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ORIGINAL ARTICLE

Polytunnel Farming Practices in Mahaweli System H, Sri Lanka: An Evaluation of Socio-Economic and Agronomic Dimensions

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Abstract

Polytunnel farming is increasingly important in Sri Lanka's dry zone, offering opportunities for year-round cultivation, efficient water use, and improved crop productivity. This study aimed to evaluate the socio-economic characteristics of growers, agronomic practices, technological adoption, and financial viability of polytunnel farming in the Mahaweli System H. Data were collected from 50 randomly selected growers using structured questionnaire and analyzed using descriptive statistics and simple cost–return analysis. Most growers were under 50 years (66%), predominantly male (88%), with 22% holding university degrees, and over half (54%) engaged in full-time farming, earning monthly incomes ranging from LKR 30,000 - 150,000. Floor areas of polytunnels were mainly 93–186 m^2 (1,000–2,000 ft^2), with 84% having chimney vents and 72% using bare-soil floors. Capsicum was the principal crop (69%), with temperature and humidity primarily managed using misters (60%) and shade nets (44%). Drip irrigation (80%) and fertigation (58%) were widely adopted to optimize water and nutrient delivery, while pest management relied primarily on chemical pesticides targeting mites, mealybugs, whiteflies, and aphids. Financial returns were generally satisfactory, though 58% of growers had not yet recovered construction costs, and market access was constrained by a lack of quality certification (84%) and dependence on middlemen. These findings highlight the need to improve pest management strategies, enhance irrigation efficiency, diversify crop selection, and implement targeted market interventions to strengthen both productivity and long-term sustainability of polytunnel farming in the Mahaweli System H.

Keywords: *Crop production, Pest management, Protected cultivation, Sustainability, Technological advancements*

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1. Introduction

Agriculture in Sri Lanka has undergone substantial technological advancements aimed at enhancing productivity, improving output quality, and increasing competitiveness (Jayathilaka et al. 2022). Protected agriculture systems, including polytunnels, greenhouses, and vertical farms, provide an environment where crop growth can be closely monitored and controlled. These systems reduce the vulnerability of crops to environmental stresses such as temperature fluctuations, pests, and drought, while also enhancing yield, quality, and production efficiency. By enabling year-round cultivation and mitigating the risks associated with open-field farming, protected agriculture contributes to greater stability and sustainability in food production (Shukla et al. 2024). In Sri Lanka, polytunnels and net houses are primarily employed for bell peppers (*Capsicum annuum*), cucumbers (Cucumis sativus), tomatoes (*Solanum lycopersicum*), and zucchini (*Cucurbita pepo*), with major adoption in Kandy, Badulla, and Nuwara Eliya districts (Kumara et al. 2015; Wijerathna et al. 2014). In the dry zone, vegetable production has traditionally relied on simple rain shelters, though polytunnels are increasingly recognized as advanced protective structures, constructed with galvanized iron frames and UV-stabilized polyethylene films, which provide partial or full microclimate control (Dias et al. 2020).

The dry zone is prone to prolonged droughts and extreme climatic events, often limiting crop productivity and consistency (Eriyagama et al. 2010). Protected agriculture techniques, including polytunnels, provide a controlled environment that mitigates temperature extremes and conserves water, facilitating year-round cultivation and enhancing crop resilience (Shukla et al. 2024). Mahaweli System H, part of the Mahaweli Development Program, is a key agricultural region contributing significantly to national vegetable production (Bamunuarachchi 2013). However, vegetable cultivation in this region faces challenges including seasonal fluctuations, pest and disease outbreaks, and declining land productivity (Kariyawasam et al. 2023).

Despite the increasing promotion of polytunnel farming through government and donor-supported initiatives in the Mahaweli System H, systematic feasibility assessments, performance monitoring studies, and outcome assessments remain largely undocumented in the scientific literature. Therefore, there is limited empirical evidence on (i) the socio-economic characteristics of beneficiary farmers, (ii) the technical performance and management efficiency of polytunnels under dry-zone conditions, and (iii) the long-term financial viability and cost recovery of investments. Therefore, the key knowledge gap lies between the recognized potential of polytunnel technology and the absence of rigorous, region-specific evaluation of its socio-economic and agronomic outcomes in the Mahaweli System H.

Furthermore, existing literature predominantly provides descriptive accounts of protected agriculture adoption (Rosário et al. 2022) with limited integration of socio-economic dimensions, agronomic practices, and financial performance within a single analytical framework. This limits evidence-based policy formulation and targeted extension interventions.

Previous studies (Dias et al. 2020) in Sri Lanka have largely focused on the adoption and technical aspects of protected agriculture. However, integrated assessments that simultaneously examine socio-economic characteristics, agronomic management practices, and farm-level financial performance remain limited. Addressing this gap is essential for developing targeted training programs, improving farm management practices, and enhancing the sustainability and profitability of protected cultivation systems. This study, therefore, provides a comprehensive evaluation of polytunnel farming in the Mahaweli System H, a dry-zone irrigation settlement. It integrates socio-economic profiling, technology adoption patterns, and agronomic management assessment using descriptive analysis. The study examines farmer demographic characteristics, farm management practices, pest and disease management, irrigation and nutrient strategies, and financial outcomes. The findings provide policy-relevant insights for improving beneficiary targeting, strengthening extension services, and designing market-oriented support policies for protected agriculture in Sri Lanka.

2. Materials and Methods

The study was conducted in the Mahaweli System H, focusing on polytunnel growers. Of the 60 registered growers, 50 were randomly selected using simple random sampling, based on the official grower registry provided by the Agriculture Unit of the Mahaweli Authority, System H. Given the relatively small and administratively defined population, the study approach closely approximates a population-based assessment rather than a narrow sample survey. Although all participants were polytunnel growers within the Mahaweli system H, the study population was not homogeneous. Variations existed in farm size, polytunnel floor area, crop types cultivated (e.g., capsicum and other vegetables), management intensity, irrigation systems, and years of experience. These variations allowed for meaningful descriptive comparisons within the study group. Primary data were collected via an interviewer-administered questionnaire, which was pre-tested with five growers to ensure clarity and relevance. Modifications were made particularly in sections regarding pest management and technological adoption.

Interviews were conducted between October 2023 and January 2024, with participants providing informed consent in line with ethical guidelines approved by the Mahaweli Authority. Quantitative and qualitative responses were coded in Microsoft Excel 2021 and analyzed using SPSS version 23. Descriptive statistics, including means, percentages, ranges, and standard deviations, were used to summarize the data. Given the exploratory nature of the study and the near-census coverage of the target population, the analysis primarily emphasized descriptive and comparative assessment rather than inferential hypothesis testing.

3. Results and Discussion

3.1 Farmer Demographics and Involvement

Farmers engaged in polytunnel cultivation in the Mahaweli System H were predominantly middle-aged, with 70% under 50 years, and the largest proportion (34%) in the 41–50 age group (Figure 1). Moderate participation was observed among younger (21–30 years, 22%) and older farmers (51–60 years, 18%), whereas those aged 61–80 were underrepresented (12%). Middle-aged farmers likely dominate due to greater financial stability, decision-making authority, and experience (Lowder et al. 2016). Youth participation, although lower, indicates growing interest in protected agriculture, driven by alternative income opportunities, government incentives, and increasing awareness of sustainable farming practices (Geza et al. 2021). The limited involvement of older farmers highlights the importance of succession planning and systematic knowledge transfer to ensure the long-term sustainability of polytunnel cultivation (Mishra et al. 2004; Bryan et al. 2024).

Male farmers represented 88% of respondents, while female participation was 12%, reflecting broader gender disparities in agricultural access to land, credit, and extension services (Bryan et al., 2024). Targeted interventions such as gender-sensitive training, microfinance schemes, and inclusive extension programs may help address these inequities. Most respondents were married (90%), highlighting the critical role of family labour and shared responsibilities in sustaining labour-intensive polytunnel operations (Bjornlund et al. 2019).

Farmers engaged in polytunnel cultivation exhibited diverse educational backgrounds, with 30% having completed General Certificate of Education – Ordinary Level (O/L), 20% General Certificate of Education – Advanced Level (A/L), and 22% holding university degrees (Fig. 1), suggesting that this farming system attracts individuals across a broad spectrum of educational attainment. Basic education equips farmers with managerial and literacy skills, while higher education may promote the adoption of modern technologies and entrepreneurial approaches. Employment patterns showed that 54% were full-time growers, whereas 46% practiced part-time cultivation alongside government or private sector employment or self-employment, reflecting livelihood diversification strategies to buffer against agricultural risks (Novickytė 2018).

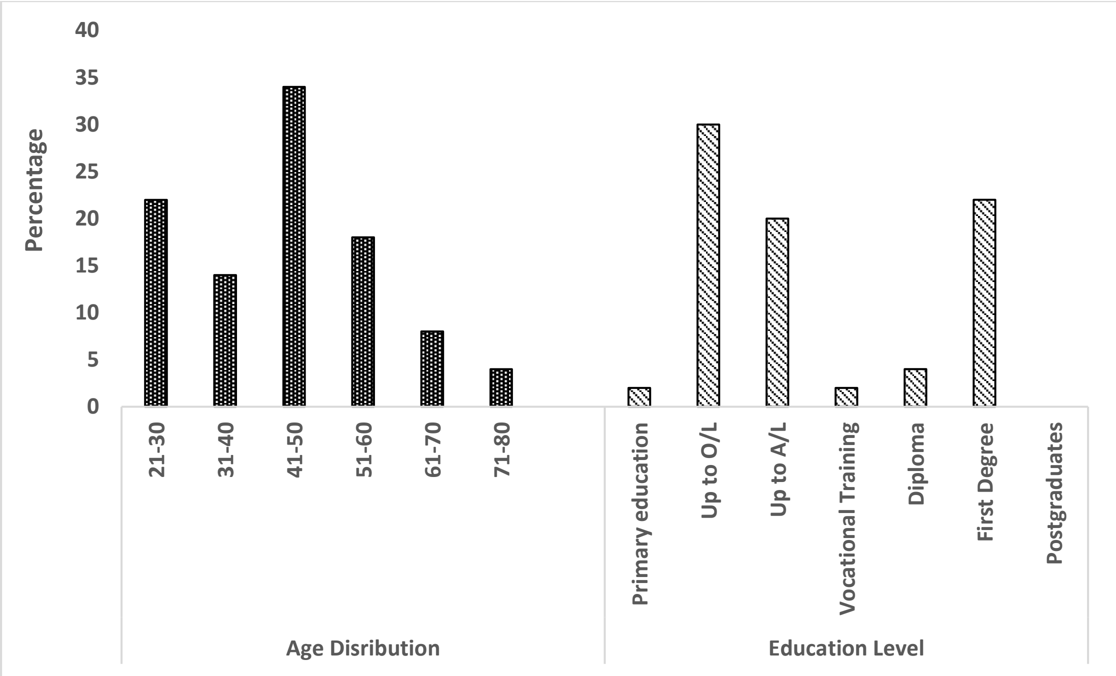

Figure 1: Age distribution and educational attainment of farmers engaged in polytunnel cultivation in Mahaweli System H.

3.2 Income Variability

The average monthly income from polytunnel farming varied between groups, with values of LKR 30,000 ± 12,395 and LKR 150,000 ± 33,538 and showed high variability, influenced by farm size, crop selection, technical expertise, and market access. Higher yields correlated with greater profitability, while reliance on middlemen and price fluctuations contributed to income disparities (Hassan and Hewapathirana 2024). Addressing these gaps requires improved extension services, access to credit, and collective marketing mechanisms.

3.3 Polytunnel Characteristics and Construction Trends

Most farmers (80%) owned a single polytunnel, with only 20% managing two or three structures. The majority of polytunnels were constructed in 2021 (36%) and 2022 (56%), reflecting the effectiveness of government and donor-supported interventions (Kumara et al., 2015). Polytunnel sizes typically ranged from 93–186 m^2 (1,000–2,000 ft^2), with 84% featuring chimney-type top vents that provide effective ventilation (Molina-Aiz et al., 2009) under dry-zone conditions, though they may be susceptible to leakage during heavy rainfall.

Flooring practices in polytunnels varied, with 72% of farmers using bare soil and 26% adopting plastic mulch to suppress weeds and improve water-use efficiency (Rohila et al. 2018).

3.4 Temperature Control and Automation

Temperature regulation was primarily achieved using misters (60%) and shade nets (44%), whereas advanced systems, such as exhaust fans with cooling pads, were adopted by only 10%, and full automation by 4% of farmers. Limited adoption is due to high costs and maintenance requirements. Previous studies have reported that automated cooling and ventilation systems in protected cultivation can increase capital costs by 25–40% compared to naturally ventilated structures, limiting accessibility for smallholders (Kariyawasam et al. 2023). In addition, higher energy consumption and technical skill requirements further constrain adoption among resource-limited farmers. Nevertheless, automated systems can improve water and energy efficiency, reduce labour, and support consistent crop quality, suggesting potential for wider adoption with financial and technical support (Kariyawasam et al. 2023).

3.5 Crop Cultivation Practices

Crop diversity was limited, with Capsicum ('Muriya' variety) (*Capsicum annuum*) dominating (69%), followed by Scotch Bonnet (*Capsicum chinense*) (10%), Tomato (*Solanum lycopersicum*) (7%), Cauliflower (*Brassica oleracea*) (7%), Long beans (*Vigna unguiculata* subsp. *sesquipedalis*) (5%), and chilli (*Capsicum annuum*) (2%). The predominance of Capsicum reflects adaptability to local conditions, high market demand, and profitability. Most growers completed one or two cropping cycles annually, influenced by labour, resources, and market constraints. Crop diversification and optimized cropping intensity could enhance income stability and resilience.

3.6 Pollination and Water Management

Pollination relied mainly on natural processes (86%), with minor adoption of plant shaking (10%) and hand pollination (4%) (Table 1). Water management was dominated by agro-wells (88%) and drip irrigation (80%), with fertigation practiced by 58%. Efficient irrigation supports water conservation and crop performance, although long-term sustainability depends on groundwater management and supplementary practices such as rainwater harvesting (Bhamoriya & Mathew, 2014).

Table 1: Distribution of pollination techniques used in polytunnels

Pollination method	No of farmers practiced	Percentage (%)
Natural pollination	43	86
Shaking plants	5	10
Hand pollination	2	4

3.7 Fertilizer and Nutrient Management

Farmers employed a combination of organic and inorganic fertilizers (90%), while only 4% relied solely on organic amendments. Fertigation (58%) enabled precise nutrient delivery, improving efficiency and reducing losses (Wato et al. 2024). Some farmers reported using imbalanced fertilizer rates, which they perceived could affect soil pH and salinity. Since this observation was based on farmer self-reporting rather than soil testing, it reflects growers' perceptions rather than measured soil parameters. Integrated nutrient management strategies, including soil testing, site-specific recommendations, and balanced inputs, are recommended to enhance yields while maintaining soil health.

3.8 Pest and Disease Management

Pest control was heavily dependent on chemical insecticides, targeting mites (36%), mealybugs (24%), whiteflies (15%), aphids (11%), and others (14%). Although effective, reliance on chemical pesticides increases the risks of resistance development and adverse effects on beneficial organisms (Kaur and Garg 2014). Limited non-chemical measures, including yellow sticky traps (52%) and natural repellents, were observed. Strengthening integrated pest management through biological control, crop rotation, and targeted training could reduce pesticide dependence and promote environmental sustainability.

3.9 Financial Returns and Market Access

Financial performance was assessed using a simplified cost–return approach based on farmer-reported establishment costs, operating expenses, and average monthly income. Financial satisfaction among farmers was moderate: 44% reported being financially satisfied with polytunnel farming, 46% were neutral, and 10% were dissatisfied with returns. Despite this, 58% of the respondents indicated that they had not yet recovered their initial construction costs. A polytunnel's useful life was assumed to be 8 years for the financial analysis. Accordingly, the break-even period was estimated to occur between the third and fifth year of operation, depending on farm performance and market prices.

3.10 Marketing and Environmental Constraints in Polytunnel Farming

The survey revealed that marketing and environmental constraints jointly limited the profitability and resilience of polytunnel farming. Price fluctuation was the most frequently reported marketing concern (90%), followed by the absence of fixed markets (70%) and weak linkages to export channels (66%) (Fig. 2). These challenges, compounded by increased intermediary involvement (36%), payment delays (22%), and the burden of meeting high-quality standards (18%), reduced farm margins and discouraged reinvestment, reflecting broader evidence on market fragility and middleman dependence in smallholder systems (Bjornlund et al. 2019; Bamunuarachchi 2013; Novickytė 2018).

Environmentally, pest and disease outbreaks (66%) and flower or fruit drop under high-temperature conditions (60%) were the primary production constraints, highlighting both biotic and abiotic vulnerabilities in protected crops (Fig. 3). Similar pest pressures and microclimatic stresses have been reported in other protected cultivation systems across the region (Kaur and Garg 2014; Kariyawasam et al. 2023). Secondary problems, including reduced light and cleanliness of tunnel roof (28%), tunnel damage from wind and rain with crop sunburn (26%), yield losses due to heavy rainfall (24%), elevated humidity (12%), and occasional water scarcity (2%), indicated that structural design, ventilation, and water-source sustainability were also critical factors affecting polytunnel productivity (Eriyagama et al. 2010; Wijerathna et al. 2014).

Considering all, these results suggested that addressing the challenges of polytunnel farming required coordinated interventions. Market-focused measures included establishing producer cooperatives, developing stable local institutional buyers, improving access to quality certification, and reducing reliance on intermediaries to stabilize prices and improve cash flow. Technical measures focused on improving tunnel design and ventilation, implementing targeted integrated pest management and biological control, selecting heat- and pest-tolerant crop varieties, protecting tunnels against heavy rainfall, and promoting sustainable groundwater and rainwater harvesting to reduce production risks and improve yield stability. Implementing a combination of market-focused and on-farm climate-resilient strategies could address the key challenges identified by farmers, making polytunnel farming in the Mahaweli System H both more profitable and sustainable.

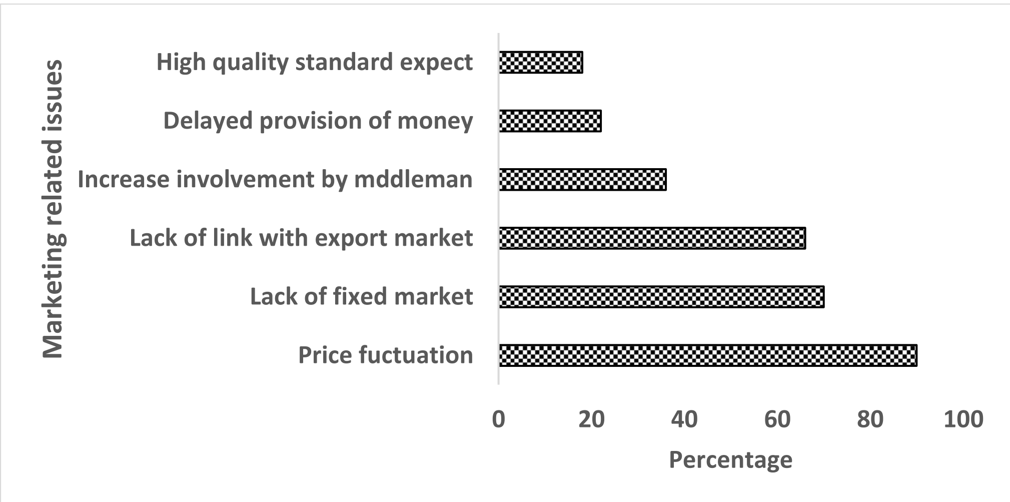

Figure 2: Marketing-related issues for polytunnel growers in the Mahaweli System H.

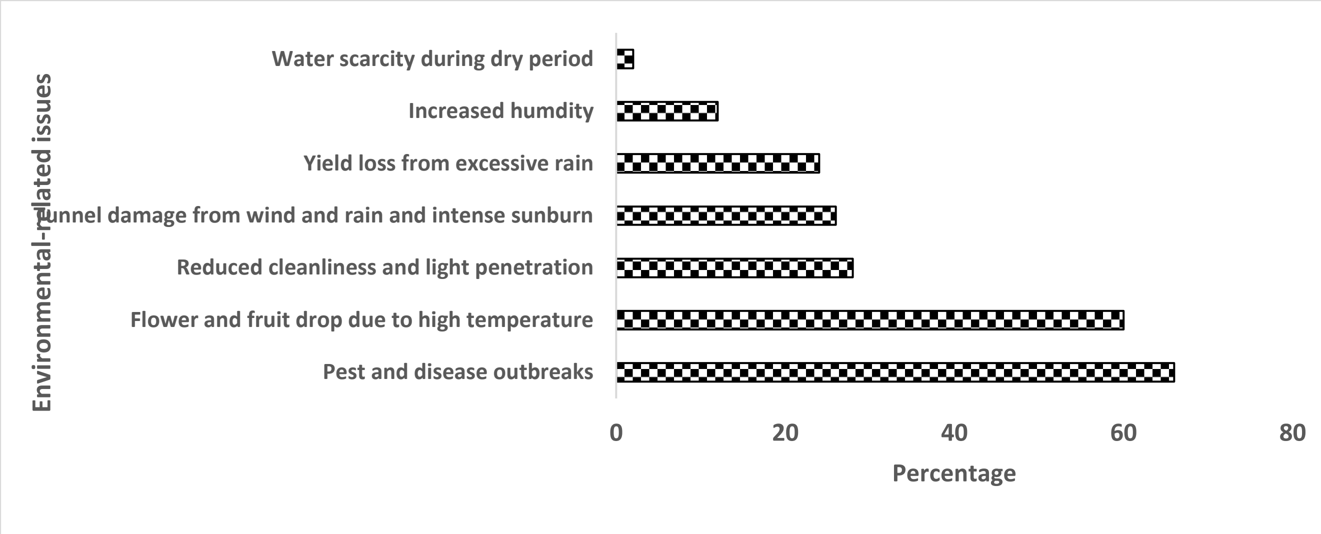

Figure 3: Environmental-related issues for polytunnel growers in the Mahaweli System H.

3.11 Limitations of the Study

This study was limited to polytunnel growers in the Mahaweli System H, and therefore, findings may not fully represent other regions of Sri Lanka. In addition, financial information was based on the farmer-reported estimates rather than detailed farm records. The analysis relied mainly on descriptive statistics, and crop yield performance was not directly measured. Future studies incorporating larger samples and detailed production data would provide deeper insights into the long-term performance of protected agriculture systems.

4. Conclusions

Polytunnel farming in the Mahaweli System H demonstrates potential for income generation and year-round vegetable cultivation; however, the present study did not directly measure crop yield improvements. Instead, findings indicate variability in farm-level income (LKR 30,000–150,000 per month) and adoption of water-saving technologies such as drip irrigation (80%) and fertigation (58%), suggesting that protected cultivation provides economic opportunities under dry-zone conditions.

The system was predominantly managed by middle-aged male farmers, with limited youth engagement and female participation. Farmers exhibited diverse educational and employment backgrounds, reflecting a mix of full-time and part-time involvement in protected agriculture. Polytunnel characteristics, crop choices, and management practices, including irrigation, fertigation, temperature control, and nutrient application, were influenced by economic constraints, technical knowledge, and environmental conditions.

Despite the benefits of polytunnel cultivation, farmers faced significant challenges. Marketing constraints, particularly price fluctuations, limited market access, and dependence on intermediaries, reduced profitability and discouraged reinvestment. Environmental constraints, including pest and disease outbreaks, heat-induced flower and fruit drop, tunnel damage, and water management limitations, further restricted productivity and system resilience.

Addressing the stated difficulties necessitates coordinated market and technological actions. Market strategies should prioritize building cooperatives, increasing access to quality certification, and establishing direct market linkages. Improved polytunnel design, efficient ventilation, integrated pest management, the use of heat- and pest-tolerant crop types, and sustainable water usage techniques are all recommended. Together, these measures can improve the productivity, profitability, and sustainability of polytunnel farming in Mahaweli System H, as well as provide recommendations for policy development, capacity building, and investment in protected agriculture in Sri Lanka's arid zone.

Ethical Approval: All participants provided their informed consent, and the study was conducted in accordance with the ethical guidelines of the Mahaweli Authority.

Conflicts of interest: The authors declare that there are no conflicts of interest related to this study.

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