
Article

Low-cost Greenhouse Design for Sustainable Agricultural Production after COVID-19

Arnon Jumlongkul ^{1,*}

¹ School of Medicine, Mae Fah Luang University; arnon.jum@mfu.ac.th

* Correspondence: arnon.jum@mfu.ac.th; Tel.: +66-53-916-569

Abstract: This study aimed to focus on how to design a low-cost greenhouse for the cultivation of crops, to propose the cost-effectiveness analysis of small agribusiness, and to promote sustainable agricultural production during and after the COVID-19 crisis for helping grassroots and anyone who lost their job. This article is qualitative engineering research, studying of literature reviews of greenhouse farming concept and Micro, Small and Medium Enterprises, then, designing low-cost greenhouse model which was preliminarily adapted for hot climate countries. Three plants that were selected as representative plants of this model include sunflower, water spinach, and wheat. The greenhouse model, measuring 5 x 7 x 4 m (W x L x H), was designed for this mission. The total cost of one building is approximately 97,994 THB. For the worthiness of the investment, farmers should build at least three greenhouse buildings, which will return total income to farmers approximately 34,666.09 THB per month. The suggestion includes further knowledge and financial supports from the government sectors among farmers, then, boost them up using high-level technology and also planting high-price agribusiness production to promote the local economy to be strong and sustainable.

Keywords: COVID-19; greenhouse; MSMEs; renewable energy; solar energy

1. Introduction

According to social distancing and lockdown policies during the COVID-19 pandemic, many economic and social systems have been directly affected. Prolonged mobility restrictions have inevitably damaged the global economy. The mobility prevention of individuals can reduce the disposable income between -10% up to -40% among both infected and non-infected workers in Italy following stop working [1]. A study showed world output fell by -7% when only China declared a lockdown policy and reached -23% after many countries were under a lockdown at the early time of crisis [2]. When considering the household income, for example, in the San Francisco Bay Area, the poverty rate increased from 17.1% up to 25.9% within three months while many developing countries in Southeast Asia, including Thailand, is predicted to decline gross domestic product (GDP) by 0.6% at the end of 2020 according to decrease in global trade, tourism, and investment [3]. The COVID-19 situation being has affected most all occupations, for example, a study in India showed the huge impact on multi-affected sectors, including, aviation, retail, capital market, tourism, and oil while Micro, Small and Medium Enterprises (MSMEs) have suffered from this severe cash crunch [4].

As part of agriculture, which is one of the most important sectors endorsing food security, the pandemic has interfered with the supply chain due to the lack of labor, production, and distribution company, especially in the crop, livestock, poultry, dairy, and fishery industries. According to the Chinese lockdown policy, global farmers have faced a shortage of initial agricultural production (e.g. seed, pesticide, manure, chemical fertilizer) for producing their agro products [5]. In China, crop production is mainly affected

according to the impact of COVID-19. The government's immediate countermeasures included, for example, continuing agricultural production, resuming farmers' work, supporting financial grants, providing agriculture technology, and providing assistance to low-income farmers. However, those actions do not include all impact aspects [6]. Global agricultural markets also impact the decline in economic growth, including, the decrease of 7-18% and 4-7% of international meat prices as well as dairy products, strong falling of biofuel price followed by feedstock, maize, and oilseeds. However, global food consumption is still unaffected according to the inelastic agricultural commodity demand and the shortage period of the stock [7]. This situation is eventually identified as a gap for creating some agro products during the pandemic.

When considering the aspect of entrepreneurship, a study showed the result of surveying of more than 5,800 small businesses that mass layoffs and closures had occurred in a few weeks after the start of the COVID-19 pandemic. Many of them have faced financial fragility [8]. For sustaining enterprise operations during the COVID-19 crisis, the Enterprises Effectiveness and Sustainability Model during Pandemic suggested that companies should have distributed leadership, workforce, and adaptive culture. Moreover, resilient enterprises should provide more informed and decentralized decision-making. Online platforms, for example, social media, integrate intranet, and internet should amalgamate with daily business routines that can establish trust and bonds among all stakeholders [9]. The challenge is how to implement all those concepts to farmers, grassroots, or anyone who lost their job during this crisis.

As mentioned above, the objectives of this article are to design a low-cost greenhouse for the cultivation of crops, to propose the cost-effectiveness analysis of small agribusiness, and finally, to promote sustainable agricultural production during and after the COVID-19 crisis.

2. Materials and Methods

A case study was proposed by the microbusiness owner in Chiang Rai Province, Thailand, who joined the Pre-talent Mobility Project organized by Mae Fah Luang University. He raised his problem related to the lack of knowledge in his business and also budgets. His proposal has never overcome the financial institutional agreements. The preliminary analysis showed that he could not select the type of plant for cultivation within his greenhouse farming or plant factory appropriately, could not evaluate the break-even point (BEP) of his business, and could not select technology-enhanced productivity properly. To solve these problems, this article is qualitative research in engineering design. The scope of this study is to explore an optimal design of a low-cost greenhouse amalgamated with local renewable energy, to make informed business planning, and to create and maintain a sustainable business. Thailand was selected as a representative of hot climate agricultural developing countries. Some essential details are discussed below;

2.1. Greenhouse concept

Greenhouse farming is one of the agricultural systems that challenge mankind to produce world food supply sufficiently and sustainably in the twenty-first century. The global research trends in the field of greenhouse have focused on water and irrigation supply, the design of optimum greenhouse structure, soil conservation, energy use, climate control, and pest control. The challenge of this sector is the economic-financial feasibility among farmers, feedback loop between farmers and the needs of the sector, supportive systems from institutions or governments to farmers, and last, filling the gap between the technological knowledge and the end-users' tradition (10). In Thailand, a case study using the smart technology for the agricultural sector showed a closed-vertical farming system that was incorporated with artificial intelligence (AI) light, controlled environment (e.g. air conditioning system, humidity, CO₂ concentration, nutrient solution), and the Internet of Things technologies. The project researchers claimed that they could produce approximately 50,552 lettuce heads per month within a plant factory, measuring

173.85 m² x 6 m in height (11). The concern of this issue is how to implement this modern farming concept into grassroots or anyone who has not a lot of money to provide high-level technology such as Internet of Things and AI systems.

According to energy supply, in general, renewable energy (RE), for example, solar, wind, water, and biomass energy are defined as the common use of resources. These alternative resources have been selected to replace the use of fossil fuels (12). Among South-east Asian Countries, ASEAN has set a policy for RE usage up to 23% by 2025. In Thailand, there is a renewable energy consumption target rising to 30% as well as an electric vehicle (EV) will be enhanced to increase to 1.2 million EVs and 690 charging stations by 2036 (13). The optimum greenhouse design therefore should generate RE or use RE as part of this novel model to support mechanical as well as electric farming devices.

2.2. *Micro, Small and Medium Enterprises (MSMEs)*

Individual business or individuals that can carry out a small-scale community economic activity also called MSMEs, which is divided into three groups following the World Bank, including, Micro Business (employees limited to 10 people), Small Business (employees limited to 30 people), and Medium Business (employees limited to 300 people), respectively. To promote these business groups, some MSMEs owners believed that using Electronic Money (e-money) will help them receive performance gains (14). In food business sector, a study showed three dimensions, which have influenced in the digitalization era, include the changing of consumer consumption pattern, business competition, as well as business environment (15). In Thailand, the government declared the national development model, namely 'Thailand 4.0', which was adapted from the industry 4.0 concept. This model also has supported creativity and innovation among regional small firms or MSMEs to create their value-added businesses. A total of 2.8 million small firms was found in 2018. The integrative new idea generation, and market-leadership orientation, are two essential keys that can drive the strategic entrepreneurial awareness among Thai owners (16). Therefore, to promote the sustainability of MSMEs, especially in Thailand, all requirements from both owners and customers should be concerned.

3. Results and discussion

Analyzed data involve in this paper was surveyed from Thai online businesses, including, plant stores, building material stores, electronic shops, retail shops, greenhouse entrepreneurs, and also contractors. Assisted-decision making details are shown as follow;

3.1. *Plant product*

The market price of each plant is the most important factor which should be considered before preparing the cultivation. Some plant values that are lesser than 100 Thai Baht (THB)/kg should be avoided because in general, the minimum wage in Thailand is higher than 300 THB. Therefore, this situation can make business owners go broke according to the lack of competitiveness with the traditional cultivation. To prevent the effects of fluctuation of market price, three popular crops that are cultivated approximately 8 days per cycle, including, *Helianthus* or sunflower, *Ipomoea aquatica* or water spinach, and also wheat were selected as the model to explain this formulation. The value of sprout of each plant is approximately 100 THB/kg. Table 1 shows the explanation of value analysis among three plants for one tray per cultivation cycle.

Table 1. Comparison of value analysis of sunflower, water spinach, and wheat for one tray per cultivation cycle.

Item	Plant			Unit
	Sunflower	Water spinach	Wheat	
Cost				
Seed/kg	22.50 [*]	17.50 [*]	12.50 ¹	THB
30 x 60 cm tray (50 THB/tray, use for 200 cycles)	0.25	0.25	0.25	THB
Seedling media (1 THB/kg/tray, use for 3 cycles)	0.33	0.33	0.33	THB
Commercial bag (170 THB/pack, 135 piece/pack)	1.26	1.26	1.26	THB
Water (1 THB/100 L)	1.00	1.00	1.00	THB
Total cost/tray	25.34	20.34	15.34	THB
Sale price				
Wholesale price 100 THB/kg (seed weight : sprout weight = 1 : 4)	60.00	50.00	125.00	THB
Summary				
Profit/tray	34.66	29.66	109.66	THB
Cost/kg	42.24	40.69	61.37	THB
Cultivation cycle (day)	8.00	8.00	8.00	Day

¹ Where: sunflower seed = 150 THB/kg, use 0.15 kg/tray; water spinach seed = 140 THB/kg, use 0.125 kg/tray; wheat seed = 100 THB/kg, use 0.125 kg/tray.

3.2. Greenhouse model

The greenhouse model, measuring 5 x 7 x 4 m (W x L x H), was designed for this mission. For the worthiness of the investment, farmers should build at least three greenhouse buildings. Therefore, only 150 m² of land (70% greenhouse farming, and 30% multi-use space) is sufficient for operating this business. In the early business phase, farmers should not make any systems amalgamate with the Internet of Things technologies because they sometimes may not overcome the total cost of greenhouse farming. The appropriate energy resource of Thailand is solar energy, then, solar cells should be applied and amalgamated with provincial electricity for supporting any electrical system. The total cost of one building is approximately 97,994 THB. Cost analysis of greenhouse construction is shown in Table 2. The greenhouse model is shown in Figure 1, 2, 3, and 4.

Table 2. Cost analysis of greenhouse construction.

Item	Value	Unit
Greenhouse structure 5 x 7 m Greenhouse roofing plastic Insect protection net Galvanized steel pipe Other materials	38,500.00	THB
Cultivation table Size 0.7 x 2.5 x 1.3 m (W x L x H) made of 0.8 inch galvanized steel rectangular tube, 1,900.00 THB/table x 5 tables	9,500.00	THB
Cooling system Air cooling fan 24V 80W, 12 inch diameter, cover 15 m ² /piece, 318.00 THB/set x 3 sets	954.00	THB
Electrical support system Polycrystalline solar panel 340W, 3,350.00 THB/set x 5 sets	16,750.00	THB
Light system Phyto lamp LED Grow Light 30W AC 220V, 366 THB/set x 3 sets/cultivation table	5,490.00	THB
Electrical and water control systems Safety breaker 550.00 THB Electric cable 25.00 THB/m x 50 m Digital timer 1,000.00 THB Set of water pipe 1,000.00 THB Set of electric box 2,000.00 THB Water pump 7,000.00 THB	12,800.00	THB
Wages Wage for water supply installation Wage for solar cell installation Wage for light system installation Wage for electrical system installation	14,000.00	THB
Total cost	97,994.00	THB



Figure 1. The overall view of greenhouse building.

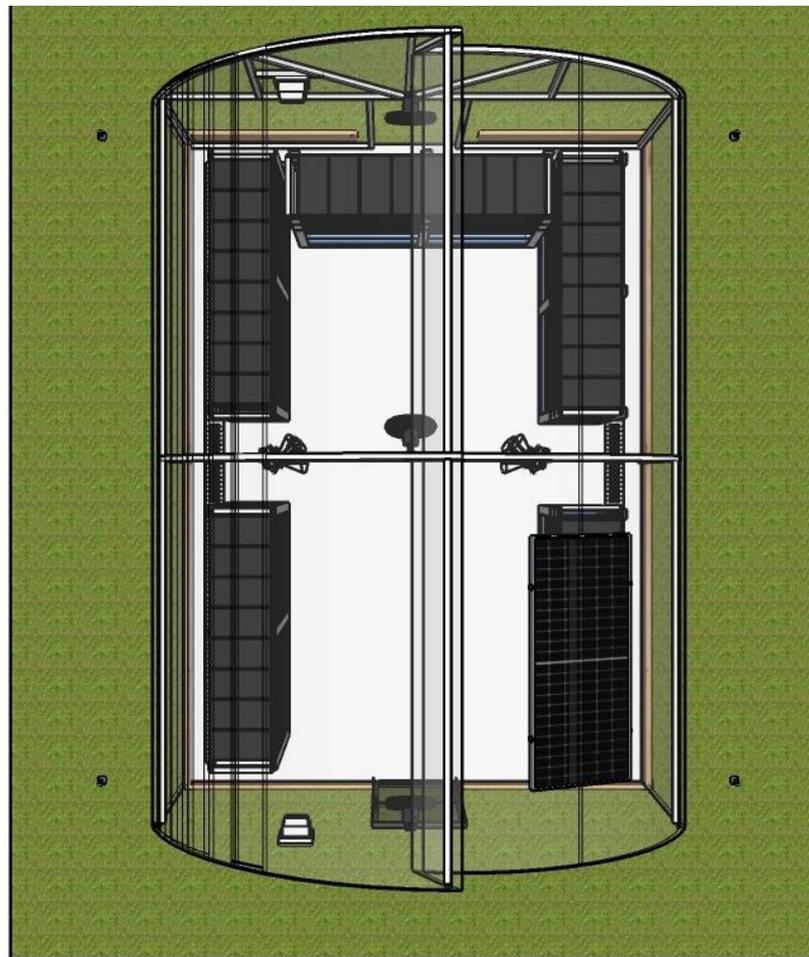


Figure 2. The top view of greenhouse building.



Figure 3. The detail of any materials position within the greenhouse building.



Figure 4. The inside view of greenhouse building.

3.3. Cost-effective analysis

In table 3, the comparison of income among one, three, and seven sunflower greenhouse buildings was calculated. Farmers should receive their wages of approximately 20,000 THB per month while employee wages should not be set lower than 300 THB per day. Profit will overcome total cost when the greenhouse construction is at least of three buildings that will return the net profit 14,666.09 THB with entrepreneurial wages 20,000 THB, then, farmers will gain approximately 34,666.09 THB per month. If farmers extend the size of the building, then, the construction cost may decline approximately 5 to 20% according to reducing of metallic materials and also electrical systems.

Table 3. Cost-effectiveness analysis of sunflower greenhouse farming.

Item	Amount numeric			Unit
Greenhouse building	1.00	3.00	7.00	Building
Cultivation table	5.00	15.00	35.00	Table
Sunflower sprout	160.00	480.00	1,120.00	Tray
Product per cycle (seed weight : sprout weight = 1 : 4)	96.00	288.00	672.00	kg
Transportation charge = 800 THB/cycle, 3 THB/km for gas within 200 km/cycle, car maintenance cost 200 THB/cycle	800.00	2,400.00	5,600.00	THB
Maximum profit per cycle without building cost and maintenance = (net profit/tray x amount of tray) – transportation charge	4,745.19	14,235.56	33,216.30	THB
Maximum profit per year without building cost and maintenance (352 workdays/year, 13 holidays/year)	208,788.15	626,364.44	1,461,517.04	THB
5% damage value per year (ungrowth plant or retardation)	10,439.41	31,318.22	73,075.85	THB
Depreciation of building per year (working life of greenhouse = 7 years)	13,999.14	41,997.43	97,994.00	THB
Electricity charge per year¹ (if use a dual system between solar cell and local electricity)	5,263.00	15,789.00	36,841.00	THB
Employee wages per year = 300 THB/person/day, 13 holidays/year, 1 laborer can manage at least 7 buildings/day	105,600.00	105,600.00	105,600.00	THB
Entrepreneurial wages per year = 20,000 THB/month	240,000.00	240,000.00	240,000.00	THB
Depreciation of instrument per year Container gardening 3,000 THB Cart 6,000 THB Sprout cutting machine 30,000 THB Agricultural instruments 8,000 THB = 47,000 THB/ 3 years (working life of any instruments = 3 years)	15,666.67	15,666.67	15,666.67	THB

Net profit per month	-15,181.67	14,666.09	74,361.63	THB
Net profit per year	-182,180.07	175,993.13	892,339.52	THB

¹ Where: working time = 10 h/day; LED 30W x 10 h x 3 sets/table x 5 tables/building x 30 days/month = 135 kW, then, 135kW x 3.2484 THB/ kW·h = 438 THB/month or 5,263 THB/year.

The low-cost greenhouse model, which is proposed in this paper, can be built immediately. However, the investment fund for grassroots or farmers is the most important challenge in this situation. To overcome this moment, the governments or academic institutes should coach the concept of greenhouse farming, principle of business and e-commerce, proposal writing, and boost up plant entrepreneurs to help them pass the financial institution agreements. Moreover, after farming establishment, they also need to prolong support until they can extend their business up to at least small enterprises to make sure that they can stand solely. After becoming of business strength, high-level technology (e.g. Internet of Things, plant factory, artificial intelligence systems), as well as high agribusiness plant (e.g. medicinal plant, biomaterials) that need high standard protective systems, should be put forward to elevate the business scale to promote agricultural sustainability for a new future.

4. Conclusions

In summary, lockdown policies in many countries have made the collapse of MSMEs during this COVID-19 pandemic. The mobility restrictions have affected multi-sectors and also labor and agricultural systems. This article was developed for helping farmers, grassroots, as well as anyone who lost their job through the plant business using low-cost greenhouse farming. Information within this paper also involves how to select appropriate plants, greenhouse farming prototype, and cost-effectiveness of the number of greenhouse building. The suggestion includes further knowledge and financial supports from the government sectors among farmers. In the future, plant business owners can scale up their firm using high-level technology and also planting high-price agribusiness production. The author hopes this model can generate ideas among many people who have suffered from the economic crisis, and also enhance the local economy to be strong and sustainable.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure 1: the overall view of greenhouse building, Figure 2: The top view of greenhouse building, Figure 3: the detail of any materials position within the greenhouse building, Figure 4: the inside view of greenhouse building, Table 1: comparison of value analysis of sunflower, water spinach, and wheat for one tray per cultivation cycle, Table 2: cost analysis of greenhouse construction, Table 3: cost-effectiveness analysis of sunflower greenhouse farming.

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