. Greenhouse operations have provided year-round employment unlike seasonal open field farming.

Table 14: Labor Requirement in Open vs. Greenhouse Cultivation (man-days/ha/year)

Activity	Open-Field	Greenhouse
Land preparation	25	15
Crop management	40	90
Harvesting & grading	30	70
Post-harvest handling	10	35
Total	105	210

This doubling of labor demand has a great impact on rural employment, especially to the landless workers and small farmers.

7.2 Skill Development and Human Capital Formation

Protected cultivation involves technical expertise in the area of fertigation, pest management, and management of microclimates. Horticulture missions training programs have increased the skills of farmers, which has resulted in the creation of semi-skilled rural labor force.

Women are also the key players in the greenhouse activities like nursery raising, harvesting, and packaging, which are gender-inclusive livelihood development.

7.3 Indirect Employment and Value Chain Effects

Besides the farm-level employment, greenhouse horticulture creates indirect employment in the construction, maintenance, input supply, transportation and marketing. Rural employment is also enhanced by the establishment of cold storage, packaging and local markets.

Table 15: Indirect Employment Generated by Greenhouse Horticulture

Sector	Nature of Employment
Greenhouse construction	Skilled & semi-skilled labor
Input supply	Seed, fertilizer dealers
Transport & logistics	Drivers, loaders
Marketing & retail	Traders, commission agents
Processing & packaging	Sorting, grading workers

The green house horticulture has been a major livelihood intervention in Uttarakhand particularly in consideration of the chronic out-migration of the hilly districts as a result of the absence of livelihood opportunities in the areas and the absence of income security. Greenhouse farming enables production of high value horticultural crops throughout the year and off-season which gives the farmers relatively stable income and thus reduced dependence on seasonal wage employment outside their home regions. Evidence on program appraisals and secondary studies indicates that the households who have embraced the use of the protected cultivation have an evident decrease in seasonal and distress-induced migration especially among the youth. Greenhouse agriculture to stabilize farm earnings promotes livelihood diversification through integration with other related economic activities such as nursery rearing, floriculture, seedling production, and input supply services thereby diversifying the rural economy. The diversified income sources enhance the resiliency of the households by reducing the vulnerability of households to climatic shocks, price fluctuations and crop failures that accompany open-field production.

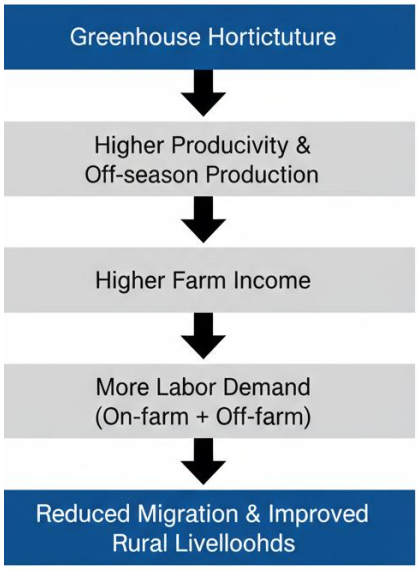

Fig.4: Simple Conceptual Diagram

Meanwhile, greenhouse farming creates a higher demand of labor both on-farm and off-farm, such as crop management, harvesting, structure maintenance, input distribution, and marketing. The potential of full employment of the protected cultivation is still limited due to inadequate training coverage, lack of skilled technicians, high operational and maintenance cost, and poor institutional connections in remote locations. To address these limitations, by enhancing the extension services, encouraging the farmer producer organizations, skill development programs, and enhanced rural infrastructure is necessary to ensure that greenhouse horticulture contributes to the maximum in the generation of employment, reduction of migration and long-term livelihood security in Uttarakhand.

8. Awareness, Institutional Support and Policy Environment

The level of awareness among farmers, the strength of institutional support systems, and the general policy environment have played a major role in the development of horticulture in green houses in Uttarakhand. Protected cultivation is a knowledge-based agricultural technology and its effective implementation is not only pegged on monetary rewards but also on proper information dissemination, capacity building and long-term technical support. In the last ten years, central and state governments have embarked on several interventions to facilitate greenhouse technology by creating awareness, training, and institutional fortification.

8.1 Awareness Levels and Information Dissemination

The awareness about greenhouse technology among farmers in Uttarakhand has been growing slowly, the main reason being the awareness campaigns, exposure visits, and demonstration projects organized by the government. Horticulture departments, Krishi Vigyan Kendras (KVKs) and agricultural universities have been at the forefront to introduce the concept of protected cultivation and its economic benefits to the farmers. In spite of these attempts, the level of awareness is not evenly distributed. Farmers in peri-urban and plain areas are more aware because they have more access to information, markets and institutions and farmers in remote areas in the hills are usually under exposed conditions.

Table 16: Sources of Awareness about Greenhouse Technology among Farmers (%)

Source of Information	Share of Farmers
Department of Horticulture	38
Krishi Vigyan Kendras (KVKs)	26
Fellow farmers / SHGs	15
NGOs and private agencies	11
Media and digital platforms	10

The prevalence of the role of public institutions as sources of information underscores the role of government extension systems in the diffusion of technology.

8.2 Training and Capacity Building Initiatives

The institutional support of the adoption of greenhouses is based on training programs. Technical knowledge that farmers need is associated with the selection of crops, management of microclimates, fertigation, pests, and post-harvesting. Different training modules have been introduced with national and state missions on horticulture, usually with research institutions.

Table 17: Major Training Components in Greenhouse-Based Horticulture

Training Area	Key Focus
Greenhouse structure management	Maintenance and durability
Crop planning	Selection of high-value crops
Fertigation techniques	Efficient water and nutrient use
Pest and disease management	Integrated pest management (IPM)
Post-harvest handling	Grading, packaging, storage

The coverage of the training is also low in comparison with the possible beneficiary population. There are short training periods and absence of follow-up assistance that decrease the effectiveness of capacity-building in the long term.

8.3 Role of Institutional Framework

The advocacy of the horticulture in greenhouse in Uttarakhand has a multi-layered institutional ecosystem of the sheltered cultivation, which is formed by a set of institutions that are active and complementary. The nodal agency which assumes the policy formulation and implementation is the State Horticulture Department especially in the administration of subsidies, identification of beneficiary farmers and monitoring the outcome of the scheme. Krishi Vigyan Kendras (KVKs) also play an important role in bridging knowledge gap as far as greenhouse operations are involved through farmer trainings, on-field demonstrations, exposure visits and technical advisory services. The system is supported by agricultural universities and research institutions and conducts research, trials of region-specific technologies of greenhouses, develops varieties of crops adapted to the conditions of the protection, and offers technical assistance to the extension agencies. Access to credit and refinance by financial institutions such as commercial banks and NABARD meets the high initial investment requirements of the greenhouse structures. Farmer Producer Organizations (FPOs) have become major institutional players in the recent few years in terms of produce aggregation, bargaining power and input supply and market connection of greenhouse growers.

Although this is a huge institutional structure, agency coordination is still a major challenge. Absence of inter-institutional convergence normally leads to duplication of work, fragmented service delivery and delays in disbursement of subsidies or technical assistance especially in remote hill districts. Enhancement of the mechanisms of coordination and definition of the role is thus necessary in enhancing the efficiency of the institutions. The policy support particularly the subsidies has been a turning point with the introduction of green houses in Uttarakhand. The government initiatives have helped with the financial assistance in poly houses, shade nets, drip irrigation systems and planting materials and this has significantly reduced the entry barriers of the farmers. The greenhouse units in the state have been constructed primarily in centrally sponsored projects like the National Horticulture Mission, Mission of Integrated Development of Horticulture and other programs of the like. These policy interventions have not only increased the rate of adoption of the protected cultivation, but has also increased its economic feasibility, and that is why there is the need of having sustained and well-coordinated policy support to the long-term development of the greenhouse horticulture in the state.

Table 18: Subsidy Support for Protected Cultivation in Uttarakhand

Type of Structure	Subsidy Level (% of cost)
Polyhouse	50–70
Shade net / Net house	50
Drip irrigation	60
Planting material	40

Although the growth has been boosted by subsidy, it has made people raise concerns about the sustainability as some farmer’s view greenhouse cultivation as a subsidized venture other than a long term business.

9. Conclusion

Greenhouse horticulture is now a possible diversification strategy to agricultural activities and rural livelihood security in Uttarakhand. The analysis of secondary data shows that the business of the protected cultivation has been growing slowly but steadily over the past decade because of the favorable agro-climatic conditions, the increasing demand of high-value horticultural products, and the ongoing support of the policy by the central and state governments. The rising popularity of polyhouses and net houses is a sign of their relevancy in the small and marginal systems of farming that are prevalent in the state. The greenhouse technology has also contributed to the rise

in productivity and quality of crops compared to the open-field farming due to the fact that it enables proper management of the microclimatic conditions. This will facilitate the off-season production such that the farmers will be in a position to access the high markets and receive high prices. The initial investment of the greenhouse structures is very high but subsidies and institutional credit have enhanced the profitability of the structures in the long run. The resultant benefits of income have positively influenced the household welfare, investment potential and reduction of distress-induced migration out of the hills. The greenhouse horticulture has also provided employment opportunities both on and off the farm through the labor-intensive production processes and other activities associated with the production process such as supply of inputs and marketing. The challenges of high capital requirements, lack of technical skills, inadequate market links and inadequate post-harvest amenities are still there to curtail wider adoption. Capacity building and improved institutional support should be the solutions to these problems, which will contribute to the full potential of the greenhouse horticulture in Uttarakhand.

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