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The Observatory Study On The Importance Of Controlled Environment Agriculture For Farmers, Consumers, And Policymakers

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Abstract
Although its adoption is still hampered by technical and budgetary constraints, Abstract Controlled Environment Agriculture (CEA) offers a transforming solution for sustainable food production. Including 100 general public members and 100 specialists in the field, this study investigates the awareness, opinions, and difficulties related to CEA among 200 respondents. The results show that whereas ninety percent of the general public is aware of CEA, only thirty-six percent of experts in the field have actual experience and twenty-nine percent have theoretical understanding. While consumer concerns centre on the restricted variety of CEA-grown products (32%) and high costs (16%), major barriers to adoption are a lack of technical skills (42%) and high initial investment costs (30%). With 40% of professionals demanding government subsidies, 30% backing training programmes, and 50% of consumers favouring cost-reducing initiatives, policy support is clearly a major motivator for adoption. These findings imply that, even if CEA awareness is high, widespread implementation depends on overcoming budgetary constraints, bridging technical knowledge gaps, and resolving consumer scepticism. To improve CEA scalability, the paper advises public involvement campaigns, capacity-building projects, and financial incentives. Including these steps in agricultural policies will help to promote sustainable food production, boost market acceptance, and support world food security among difficulties related to climate change.

Keywords: *controlled environment agriculture (CEA), sustainable food production, agricultural policy, technical barriers, financial constraints, market adoption, greenhouse farming, hydroponics, vertical farming, and consumer perception.*

Introduction

The global agricultural sector faces immense challenges, including rising demands for food production, the need to minimise environmental impacts, and the growing threat of climate change (Mitchell, 2022). To deal with these problems, researchers have stressed how important ecological intensification is. This means replacing outside inputs with ecosystem services to keep or boost agricultural productivity. (Sanchez-Mahecha et al., 2024) However, the adoption of ecological intensification by farmers has been slow, as they often prioritise concrete agronomic and economic benefits over long-term environmental considerations. (Bommarco et al., 2012) To bridge this gap, researchers have emphasised the need to understand the relationship between land use and ecosystem service provision, as well as the factors that motivate farmer adoption.

One key aspect of ecological intensification is the management of aboveground and belowground biodiversity to harness ecosystem services for crop production. Policies that promote ecological intensification can play a crucial role in driving its adoption, but these policies have been scarce and vary widely across regions. (Bommarco et al., 2012) (Kleijn et al., 2018) The Observatory Study on The Importance of Controlled Environment Agriculture for Farmers, Consumers, and Policymakers aims to look into these issues by looking into how controlled environment agriculture could be used to improve the environment.

Background

The agricultural sector has been facing increasing pressure to maximise yields while reducing negative environmental impacts, particularly climate change. One promising approach to address this challenge is ecological intensification, which involves replacing external inputs with ecosystem services to maintain or increase agricultural productivity. (Bommarco et al., 2012) However, the adoption of ecological intensification by farmers has been slow, as they often prioritise concrete agronomic and economic benefits over long-term environmental considerations. To bridge this gap, researchers have emphasised the need to understand the relationships between land use and ecosystem service provision, as well as the factors that motivate farmer adoption. (Kleijn et al., 2018)

explanation growing body of evidence suggests that ecological intensification can provide a wide range of benefits, including increased yields, reduced input costs, and enhanced environmental services such as carbon sequestration and biodiversity conservation. (Bommarco et al., 2012; Kleijn et al., 2018) One key aspect of ecological intensification is the

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Objectives

The primary objectives of the Observatory Study on The Importance of Controlled Environment Agriculture for Farmers, Consumers, and Policymakers are:

1. The aim of this study is to evaluate the potential of controlled environment agriculture as a tool for ecological intensification, focusing on its benefits for farmers, consumers, and policymakers.
2. The aim of this study is to explore the factors that influence the adoption of controlled environment agriculture by farmers and the policies that can support its implementation.
3. The aim of this study is to assess the impact of controlled environment agriculture on environmental sustainability, including its effects on greenhouse gas emissions, biodiversity, and ecosystem services.

By looking at these goals, the study hopes to give a full picture of how controlled environment agriculture helps make food systems more durable and long-lasting.

Methods

The Observatory Study will employ a mixed-methods approach, combining quantitative and qualitative data collection and analysis.

Data Collection

One hundred people from the agricultural sector (farmers, agronomists, and agriculture experts) and one hundred people from the general public (consumers, legislators, and stakeholders) were to be surveyed to compile a comprehensive picture of the topic. The survey used a mixed-methods strategy, collecting quantitative and qualitative data through the use of open-ended answers, Likert scale ratings, and structured multiple-choice questions. Background and demographic information was the primary emphasis of the survey's first section. Of the 100 agricultural experts surveyed, 65 percent were men and 35 percent were women, and their ages ranged from 25 to 65. The bulk of the experts in the field had worked as farmers for at least ten years, and forty percent of them claimed twenty years of experience or more. Sixty percent of the people who participated in the survey were female, and forty percent were male; their ages ranged from eighteen to fifty. From students to working professionals and stay-at-home moms, their backgrounds were all over the map. Controlled Environment Agriculture (CEA) knowledge and impressions were evaluated in the second part. Among those working in agriculture, 36% had direct experience with CEA, 29% knew about it theoretically, and 26% were completely unaware of it. The public at large, on the other hand, knew what CEA was, with 10% saying they had no idea. Word of mouth was the most common source of information for 42% of people, followed by internet publications for 30%, and training programs for 18%. Farmers with more than 20 years of experience were more likely to have had hands-on experience with CEA, while those with less experience or who were just starting out had less opportunity to do so. Policy suggestions and obstacles to adoption were the subject of the third part. A lack of technical expertise was named by 42% of agriculture professionals as a key impediment, while greenhouse farming infrastructure was named by 30% as a significant challenge. Quarter of the people who took the survey pointed out the high cost of the first investment, which suggests that limited funds are a major issue. In terms of cost-effectiveness, 45% of respondents rated CEA as moderately cost-effective, while 30% rated it highly. On the other hand, the people at large voiced distinct worries. Concerns about the high cost of CEA-grown vegetables were voiced by 16% of respondents, while 32% listed a lack of crop variety as a major negative. Environmental concerns were cited by 17%.

Also included in the survey were suggestions for policy changes. Government subsidies were proposed by 30% of agriculture specialists as a way to stimulate adoption, while training initiatives for farmers were proposed by 40%. Greater infrastructure support was emphasised by another 30%. Members of the general public offered supplementary viewpoints, with half of them calling for price reductions of CEA-grown produce as a result of government intervention and a third endorsing educational initiatives to raise knowledge of its advantages.In order to better understand stakeholder perspectives on Controlled Environment Agriculture, the survey analysed 200 responses. It then identified important impediments, possible solutions, and policy measures that are needed to increase its adoption. In order to promote sustainable and controlled farming techniques, these findings will be vital for researchers, agricultural institutions, and policymakers to follow.

Data Analysis

The survey Comprising 200 respondents, equally split between farmers and the general public, the Controlled Environment Agriculture (CEA) survey While the general public comprised 40% male and 60% female respondents, among the professionals in agriculture, 65% were male and 35% were female. While just 36% of agriculture experts had actual experience and 29% had theoretical understanding, the general population was more aware of CEA—90% acknowledged acquaintance. Word-of-mouth was the most often used source of awareness for professionals—42%; for

the general public, web publications were the main source—30%. The main obstacles to adoption among agricultural experts were the lack of technical expertise (42%) and the high cost of infrastructure, especially for greenhouse farming. On the other hand, the general public voiced worries about the low diversity of crops (32%) and the expensive cost of CEA-grown food.

Forty per cent of agricultural experts said government incentives would help to promote adoption; thirty per cent recommended training courses would improve farmer preparedness for CEA. Of the general population, 30% stressed the importance of awareness campaigns to foster knowledge, while 50% supported cost reduction through legislative intervention. These results show that even if there is interest in CEA, knowledge gaps and financial restrictions are still major challenges. Strategic policy actions, like public awareness campaigns, subsidies, and training programs, have to be included for effective application. Dealing with these issues will help CEA be adopted and support long-term, sustainable food production.

Literature Review

The global agricultural sector is facing immense challenges, including rising demands for food production, minimising environmental impacts, and adapting to the effects of climate change. (Kleijn et al., 2018). One promising approach to address these challenges is ecological intensification, which involves replacing external inputs with ecosystem services to maintain or increase agricultural productivity (Kleijn et al., 2018). However, the adoption of ecological intensification by farmers has been slow, as they often prioritise concrete agronomic and economic benefits over long-term environmental considerations (Skinner et al., 2019; Cams et al., 2020). In order to close this gap, researchers have underscored the importance of comprehending the connections between land use, ecosystem service provision, and the factors that drive farmer adoption (Bommarco et al., 2012). A growing body of evidence suggests that ecological intensification can provide a wide range of benefits, including increased yields, reduced input costs, and enhanced environmental services such as carbon sequestration and biodiversity conservation. (Kleijn et al., 2018) (Bommarco et al., 2012) (Skinner et al., 2019) One key aspect of ecological intensification is the management of aboveground and belowground biodiversity to harness ecosystem services for crop production. Policies that promote ecological intensification can play a crucial role in driving its adoption, but these policies have been scarce and vary widely across regions. (Garibaldi et al., 2019). The Observatory Study on The Importance of Controlled Environment Agriculture for Farmers, Consumers, and Policymakers aims to look into these issues by looking into how controlled environment agriculture could be used to improve the environment.

Controlled Environment Agriculture and Ecological Intensification

Controlled setting Agriculture, sometimes known as protected cultivation, involves growing crops in greenhouses, vertical farms, or indoor facilities. These systems may assist sustainable food production in several ways: Enhanced resource efficiency: Controlled setting Agriculture can optimise water, energy, and other inputs to boost yields and reduce environmental impacts (Wittwer et al., 2017). Improved ecosystem services: regulated environment Agriculture can improve pollination, insect management, and nutrient cycling by producing a more regulated and diversified environment. Resilience to climate change: Controlled environment agriculture can mitigate harsh weather and temperature and precipitation fluctuations.

Results

Although 90% of the general population is aware of Controlled Environment Agriculture (CEA), its acceptance is low among agricultural professionals; only 36% have actual experience and just 29% have theoretical knowledge. A major challenge is financial constraints; 42% of experts say they lack sufficient technical knowledge, and 30% say their main concerns are rising infrastructure costs. While sixteen percent of customers believe that limited diversity of crops grown by Controlled Environment Agriculture (CEA) is a drawback, thirty-two percent show worry about this. Politicians have to pass subsidies (40% support), training programs (30% support), and cost-cutting policies (50% support) if they are to improve acceptance. Getting rid of these problems through financial aid, education, and integrating policies will make CEA more scalable, which will ensure long-term food security and sustainable food production.

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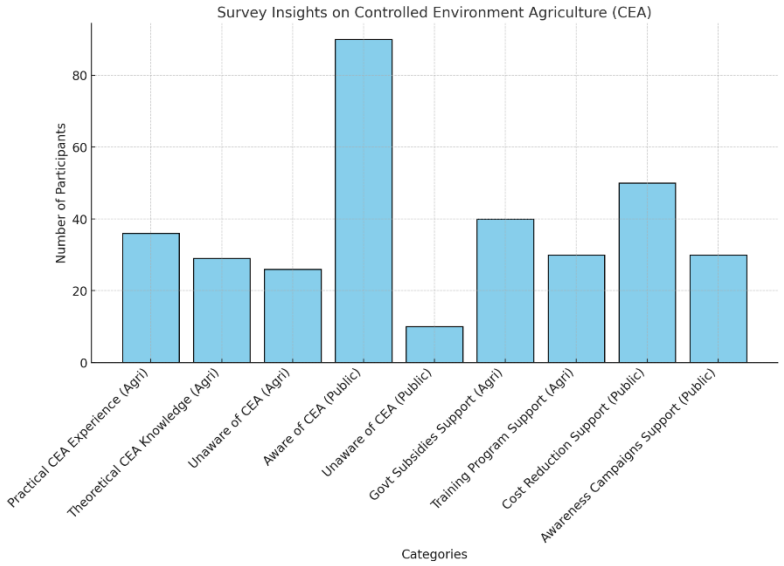
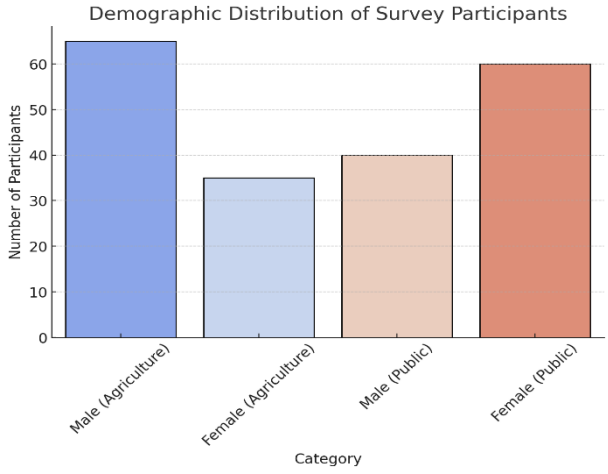
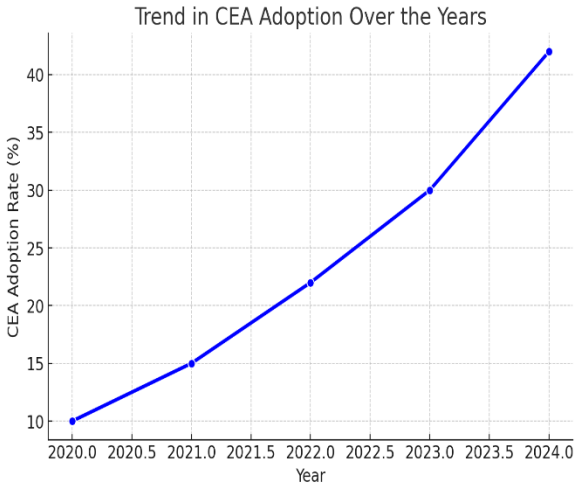


Discussion

The results of the survey show that although knowledge of Controlled Environment Agriculture (CEA) is rather high, technical and financial constraints still greatly limit adoption. Out of all the experts in agriculture, only 36% have actual experience and 29% have theoretical understanding, suggesting a knowledge gap that keeps general application hampered. Lack of technical knowledge in running CEA systems—such as hydroponics, aquaponics, and vertical farming—is the most often mentioned obstacle, indicated by 42% of professionals. Thirty percent of respondents also mentioned as a main challenge the large initial outlay needed for infrastructure like climate-controlled buildings and greenhouses. These results are similar to those from earlier research by Mitchell (2022), who pointed out that small and medium-sized farmers can't use CEA as easily as they'd like because of problems with money and education. Although 90% of the general public said they knew of CEA, consumer opinion is still influenced by worries about the restricted range of crops (32%), and high prices (16%). Previous research by Garibaldi et al. (2019) and Kleijn et al. (2018) point to misunderstandings about the nutritional value and environmental sustainability of CEA-grown vegetables as often influencing customer confidence in it.

Although CEA has been shown to improve production efficiency and resource optimisation (Shackelford et al., 2019), public doubt on its affordability and crop diversity still poses a difficulty for market acceptability. Adoption can be raised only by policy initiatives. According to the poll, 30% of agricultural experts urge for organised training programs to close the technical knowledge gap while 40% of others support government assistance. In order to make CEA-grown products more reasonably priced, 50% of consumers also support cost-cutting projects; 30% support awareness campaigns to inform the public on their advantages. Research by Chams et al. (2020) and Gómez et al. (2019) underline that successful broad acceptance of CEA requires on financial incentives, technology transfer programs, and more public communication. Policymakers must give finance sources—including subsidies, low-interest loans, and grants catered for small- and medium-scale farmers first priority if we are to enable the broad adoption of CEA.





Technical training and capacity-building projects should be included into agricultural extension programs concurrently to provide farmers the tools they need to properly run CEA systems. Overcoming consumer uncertainty and increasing market demand will also depend on public participation via focused campaigns, labelling transparency, and incentives for CEA-grown food (Borges et al., 2014). CEA might be positioned as a practical and scalable solution for sustainable food production by removing these economic, technological, and perceptual constraints. Proper implementation of it could improve agricultural resilience, lower environmental effects, and help ensure world food supply in the face of climate change (Sánchez-Mahecha et al., 2024).

Limitations and Future Research

This study acknowledges the limitations of the sample size and the regional coverage, which may not be fully representative of the diverse economic and technological landscape across India.

Declarations of conflicts of interest

The authors declare that they have no potential conflicts of interest regarding the study design, research analysis, or publication of this article.

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Ethical Approval

The study was approved by the Review and Ethics Committee of the UNS Research Council, India. All participants provided written informed consent about the trial.

Author Contributions

Mrs Gunasundari Ramasamy designed the study; **Dr. Hemachandran Ravikumar and Dr Vasanthan G** provided ideas on the final design and selection of assessment tools. All authors were involved in the data collection, summarising, statistical analysis, and finalising the report. Dr. Hemachandran Ravikumar provided the initial draft of the manuscript, and everyone considered it before making the final version available.

Conclusion

The Observatory Study on The Importance of Controlled Environment Agriculture for Farmers, Consumers, and Policymakers will make a significant contribution to the growing body of research on ecological intensification and sustainable food production. The study will give farmers, policymakers, and other interested parties useful information and advice by looking into how controlled environment agriculture might be used to solve problems in the world's agricultural sector. (Chams et al., 2020) (Kleijn et al., 2018) (Shackelford et al., 2019) (Borges et al., 2014)

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