

Perspective of Protected Agriculture in Sri Lanka: A Review

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Abstract- The purpose of this review is to discuss the Sri Lankan perspective of protected agriculture and to review the necessity and possibility of adopting protected agriculture in Sri Lanka. Crop cultivation under protective covers is termed as protected agriculture and it is a subset of controlled environment agriculture and the micro-climate of a crop is fully or partially modified and or controlled depending on the extent of technology applied. Protected cultivation has gained significant attention at present due to frequently occurring adverse environmental conditions, rapidly declining arable lands and the necessity of increased productivity. Protected agriculture delivers the benefits of improved quality and productivity and year round production despite the additional investments incurred. Sri Lanka being located in the tropical belt with year round favorable weather and optimal soil conditions, had been rather stable in open field cultivation. Protected cultivation is practiced for high value export crops and seedling production. Even though attempts have been made to establish protected cultivation, it has not been sustained due to various reasons. The reluctance in adopting protected cultivation is mainly due to excessive initial investment, inadequate technical and extension services, and deprived return for the investment made due to improper marketing channels. Therefore, it is timely to promote protected cultivation within the

country due to several obvious reasons; maintaining sustained supply of quality perishables despite the adverse environmental conditions, locally growing perishables with minimum or zero inorganic inputs for growth promotion and plant protection, enticing youth for modern agriculture by providing financial facilities in starting up protective cultivation.

Index Terms- Protected Agriculture, Micro-climate, Controlled Environment

I. INTRODUCTION

Development of sustainable agriculture is the key element in ensuring food security. Agricultural sustainability rests on the principle that the present needs are fulfilled without compromising the ability of future generations to meet their own needs. Therefore, long-term stewardship of agriculture cannot be postponed allowing only to gain short-term economic benefits. The national policies aims at 'improved health and lifestyles through the promotion of safe agricultural production'. The escalating population demands food that are resource intensive to produce and accompanies higher carbon footprint. Extended crop

production would not be possible unless novel technologies are introduced, and available technologies are optimally used. Protected agriculture uses technology to modify the crop's micro-environment for enhancing the quality and productivity.

Protected agriculture is the cultivation of crops including vegetables, fruits, ornamental foliage and cut flowers under protective covers including glass-houses, net-houses, poly-tunnels and rain shelters (Wijerathne et al., 2014 and Kumara et al., 2015). In a broader perspective, it is defined as a cultivation system in which micro climate of the plant is fully or partially controlled during the crop growth according to the requirements of the crop (Mishra et al., 2010). Protected agriculture is a feasible technology to obtain quality agricultural produce with lower inputs regardless of the climate change (Abukari and Tok, 2016). Environmental factors including light, temperature, humidity and nutrients are controlled ensuring year round production (Sabir and Singh, 2012) with 3 -5 folds yield increment compared to open field crop production (Santosh et al., 2017). The produce grown under protected environments receives higher demand in local and international markets hence the return to the grower is usually higher despite the initial investment.

The per capita agricultural land holding is predicted to further diminish due to various reasons including escalating population and diminishing of arable lands and industrialization (Dubois, 2011). Thus, the future crop production inevitably has to depend on some forms of intensive cultivation for meeting the ever increasing demand for safe and healthy foods. Sri Lanka, being a country with agriculture based economy need to focus on the possible shifts in cultivations technologies for securing the sustainability of the agricultural sector.

The consumer awareness on the debatable and extensive use of agro chemicals in open field cultivation has increased in the recent past. The abundance of chemical residues in perishables is well established (Blasco et al., 2002; Keikothaile and Spanoghe, 2011) and the public is hesitant in relying on market available produce. If consumers are guaranteed with organically produced crops especially vegetables and leafy green, the consumption patterns could be reversed. One of the options is to locally grow these annual crops in protected environments in which pest and diseases incidence will be properly controlled and crop can be conveniently supplied with organic fertilizer. The added carbon footprint if there is any in growing under protected environment would possibly be negated over the transportation from distant open fields and putting the postharvest losses to a minimum. The promotion of urban/local protected cultivation will provide safe and fresh produce with minimum postharvest losses, entice youth for modern agriculture (Kwakye et al., 2021) in which appropriate technologies are used and uplift the economic status of those who are engaged in agriculture sector.

The country's crop production is already affected by the unpredictable weather patterns (Esham et al., 2018) as well as declining land productivity (Wickramaarachchi and Weerahewa, 2016). Varying climatic conditions of untimely rainfall followed by high humid seasons have a critical impact on fruit setting and occurrence of pest and diseases in field grown fruits and vegetables (Saqib et al., 2022) whereas climate changes have minimal impact on plants grown indoors. In the backdrop of problems associated with field grown crops, protected cultivation seems to solve some of the problems (Gleku et al., 2021).

Protected cultivation have undergone transformation from small scale minimum investment facilities to significantly large scale facilities that compete directly with land-based conventional food production. Efforts have been made to introduce and start up protected cultivation in Sri Lanka and several local entrepreneurs engage in protected cultivation targeting the overseas markets. This review attempt to discuss the global trends in the controlled environment agriculture and to appraise the necessity and possibility of adopting protected agriculture in Sri Lanka.

1. Trends in Global Protected Agriculture

Owing to the high investment capacities and rigorous research, development and innovative interventions, the developed world has adopted the precious protected agriculture in the form of Controlled Environment Agriculture (CEA). It is an often used term in literature along with protected agriculture. CEA is a more sophisticated method of agriculture compared to protected agriculture in which both root and aerial levels of a crop are fully controlled in order to provide optimum conditions for the crop growth and obtain the maximum yield (Albright and Langhans, 1996). Protected agriculture implies growing plants in enclosed structures in order to provide optimum light for the plant growth while protecting plants from adverse climatic conditions (Jensen and Malter, 1995). The level of complexity in CEA operations are higher than that of protected agriculture (Weerakkody et al., 2001). The urban consumers are now seeking locally produced perishables year round. Europe holds the largest share of the indoor farming market owing to the early adoption of greenhouses and vertical farming.

The concept of protected agriculture first emerged in developed countries in the Northern hemisphere to combat extreme cold climates and protect crops from lower temperatures thus, continue the crop production even in the winter season (Jensen and Malter, 1995). Also, countries in desert regions used this particular crop production system in order to protect crops from extremely high temperatures and excessive water loss (Kumara et al., 2015). Thus, arid lands in both tropical and temperate regions of the world are efficiently used in agricultural production with the development of protected agriculture along with CEA (Jensen, 2010).

By 2011, the total land area under most sophisticated greenhouses in the world is more than 627,000 ha out of which 443,000 ha is in the Asian region (Encyclopedia of Food and Agriculture). Asia and Mediterranean region have accounted for much of the areas and growth of protected agriculture (Takeshima and Joshi, 2019). The fastest development of protected agriculture in the world has recorded in China (Zhang, 1999) whereas China and Japan accounted for the largest land area under protected cultivation within Asia (Takeshima and Joshi, 2019). Interestingly, more than 90% of China's protected agriculture is employed for vegetable production (Sabir and Singh, 2012). Apart from China and Japan, India, Iran, Pakistan and Afghanistan are the leaders of protected agriculture in Asia while tomato, capsicum, leafy vegetables, eggplant and cucumber been the most cultivated crops (Dias et al., 2020). Even though the developed countries have embraced the CEA and Asia is on its' way for adapting the CEA technology the involvement of Sri Lanka in protected cultivation remains at rather initial stage thus apart from CEA.

One of the latest developments in CEA is high density vertical crop growing system which also known as “Verti-Crop Technology”. This cultivation system ensures least land usage with improved quality and quantity of harvest. Verti-Crop technology is practiced in glass-houses and poly-tunnels and studies indicate that it could produce up to 20 times higher yields with only using 8% of water used in irrigated fields (The Economist, 2010).

One of the greatest challenges for present agriculture is transforming agricultural practices to reduce agriculture’s environment footprint while achieving United Nations’ sustainable development goals (Foley et al., 2011 and Eyhorn et al., 2019). Organic farming has gained more attention as a viable alternative (Tittarelli, 2020) as it has proven to improve soil quality, lower greenhouse gas emission and minimize the rate of biodiversity loss with respect to conventional agriculture (Letourneau and Bothwell, 2008; Mazzoncini et al., 2010 and Skinner et al., 2019) even though it still represents a niche sector in global agricultural production systems (Rahmann et al., 2017). Also, literature implies that organic greenhouse production has high performances with respect to the utilization of water, soil, energy and organic matter (Ohyama et al., 2020). In Europe, with the debate on the need of an agro-ecological approach to organic production, a strong discussion on the principles of organic farming has been carried out by the main actors of the sector (producers, consumer association and policymakers) as a consequence of the diffusion of organic systems of production characterized by a high level of intensification (Tittarelli, 2020). The said intensification of organic crop production is associated with and benefitted by the CEA. In the forthcoming policy change on the use of inorganic fertilizer and plant protection chemicals in Sri Lanka, revisiting the potential incorporation of protected agriculture for organic farming is of timely importance.

II. MERITS AND DEMERITS OF PROTECTED AGRICULTURE

There are several obvious benefits of protected agriculture compared to the conventional agriculture. The crop’s micro-environment is modified and controlled so that the plants receive optimum growth conditions and minimum environmental stress. Thus, plants grow vigorously and perform best to its genetic potential compared to the field grown plants. Studies have shown that protected agriculture results in higher yields than conventional agriculture (Weerakkody et al., 2000 and Jensen, 2010). Also, protected agriculture return higher outputs per unit input and protect the environment by extended water and land use efficiency. According to Paroda (2013), 10-100 times higher annual returns per unit area could be achieved by protected agriculture compared to open field crop production.

Most importantly, this cultivation technology has the potential of converting arid and dessert lands into arable lands by mitigating the impact of harsh weather on crops. Therefore, protected agriculture along with CEA is the future of crop production in order to minimize the effect of climate change on food production in addressing the global food security. Nevertheless, rapidly declining land availability for vegetable production due to increasing urbanization, water scarcity, government policies and regulations on fertilizer and chemical

usage in agriculture could be effectively managed by adopting protected agricultural techniques (Kumara et al., 2015).

Studies have shown that leafy vegetables cultivated in protected environments yield more quality and quantity than those cultivated in open fields (Amit, 2007). It has been cited that bell pepper and tomato grown in poly-tunnels receive higher productivity and returns (Singh and Asrey, 2005). Other than producing high quality fruits and vegetables, possibility of off-season cultivation in protected agriculture offers higher market prices for the produce and improve grower’s profit (Singh and Sirohi, 2006). Also, ensures market availability of fruits and vegetables throughout the year without seasonal fluctuations.

Another distinct benefit of cultivation in protected environments is the ability of practicing climate compatible crop production thus reducing the adverse environmental effects encounter in open field agriculture (Omobowale, 2011). Agriculture is becoming an unattractive employment sector due to lower returns and labor intensive works in conventional farming but drudgery less CEA and protected agriculture are better solutions for attracting well educated and skilled youth for agriculture sector (Sanwal et al., 2004).

Major barrier which discourages entrepreneurs starting protected agricultural enterprises is higher initial investments. Also protected crop cultivation has considerably higher production costs compared to open field cultivation. Still, these additional costs could be recovered by ensuring higher returns per unit area with higher productivities (Jensen et al., 1995 and Jensen, 2010). Higher risks of disease spread due to increased cropping intensity and elevated uncertainty are two drawbacks of the industry (Aoki, 1995 and Weerakkody, 2000). Technological knowledge and proper decision making ability are another crucial factors to run a profitable protected agriculture venture.

III. PRESENT STATUS OF PROTECTED AGRICULTURE IN SRI LANKA

Agriculture, industry, and services are the key economic activities of Sri Lanka which contributes to the GDP are 6.9 %, 25.9 % and 58.3 % respectively (Central Bank, 2021). The country has identified as a developing country and one of the potentially richest nations in South Asia with natural resources of fertile soil and easily accessible groundwater, relatively favorable weather conditions for agriculture. The farming community who are practicing agriculture as the main source of living in the country represent almost one third of the total population. Apart from them, considerable population relies on agriculture as indirect income generating sources (Dissanayeke and Wanigasundera, 2014). The conventional agriculture supplied the fruit and vegetable demand of the country with open field cultivation but it has been noticed that it is not sustainable and lacking the capability of fulfilling the rapidly growing demand for high quality and safe agricultural produce.

Even though the term CEA is widely used along with protected agriculture, what is practiced in Sri Lanka is not CEA but the protected agriculture where crops are grown under various types of protective covers mainly in greenhouses (Weerakkody et al., 2000). The main purpose of introducing protected agriculture to Sri Lankan farmers in 1997 was to protect high value horticultural crops from prolonged and intensive rainfalls and to

provide optimum environmental conditions for the crop growth (Weerakkody, 2004). Ensuring continuous crop production without seasonal variations, guaranteeing satisfactory farmers' income with no effects from adverse weather and pest and disease problems, overcoming land and labor scarcity in agriculture and attracting younger generations more towards farming by utilization of modern technologies in agriculture were the other main reasons of promoting protected agriculture in Sri Lanka (Kumara et al., 2015). Net houses, poly-tunnels and rain shelters are the most widely established protected agriculture techniques in Sri Lanka mainly for the cultivations of bell pepper, cucumber, tomato and zucchini mainly in Kandy, Badulla and Nuwara Eliya districts (Wijerathne et al., 2014 and Kumara et al., 2015).

Department of Agriculture, Export Development Board, National Agribusiness Centre along with various projects and funding agencies are the key promoters of protected agriculture technologies in the country (Kumara et al., 2015). Protected Agriculture Entrepreneurs Association (PAEA) is the pioneer active body of protected agriculture field in Sri Lanka. There is limited published information on recent development of protected agriculture in Sri Lanka. As mentioned by Wijerathne et al. in 2014, the number of annual registrant in PAEA has showed no noticeable increase other than a swift surge in 2006 and that was due to an introduced subsidy scheme for protected agriculture growers by German Technical Cooperation.

Table 1: Percentage of farmer distribution by type of PA structure (Adapted from: Kumara et al., 2015)

Type of structure	Distribution of farmer by District (No./Percentage)				Overall
	Nuwara Eliya	Badulla	Kandy	Matale	
Net houses	40%	19%	42%	-	30%
Rain shelters	-	-	-	100%	45%
Poly-tunnels	34%	46%	20%	-	25%
Total	28%	26%	21%	25%	100%

Also, Niranjan et al. (2005) has mentioned on discontinued protected agriculture entrepreneurs in Sri Lanka suggesting that there is a tendency for discontinuation after several growing seasons and the involvement of the females in the industry remains low. The reasons for higher discontinuation may include inadequate profit margins, higher cost of operations and transportation costs, availability of alternative job opportunities for youth and need of higher level of knowledge, technology and decision making abilities for protected agricultural operations compared to conventional agriculture (Mahaliyanaarachchi et al., 2004). According to a study conducted by Wijerathne et al., 2014, 50% of discontinued farmers had issues with marketing and transportation while 13% had given up the due to severe pest and disease incidents. The third and fourth reasons were labor unavailability (10%) and low profits and maintenance problems

(7%). The majority of the discontinued group was small scale farmers who grew relatively less value crops and the cultivated area under protection was less than 186 m² (2000 ft²). The demand and return for good quality protected agricultural produces have increased over past years but not adequately to cope with cost of production. This is one of the most sensible reasons for farmers to move away from the industry.

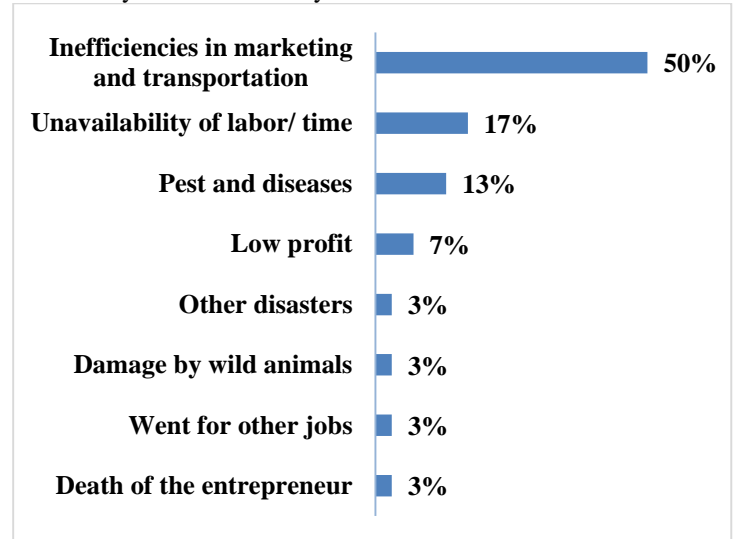


Figure 1: Reasons for discontinuation of protected cultivation given by discontinued members (Adapted from: Wijerathne et al., 2014)

Other than the channeled group of growers for export markets, a few grower and end use arrangements are functioned in the protected agriculture sector through PAEA; airline catering, super market networks and business ventures related to tourism are few of those. Even though the producers receive a fixed but fairly decent return for their produce through this channel, proper harvesting, packing and transporting fresh produce to PAEA collection centers is challenged by several related factors. As most of the farmers engaged in protected agriculture at present are running at small scale, packing and transporting by their own means ensuring quality is much difficult for them and farmers tend to be discouraged due to higher transportation costs associated in the process (Wijerathne et al., 2014). The total annual sales and gross profit of protected farmed vegetables from 2007 to 2011 are shown in Figure 2. Despite the fact that sales have grown quickly over the analyzed time, profit has not grown substantially.

Also, the tendency of the youth moving away from the agriculture sector is apparent and the issue had not been properly addressed in the policy making and implementation. According to Chinsinga et al., (2012), youth strongly believe that agriculture is not a way of achieving their vision of "the good life". This thinking pattern has generated and established in the society as there is no evidence of improved social and economic status of the population engaged in agriculture. Contrarily, the mature and traditional farmer community is more resistant to move towards protected agriculture which involves relatively high technical and capital inputs.

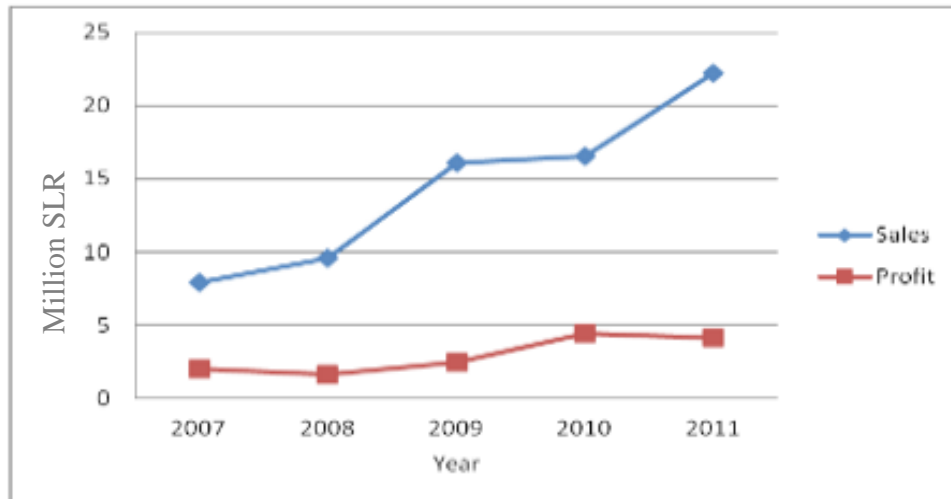


Figure 2: Total annual sales and gross profit of protectively grown vegetables 2007-2011 (Financial reports of PAEA from 2007 to 2011)

Kumara et al. (2015) mention the reasons for protected agriculture to be less famed among farmers in the country, namely poor adoption to latest technologies, lack of guaranteed markets, unavailability of quality seeds, inadequate credit access and subsidies, poor extension services. More or less same reasons are cited by Dias et al. (2020) and state the reasons for lesser willingness of Sri Lankan farmers to get engaged in protected agriculture; relatively larger initial investments, not having adequate skills and skill development and capacities, inadequate technological knowledge and precise decision making abilities. Moreover, Mufeetha et al. (2021) mentioned that the high initial cost of constructing this protected system is creating a high degree of uncertainty for small and middle size growers' efforts toward protected agriculture.

Even though the individual farmers are not much engaged in the industry at present, it is clear that the large scale companies which engaged in agriculture are expanding their shares in protected agriculture sector at a noticeable rate. One of the rapidly expanding protected agriculture sector in the country at present is floral industry. Due to increasing demands for high quality cut flowers and foliage including Roses, Gerberas, Tulips, and Chrysanthemums etc. at local and foreign markets, low tech protected agricultural practices like net houses, polytunnels are highly used in leading floral companies including Lassana flora, Amalka flora, Shirohana etc. And also there is a tendency among individual small or medium scale floriculture growers to employ protected environments to improve quality and quantity of their production. Apart from floral industry, large scale exotic fruits and vegetables producers like CIC agri business, Hayleys agriculture, Ceylon agroventure, Kanara exports, etc. also heavily employ protected agricultural practices for crops including Bell pepper, Broccoli, Tomato, Strawberry, Cherry tomato etc. Other than large scale producers directly engage in the industry, large scale super market chains and suppliers including Keels super, Cargills, Glomark etc. are enhancing small scale individual farmers to practice protected agriculture in a manner where they invest money on the business and farmers only have to cultivate the crops

for them and sale the harvest to the investors at a pre-determined and agreed price.

IV. FACTORS TO PAY ATTENTION IN PROMOTING PROTECTED AGRICULTURE IN SRI LANKA

Even though dry zone is a major vegetable producing region in the country, the area more frequently undergoes extended droughts, unexpected extreme climatic events which disturb continuous vegetable production (Eriyagama et al., 2010). In order to minimize the effect of such harsh climatic conditions on the production process and to ensure continuous vegetable supply, protected agriculture would be a promising solution. But still, protected farming practices are not much established in dry zone and mainly practiced in up country and low country wet zone mostly for the vegetables of tomato, bell pepper, lettuce, cauliflower, Japanese cucumber and broccoli (Dias et al., 2020; Mufeetha et al., 2021). But, various researches have proven that protected crop production has a high potential to expand and adopt well in different agro ecological regions of the country thus, be a sustainable income generator for vegetable growers (Weerakkody et al., 2000 and Niranjana et al., 2005). According to Baille, 2001 and Fernandez et al., 2018 the main characteristics of presently employing PA structures in mild winter climates includes simple low-tech structures with low level of mechanization and automation and poor usage of environmental parameters controlling devices which makes the environment inside the PA structures depends heavily on external climatic conditions. The situation of PA structures employed in Sri Lanka is also the same and sometimes may be poorer (Ex: rain shelters). Critical factors affecting in controlling microclimate inside a PA structure include temperature and light intensity control. High inside temperature could be pointed out as a main problem associated with protected agriculture in dry zone Sri Lanka whereas, lower incoming solar radiation could be identified as a major issue in up country areas. Thus, an enough attention should be given for suitable technologies which could be used to lower the inside temperature of PA structures in dry zone while introducing technologies to

capture more solar radiation in up country and low country wet zone areas in most economically feasible ways with minimum use of external energy.

One of the main factors causing lower adoptability to PA among dry zone farmers could be pointed out as limited access to new technologies. Thus, ensuring availability of reliable information on latest agricultural practices for farmers is a must in order to popularize PA in dry zone of the country (Dias et al., 2020).

After 2009 war conflict, there is an increasing demand for good quality fruits and exotic vegetables in the local markets due to the rapid expansion of tourism industry in the country. Also, more frequent rigorous fluctuations in weather have become a huge threat for open field fruits and vegetables cultivation could be encouraging courses for farmers to engage more in the industry. There are a few very important questions to be answered by an entrepreneur before commencing a protected agriculture venture. First one is what is the target market for the products or to whom the products will be sold? Is there any market already available? What will be the expenses on sorting, grading, packaging etc. operations? Also, means of transportation and costs involving are another important question to be clarified at the beginning. More importantly the growers have to study the potential market well prior to starting a business and be aware with the possible fluctuations in the market and have to be competent for those too (Hanan, 1997).

Improved extension services and effective training are the key factors to run a successful long term protected agriculture enterprise. Better the knowledge and training the grower possesses higher the profitability (Bertuglia and Calatrava, 2012). Thus, proper trainings at farmer's level and introduction and utilization of latest technologies in the field are essential to uplift the status of protected agriculture in Sri Lanka at present. Extension services has a major role in determining the level of farmer's adoption. Dias et al., 2020 suggests that farmers with higher accessibility to good quality extension services showed a higher adoptability to latest technologies. Thus, evaluating ongoing and completed protected agricultural projects in terms of both technological and socio-economic feasibility and sustainability is a must in order to identify the past issues and for the future improvements (Wijerathne et al., 2014). Researchers have found that farmers with more access to credits show a higher willingness to move towards protected agriculture (Dias et al., 2020). Thus, improving access to credit for the investment on protected agriculture especially among small scale farmers is also very important to move farmers towards the sector. And linking small scale growers with monitoring and advisory programs in order to minimize production costs, risks and improve profit margins is a must.

Paying more attention towards attracting younger farmers to protected agriculture would be effective (Dias et al., 2020) as the studies has shown that willingness to try and invest more on new technologies is significantly higher among younger farmers than older farmers. Nevertheless, young farmers have the ability to adopt to latest technologies faster than older farmers who are used to conventional agricultural practices (Nyanga, 2012; Alam, 2015; Arellanes and Lee, 2003). Also, reorganizing supply chain processes including collection, transportation, storage and marketing which requires huge costs at present is a critical factor to ensure the supply of good quality fruits and vegetables from

protected agricultural ventures with low costs (Wijerathne et al., 2014).

V. CONCLUSION AND RECOMMENDATIONS

Even though CEA and protected agriculture are the modern trends in the world for minimizing effect of climate change on crop production and to improve the productivity, Sri Lankan farmers and agro-entrepreneurs are reluctant in moving towards protected cultivation yet. Protected cultivation is presently practiced in small scale in several districts in the country. Locally, the protected agriculture sector has a great potential for expansion in supplying quality agricultural produce grown with minimum agro chemical use while encountering seasonal fluctuations with sustained farmer's income. The stake holders of agriculture sector have made efforts in popularizing protected culture in the country over past three decades but with curtailed results. Therefore, identifying the gaps and issues related to the industry is very important. Credit unavailability, issues and costs associated with the supply chain and inadequate extension services and instabilities encountered in long term endurance were identified as major factors discouraging farmers from engaging in protected agriculture in Sri Lanka. Therefore, farmers should be encouraged by supportive startups, proper extension services with improved training programs, reorganizing supply chain and establishing a valued local and export market for promoting the sector in the country.

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