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연구논문

Cost-Benefit Analysis of a Smart Greenhouse Facility in Western Visayas (Region VI) and Northern Mindanao (Region X), Philippines

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Abstract

This study analyzed the costs and benefits of establishing a smart greenhouse facility in Iloilo City in Western Visayas and Bukidnon in Northern Mindanao in the Philippines to determine the required investments and possible returns in adopting the technology. Various financial metrics were used to determine

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the technology's profitability. The findings revealed that a substantial initial investment was needed to establish and operate the facility because the materials used to construct its physical structure and the equipment procured are imported. Moreover, the facility's full capacity utilization and benefits had not been fully realized and maximized yet. This resulted in varying degrees of financial feasibility and profitability. Overall, shiitake mushroom cultivation demonstrated financial profitability despite high initial investment costs, while production of honeydew melons, netted melons, strawberries, and cherry tomatoes showed uncertain and potentially unprofitable results. The baseline data developed can be used by project implementers to conduct follow-up project evaluations and return on investment analyses for smart greenhouses. Furthermore, the results of this cost-benefit analysis can help farmers decide whether to invest in smart farms. Finally, the results of this study can be used to craft relevant policies and guidelines to encourage and accelerate the local development and adoption of smart agriculture ICT-based technologies in the Philippines.

Key words: Smart Greenhouse Technology in Korea, Cost Benefit Analysis, Investment Cost of Smart Greenhouse, Profit of Smart Greenhouse, High-Value Crops

Ⅰ. INTRODUCTION

The Philippines is primarily an agricultural country due to its terrain and tropical climate condition. However, a slow growth in this sector is due to many factors including the conversion of arable lands to residential subdivisions and other industrial or commercial areas. Moreover, the country's geographical location makes it particularly susceptible to the adverse effects of climate change and the associated risks of natural disasters. With climate change, agriculture and fisheries are extremely vulnerable. Despite efforts to enhance food production and food security, these gains are threatened by looming losses and damages due to increasing frequency and scale of extreme weather events, such as typhoons, El Niño-related droughts and dry spells, severe flooding, and La Niña, as well as unforeseen impacts resulting from atmospheric changes and other natural disasters, including volcanic eruptions. The consequences of climate change have far-reaching implications, extending to the agricultural and fisheries production systems. These adverse effects not only compromise the overall sustainability of these sectors but also result in annual losses in Gross Domestic Product and a decline in the economic well-being of farmers and fisherfolk (National Agriculture and Fisheries Modernization and Industrialization Plan, 2022: 52).

As a response to these challenges the Philippines Department of Agriculture (DA) makes efforts to modernize and strengthen its sector. One of which is the requested grant aid to the Korean Government for the introduction of the use of smart greenhouse facilities and capacity building.

The first smart greenhouse was established through the project entitled Enhancing Productivity and Producing High Quality Tomato through Smart Greenhouse in the Philippines. This project is a USD 2.43 million grant assistance from the Korean Government through the public private partnership arrangement of the Korea International Cooperation Agency (KOICA), Korea Agency of Education, Promotion and Information Service in Food, Agriculture, Forestry and Fisheries (EPIS) and other Korean private companies with a Government of the Philippines (GOP)/DA counterpart of around USD 1.794 million. This project intends to improve agricultural technology through introduction of development model for horticultural facility by greenhouse cluster farming system with Korean advanced technology and experience. Nine (9) smart greenhouses were established at the DA Bureau of Plant Industry Baguio National Crop Research Development and Production Support

Center in Baguio and ten (10) at the DA Rizal Agricultural Research and Experiment Station in Tanay Rizal (Amended, 2019; Project MOA, 2018).

To further push the development of the smart greenhouse technology in other regions of the country, the DA requested another project entitled Establishment of Smart Greenhouse and Capacity Building in the Philippines. This project is a 3.15 billion Korean Won or approximately USD 2.645 million (PHP 138.07 million) grant assistance from the Korean Government through the Ministry of Agriculture, Food and Rural Affairs (MAFRA) with a GOP/DA counterpart of around USD 0.92 million (PHP 47.971 million). It intends to enhance production competitiveness of small and mid-sized farmers by establishing smart greenhouses with appropriate technologies for value-added agro-products. This was implemented by the DA Regional Field Offices in Western Visayas (DA RFO 6) and Northern Mindanao (DA RFO 10) in partnership with the EPIS until December 2023. Ten (10) smart greenhouses were established at the DA Western Visayas Integrated Agricultural Research Center (WESVIARC) in Hamungaya, Buntatala, Jaro, Iloilo City and eleven (11) at the DA Northern Mindanao Agricultural Crops and Livestock Research Complex (NMACLRC) in Dalwangan, Malaybalay City, Bukidnon. These smart greenhouse facilities served as the learning school for farmers, DA technical staff and researchers in both project sites. Selected farmers are trained on crop production and smart greenhouse operation for the whole cropping season (Project MOA, 2020).

Smart agriculture provides promising and trending technologies to contribute in achieving the overall goals of the Philippines' agriculture sector. The development and implementation of smart greenhouse technology in the country are at the infancy stage and conducting a cost-benefit analysis is a critical undertaking that can contribute to the DA's initiative of introducing this technology to Filipino farmers. Determining the profitability of establishing a smart greenhouse facility can help local farmers in their decision making of adopting the said technology.

Ⅱ. LITERATURE REVIEW

Most cost benefit analysis covers only conventional greenhouse crop production. Some of which only focused on the productivity and prices while others mostly on the advantages and benefits of establishing greenhouses but not directly providing information on its financial viability. There is no literature available yet on the cost benefit analysis for establishing smart greenhouse technology, hence this study will contribute in addressing this gap.

For example, a recent study by Park (2024: 123-124) has been conducted for international development cooperation projects on smart greenhouse for high value crops being carried out in four (4) countries (Philippines, Cambodia, Vietnam and Indonesia) targeting the small to medium scale farmers. For the Philippines, results showed that the productivity of tomatoes increased by more than six times (from 1.4 kg/m^2 in 2020 to 10 kg/m^2 in 2022). The producer sale price of tomatoes also increased from 70 pesos per kilogram to 150 pesos per kilogram. While this has been the case, there is no evidence that shows its financial viability considering that the investment cost for establishing the facility is significant.

Montero et al. (2011: 12-14) on the other hand, compared the economic profiles of the greenhouse production systems in Europe. A multi-tunnel greenhouse tomato production in Spain showed that tangible assets and labor accounted for almost 60% of the total costs. The structure of the greenhouse and other equipment made up almost one-third of the total cost. The variable costs for crop protection and energy were low at 3%–4% while fertilizer constituted about 7% of the total costs. In Hungary, tangible assets, labor, fertilizers and energy contributed 75% of the total costs in a venlo greenhouse for tomatoes. In comparison, the Netherlands' greenhouse production is more capital intensive than those in Hungary and Spain. This is mainly due to greater investments in greenhouse structure, climate control systems and fertigation systems. The total costs mainly depended on natural gas consumption, tangible assets and labor, with energy accounting for about 31% of total costs.

In Alberta Canada, the most significant cost items for greenhouse crop production in the 2017 Report on the costs and returns (Laate, 2018: 7) were labor (hired and operator), material inputs (growing media, seed/cuttings, fertilizer and chemicals, trays, boxes and other packaging materials), marketing and natural gas.

It is expected that greenhouse production offers advantages such as season extension, increased yields, and reduced pesticide use. However, investment costs are substantial, and financial viability remains uncertain. Athearn et al. (2018: 102) analyzed the costs and returns of small-scale greenhouse tomato production in Florida. Results showed that a grower must achieve a USD 2.50/lb average retail price in order to be profitable with a Net Present Value (NPV) of USD 23,517 or an Internal Rate of Return (IRR) of 13%. The most significant cost items are the operation and maintenance of the greenhouse and environmental controls, labor, and energy, which together account for 60% of the total annual costs.

Meanwhile, Oruç & Gözener (2020: 107) showed that tomato production in Antalya Province in Turkey, especially in the greenhouse system, generally provides a return above the expenses. The level of profitability varies significantly.

Ⅲ. RESEARCH OBJECTIVES AND METHODOLOGY

This study is generally aimed at determining the profitability of establishing a smart greenhouse facility through analyzing the projected costs and benefits (or opportunities) of establishing a Smart Greenhouse technology and the profitability for farmers to own or establish their own smart greenhouse.

This research involved a comprehensive review of various Project-related documents. The researcher also assessed the projected costs and benefits of the smart greenhouses through a developed online survey form. The primary data for this analysis were collected from representatives of the DA RFO Western Visayas and Northern Mindanao from 21 November 2023 to 25 March 2024. In addition, online interviews were also conducted to key focal persons of the DA RFO VI Project implementers on 5 March 2024 and of the DA RFO X Project implementers on 6 March 2024, to validate the collected data.

The raw data obtained were processed and analyzed using several financial metrics calculated using Microsoft (MS) Excel:

1) Financial Internal Rate of Return (FIRR) to measure the profitability of an investment. The IRR is the rate that makes the investment's costs and returns equal over time. Based on the IRR rule, an investment is acceptable if the IRR exceeds the required return.
2) Financial Net Present Value (FNPV) to measure how much value is created or added today by undertaking an investment. If the project is economically feasible, its NPV is greater than zero. When the NPV is positive, it means that the benefits of the project are greater than its costs.
3) Benefit-Cost Ratio (BCR) to compare the present value of benefits to the present value of costs to assess the efficiency of an investment. A BCR greater than one (1) indicates that the benefits of the project outweigh the costs, making it a potentially good investment.

4) Return on Investment (ROI) to measure the gain or loss generated relative to the amount of money invested. A positive ROI means that the total gains from an investment exceed the total costs. The higher the ROI, the more desirable the investment.

Financial metrics are calculated in Philippine Pesos (PHP), with conversions to US Dollars (USD) using the average exchange rate for 2023 of PHP 55.6304 to USD 1, as provided by the Bangko Sentral ng Pilipinas.

This study is focused on the established smart greenhouses in Iloilo City, Western Visayas and Malaybalay City, Bukidnon, Northern Mindanao. This is a grant assistance project from the Korean Government that provided all the facilities in kind. Thus, the costs obtained are part of the grant proceeds which may only be an estimation based on the data provided and validations from key persons. There will also be some factors that can affect the production (benefits) figures such as diseases and/or other related production concerns that were not considered due to limited data. Furthermore, this study primarily focuses on the determination of the costs and benefits of the established smart greenhouses and does not undertake analysis on the technology's technical feasibility as well as its impact in the Philippine setting.

Ⅳ. RESULTS AND DISCUSSION

1. Costs of Establishing Smart Greenhouse in WESVIARC

Ten (10) smart greenhouses were established at the WESVIARC project site for the cultivation and training of cherry tomatoes, paprika, honeydew melons, netted melons and shiitake mushrooms. The construction costs of these greenhouse structures vary, ranging from about PHP 1.2 million (USD 21,500) to PHP 3.5 million (USD 62,900), depending on the size and intended purposes. Among these structures, an 844.8 sqm interlocking unit was constructed amounting to PHP 3.5 million (USD 62,900) which is used for the production and training of high value crops such as cherry tomatoes and paprika. Additionally, three (3) single units, varying in size from 273 sqm to 314.6 sqm with construction costs from PHP 800,000.00 (USD 14,000) to PHP 2.4 million (USD 43,000) are used for the production and training of high value crops, including netted melons and honeydew melons (specifically the Jade Lady variety). Moreover, five (5)

185 sqm single units are used for the production and training of mushrooms, while one (1) 273.8 sqm single unit serves as a nursery for mushrooms, equipped with the necessary laboratory tools for preparing mushroom fruiting bags. Its construction costs range from PHP 600,000.00 (USD 10,700) to PHP 1.1 million (USD 19,700) per unit.

For the purpose of this study, the researcher obtained the costs for the establishment of a smart greenhouse for the honeydew melon, netted melon and shiitake mushroom production.

The total investment required to establish a single unit smart greenhouse for honeydew melon and netted melon production in WESVIARC amounts to approximately PHP 5.9 million (USD 106,000). About 66.44% of the total investment is accounted for by the land. Land in Jaro Iloilo City is considered a prime lot with an average cost per square meter of PHP 12,500.00 (USD 220). Accounting for around 20.04% of the total investment or around PHP 1.2 million (USD 21,500) is the greenhouse equipment costs wherein bulk of it comes from the costs of the essential equipment such as computer, control server and solar system for the greenhouse to operate smartly. Representing about 13.52% of the total investment is the costs associated with constructing the physical structure of the greenhouse amounting to PHP 800,000.00 (USD 14,300) (〈Table 1〉).

The estimated average production cost of cultivating honeydew melon and netted melon is approximately PHP 317,295.00 (USD 5,700). The bulk of these costs comprises annual depreciation, accounting for about 45.51%, followed by fertilizer procurement at 17.55% and internet subscription fees at 15.93%. Other input costs include seeds, seedling tray, plastic mulch, decomposed sawdust, vine clipper, trellising vine with hooks, insecticides and fungicides (〈Table 2〉).

The establishment of a smart greenhouse for shiitake mushroom production in WESVIARC requires an investment of approximately PHP 8.9 million (USD 160,000). Similarly, in melon production, the majority of the investment, around 64.11%, is allocated to land acquisition. Approximately PHP 1.7 million (USD 30,500) or 19.23% of the total investment covers the construction of the physical structure of the greenhouses. A larger area is designated for the nursery, which includes an incubation area. Additionally, 16.67% of the total investment or about PHP 1.5 million (USD 27,000) represented the costs of procuring the necessary equipment for the nursery, including the cold storage (〈Table 3〉).

The estimated average production cost of shiitake mushroom cultivation is approximately PHP 842,237.00 (USD 15,100). These costs are primarily composed of utility expenses, with electricity accounting for 52.63%, which is crucial for maintaining the moderate temperatures necessary for optimal mushroom growth. Other input costs include sawdust, rice bran and polypropylene bags (〈Table 4〉).

2. Benefits of Smart Greenhouse Cultivation in WESVIARC

Based on the initial greenhouse operations, the average production per cycle of honeydew melons, netted melons and shiitake mushrooms is 386.7 kg, 388.2 kg, and 623.6 kg, respectively. Currently, honeydew melons are sold at PHP 120.00 (USD 2.16) per kilogram, netted melons at PHP 100.00 (USD 1.80) per kilogram, and shiitake mushrooms at PHP 700.00 (USD 12.58) per kilogram. Melons and mushrooms can be cultivated at two (2) cropping cycles annually in the smart greenhouse facilities (〈Table 5〉).

〈Table 1〉 Identified investment costs of establishing a smart greenhouse facility for the honeydew melon and netted melon production in WESVIARC

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Investment costs				
Land	314.60	sqm	12,500.00	3,932,500.00
Greenhouse structure (single unit)	1	unit	800,000.00	800,000.00
Equipment				1,186,000.00
Irrigation machine	1	unit	50,000.00	50,000.00
Screen motor	1	unit	16,000.00	16,000.00
Control panel	1	unit	120,000.00	120,000.00
Circulating fan	8	unit	2,000.00	16,000.00
Temperature sensor	1	unit	8,000.00	8,000.00
Smart farm system	1	unit	150,000.00	150,000.00
Solar system (10 kwh)	1	unit	300,000.00	300,000.00
Server room	1	unit	34,000.00	34,000.00
Aircon for server room	1	unit	12,000.00	12,000.00
Computer and control servers	1	unit	480,000.00	480,000.00
Total				5,918,500.00

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center.

〈Table 2〉 Estimated production costs (PHP) for 20 years of honeydew melon and netted melon cultivation in the smart greenhouse facility in WESVIARC

Year	Variable costs			Fixed costs		Total
	Labor cost	Fertilizer	Other input cost	Internet	Annual depreciation	
1	23,400	41,030	25,709	37,248	142,740	270,128
2	24,125	42,302	26,506	38,402	142,740	274,077
3	24,873	43,613	27,328	39,593	142,740	278,148
4	25,644	44,966	28,175	40,820	142,740	282,346
5	26,439	46,359	29,048	42,086	142,740	286,674
6	27,258	47,797	29,949	43,390	142,740	291,136
7	28,103	49,278	30,877	44,735	142,740	295,736
8	28,975	50,806	31,835	46,122	142,740	300,479
9	29,873	52,381	32,822	47,552	142,740	305,369
10	30,799	54,005	33,839	49,026	142,740	310,410
11	31,754	55,679	34,888	50,546	146,048	318,917
12	32,738	57,405	35,970	52,113	146,048	324,276
13	33,753	59,185	37,085	53,728	146,048	329,801
14	34,799	61,019	38,234	55,394	146,048	335,497
15	35,878	62,911	39,420	57,111	146,048	341,370
16	36,990	64,861	40,642	58,882	146,048	347,425
17	38,137	66,872	41,902	60,707	146,048	353,668
18	39,319	68,945	43,200	62,589	146,048	360,104
19	40,538	71,082	44,540	64,529	146,048	366,740
20	41,795	73,286	45,920	66,530	146,048	373,581

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center.

〈Table 3〉 Identified investment costs of establishing a smart greenhouse facility for the shiitake mushroom production in WESVIARC

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Investment costs				
Land (growing area)	185	sqm	12,500.00	2,312,500.00
Land (nursery)	273.8	sqm	12,500.00	3,422,500.00
Greenhouse structure (growing area)	1	unit	600,000.00	600,000.00
Greenhouse structure (nursery)	1	unit	1,120,000.00	1,120,000.00
Equipment				1,491,000.00
Electric generator (15 kva)	1	unit	195,000.00	195,000.00
Cold storage	1	unit	160,000.00	160,000.00

〈Table 3〉 Continued

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Mixer	1	unit	400,000.00	400,000.00
Bagger	1	unit	160,000.00	160,000.00
Super boiler	1	unit	200,000.00	200,000.00
Aircon	5	unit	24,000.00	120,000.00
Humidifier	3	unit	5,333.33	16,000.00
Inoculation chamber	1	unit	120,000.00	120,000.00
Autoclave	1	unit	120,000.00	120,000.00
Total				8,946,000.00

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center.

〈Table 4〉 Estimated production costs (PHP) for 20 years of shiitake mushroom cultivation in the smart greenhouse facility in WESVIARC

Year	Variable costs				Fixed cost	Total
	Electricity	Labor cost	Fuel	Other input cost	Annual depreciation	
1	326,611	96,300	24,000	16,200	211,590	674,701
2	336,736	99,285	24,744	16,702	211,590	689,058
3	347,175	102,363	25,511	17,220	211,590	703,859
4	357,938	105,536	26,302	17,754	211,590	719,120
5	369,034	108,808	27,117	18,304	211,590	734,853
6	380,474	112,181	27,958	18,872	211,590	751,074
7	392,268	115,659	28,825	19,457	211,590	767,798
8	404,429	119,244	29,718	20,060	211,590	785,041
9	416,966	122,941	30,639	20,682	211,590	802,818
10	429,892	126,752	31,589	21,323	211,590	821,146
11	443,219	130,681	32,569	21,984	211,590	844,202
12	456,958	134,732	33,578	22,665	211,590	863,684
13	471,124	138,909	34,619	23,368	211,590	883,770
14	485,729	143,215	35,692	24,092	211,590	904,479
15	500,787	147,655	36,799	24,839	211,590	925,829
16	516,311	152,232	37,939	25,609	211,590	947,842
17	532,317	156,951	39,116	26,403	211,590	970,536
18	548,818	161,817	40,328	27,222	211,590	993,935
19	565,832	166,833	41,578	28,065	211,590	1,018,059
20	583,373	172,005	42,867	28,935	211,590	1,042,930

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center.

〈Table 5〉 Average production per cycle in a smart greenhouse facility in WESVIARC

Crops harvested	Quantity per cycle (kg)	Price per kg (PHP)	Total (PHP)
Honeydew melon	386.7	120.00	46,404.00
Netted melon	388.2	100.00	38,820.00
Shiitake mushroom	623.6	700.00	436,520.00

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center.

3. Costs of Establishing Smart Greenhouse in NMACLRC

Eleven (11) smart greenhouses were established at the NMACLRC project site for the cultivation and training of strawberries, cherry tomatoes, lettuce, melon and for research of white potatoes. Among these structures, an 800 sqm interlocking unit was constructed amounting to about PHP 5.7 million (USD 102,000). This has a high-tech smart technology with an irrigation system and climate environment system. Moreover, nine (9) 400 sqm single units with construction cost of about PHP 2.8 million (USD 50,300) per unit are used for the production and training of high value crops. These units have a medium-tech smart technology with fertigation and climate sensor. Some of these greenhouse units are also utilized for the mother plant nurseries, irrigation/control house and storage house with cold storage facility.

For this study, the researcher obtained the costs for the establishment of a smart greenhouse for the strawberry (interlocking unit) and cherry tomato (single unit) production.

The total investment required to establish an interlocking unit smart greenhouse for strawberry production in NMACLRC amounts to approximately PHP 7.2 million (USD 129,000). About 78.76% of the total investment is accounted for construction of the greenhouse physical structure amounting to PHP 5.7 million (USD 102,000). Around 11.45% of the total investment or PHP 824,000.00 (USD 14,800) is spent on greenhouse equipment where bulk of the costs is on essential equipment such as control panel, smart farm system, computer, control server and solar system for the greenhouse to operate smartly. Unlike in Iloilo City, the land acquisition cost in Malaybalay City, Bukidnon is cheaper, about PHP 880.00 (USD 15.82) per square meter (〈Table 6〉).

The estimated average production cost of strawberry cultivation is approximately PHP 667,342.00 (USD 12,000). Similar to honeydew melon and netted melon at WESVIARC, the bulk of these costs, about 49.50% are from annual depreciation.

Approximately, 22.78% of the total production costs are attributed to the procurement of inputs such as growing medium, planting materials, chemicals and fertilizer. Labor payments also account for 21.48% of the total production costs, with a field worker being paid PHP 400.00 (USD 7) per day for six (6) months (〈Table 7〉).

The establishment of a single unit smart greenhouse for cherry tomato production in NMACLRC requires an investment of approximately PHP 3.5 million (USD 62,900). Similarly, in strawberry production, the majority of the investment, around 79.29%, is allocated for the construction of the physical structure of the greenhouse. Procurement of the necessary equipment is approximately PHP 388,000.00 (USD 6,900) or 10.86% of the total investment (〈Table 8〉).

The estimated average production cost for cherry tomatoes cultivation is approximately PHP 455,423.00 (USD 8,200). Similar to strawberry production, the bulk of these costs are attributed to annual depreciation, followed by labor payments, which is about 31.4% of the total. Additionally, about 26.68% of the costs are allocated to the procurement of inputs such as planting materials, chemicals, fertilizers, growing media and other necessary supplies (〈Table 9〉).

4. Benefits of Smart Greenhouse Cultivation in NMACLRC

Based on the initial greenhouse operations, the average production per cycle of strawberries is 478 kg, marketed at PHP 500.00 (USD 9) per kilogram. Further, the single unit greenhouse produces an average of 1,209 kg of cherry tomatoes with a market price of PHP 150.00 (USD 2.70) per kilogram. Both high value crops can be cultivated in two (2) cropping cycles annually in the smart greenhouse facilities (〈Table 10〉).

〈Table 6〉 Identified investment costs of establishing an interconnected smart greenhouse facility for the strawberry production in NMACLRC

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Investment costs				
Land	800	sqm	880.00	704,000.00
Greenhouse structure (interlocking unit)	1	unit	5,667,354.00	5,667,354.00
Equipment				824,000.00
Irrigation machine	1	unit	50,000.00	50,000.00
Screen motor	1	unit	16,000.00	16,000.00

〈Table 6〉 Continued

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Vent motor	4	unit	12,000.00	48,000.00
Control panel	1	unit	120,000.00	120,000.00
Circulating fan (hanging type)	16	unit	2,000.00	32,000.00
Temperature sensor	1	unit	8,000.00	8,000.00
Smart farm system	1	unit	150,000.00	150,000.00
Solar system 10 kwh	1	unit	300,000.00	300,000.00
Computer and control servers	1	unit	100,000.00	100,000.00
Total				7,195,354.00

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex.

〈Table 7〉 Estimated production costs (PHP) for 20 years of strawberry cultivation in the smart greenhouse facility in NMACLRC

Year	Variable costs					Fixed costs				Total
	Water and electricity	Labor cost	Chemicals & fertilizer	Growing media	Other input cost	Inter-net	Routine repair and inspection	Other main-tenance expenses	Annual depre-ciation	
1	14,876	105,600	12,000	80,000	20,000	2,182	3,636	10,000	329,191	577,485
2	15,337	108,874	12,372	82,480	20,620	2,249	3,749	10,310	329,191	585,182
3	15,813	112,249	12,756	85,037	21,259	2,319	3,865	10,630	329,191	593,118
4	16,303	115,728	13,151	87,673	21,918	2,391	3,985	10,959	329,191	601,300
5	16,808	119,316	13,559	90,391	22,598	2,465	4,109	11,299	329,191	609,735
6	17,329	123,015	13,979	93,193	23,298	2,542	4,236	11,649	329,191	618,432
7	17,866	126,828	14,412	96,082	24,020	2,620	4,367	12,010	329,191	627,398
8	18,420	130,760	14,859	99,061	24,765	2,702	4,503	12,383	329,191	636,643
9	18,991	134,813	15,320	102,131	25,533	2,785	4,642	12,766	329,191	646,174
10	19,580	138,993	15,795	105,297	26,324	2,872	4,786	13,162	329,191	656,000
11	20,187	143,301	16,284	108,562	27,140	2,961	4,935	13,570	331,490	668,430
12	20,813	147,744	16,789	111,927	27,982	3,053	5,088	13,991	331,490	678,875
13	21,458	152,324	17,310	115,397	28,849	3,147	5,245	14,425	331,490	689,644
14	22,123	157,046	17,846	118,974	29,744	3,245	5,408	14,872	331,490	700,747
15	22,809	161,914	18,399	122,662	30,666	3,345	5,576	15,333	331,490	712,194
16	23,516	166,934	18,970	126,465	31,616	3,449	5,748	15,808	331,490	723,996
17	24,245	172,109	19,558	130,385	32,596	3,556	5,927	16,298	331,490	736,164
18	24,997	177,444	20,164	134,427	33,607	3,666	6,110	16,803	331,490	748,709
19	25,772	182,945	20,789	138,594	34,649	3,780	6,300	17,324	331,490	761,642
20	26,571	188,616	21,434	142,891	35,723	3,897	6,495	17,861	331,490	774,977

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex.

〈Table 8〉 Identified investment costs of establishing a single unit smart greenhouse facility for the cherry tomato production in NMACLRC

Particulars	Quantity	Unit	Unit cost (PHP)	Total cost (PHP)
Investment costs				
Land	400	sqm	880.00	352,000.00
Greenhouse structure (single unit)	1	unit	2,833,677.00	2,833,677.00
Equipment				388,000.00
Irrigation machine	1	unit	200,000.00	200,000.00
Screen motor	1	unit	16,000.00	16,000.00
Vent motor	2	unit	12,000.00	24,000.00
Control panel	1	unit	120,000.00	120,000.00
Side fan	10	unit	2,000.00	20,000.00
Temperature sensor	1	unit	8,000.00	8,000.00
Total				3,573,677.00

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex.

〈Table 9〉 Estimated production costs (PHP) for 20 years of cherry tomato cultivation in the smart greenhouse facility in NMACLRC

Year	Variable costs					Fixed costs				Total
	Water and electricity	Labor cost	Chemicals & fertilizer	Growing media	Other input cost	Inter-net	Routine repair and inspection	Other main-tenance expenses	Annual depre-ciation	
1	7,438	105,600	6,000	40,000	43,520	1,091	1,818	10,000	162,435	377,903
2	7,669	108,874	6,186	41,240	44,869	1,125	1,875	10,310	162,435	384,582
3	7,906	112,249	6,378	42,518	46,260	1,160	1,933	10,630	162,435	391,469
4	8,151	115,728	6,575	43,837	47,694	1,196	1,993	10,959	162,435	398,569
5	8,404	119,316	6,779	45,195	49,173	1,233	2,054	11,299	162,435	405,889
6	8,665	123,015	6,989	46,597	50,697	1,271	2,118	11,649	162,435	413,436
7	8,933	126,828	7,206	48,041	52,269	1,310	2,184	12,010	162,435	421,217
8	9,210	130,760	7,430	49,530	53,889	1,351	2,251	12,383	162,435	429,239
9	9,496	134,813	7,660	51,066	55,559	1,393	2,321	12,766	162,435	437,510
10	9,790	138,993	7,897	52,649	57,282	1,436	2,393	13,162	162,435	446,037
11	10,094	143,301	8,142	54,281	59,058	1,480	2,467	13,570	163,518	455,911
12	10,406	147,744	8,395	55,964	60,888	1,526	2,544	13,991	163,518	464,976
13	10,729	152,324	8,655	57,698	62,776	1,574	2,623	14,425	163,518	474,321
14	11,062	157,046	8,923	59,487	64,722	1,622	2,704	14,872	163,518	483,956
15	11,405	161,914	9,200	61,331	66,728	1,673	2,788	15,333	163,518	493,889

〈Table 9〉 Continued

Year	Variable costs					Fixed costs				Total
	Water and electricity	Labor cost	Chemicals & fertilizer	Growing media	Other input cost	Inter-net	Routine repair and inspection	Other main-tenance expenses	Annual depre-ciation	
16	11,758	166,934	9,485	63,232	68,797	1,725	2,874	15,808	163,518	504,131
17	12,123	172,109	9,779	65,193	70,930	1,778	2,963	16,298	163,518	514,690
18	12,498	177,444	10,082	67,214	73,128	1,833	3,055	16,803	163,518	525,576
19	12,886	182,945	10,395	69,297	75,395	1,890	3,150	17,324	163,518	536,800
20	13,285	188,616	10,717	71,445	77,733	1,948	3,248	17,861	163,518	548,372

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex.

〈Table 10〉 Average production per cycle in a smart greenhouse facility in NMACLRC

Crops harvested	Quantity per cycle (kg)	Price per kg (PHP)	Total (PHP)
Strawberry	478.0	500.00	239,000.00
Cherry tomato	1,209.5	150.00	181,425.00

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex.

5. Financial Feasibility Indicators of WESVIARC

The analysis was calculated over 20 years with the weighted average cost of capital or WACC computed at 6.05%.

The negative FIRR indicates that melon production is financially not viable, as it is expected to lose value over time. It signifies that the returns are not sufficient to cover the initial investment. The substantial negative FNPV corroborates the negative FIRR, reinforcing that the project is expected to result in a significant financial loss. Further, a BCR less than one (1) signifies that the costs outweigh its benefits. This further confirms that it is financially not feasible, suggesting that it does not provide sufficient value to justify the investment. Despite the modest ROI of 2.75%, the negative FIRR and FNPV and the low BCR indicate that melon production is not financially feasible when accounting for the time value of money and overall cost-benefit analysis. Moreover, the researcher was not able to compute its payback period over the 20 years. Same scenario was shown in the sensitivity analysis, wherein it is more likely that it will not withstand changes under more challenging conditions: (a) increased in expense; and, (b) decreased in revenue (〈Table 11〉).

In contrast to the melon production, producing shiitake mushroom in a smart greenhouse facility shows positive financial feasibility with an FIRR of 19%. This suggests that it expects a return of 19% higher than the cost of capital, indicating a robust profitability. Along with its positive FNPV of 27,380,670.20 reflecting a healthy surplus after covering all costs. Furthermore, a BCR of 2.82 which is greater than one (1) signifies that its benefits outweigh its costs, confirming its feasibility and attractiveness. An ROI of 48.33% also implies that for every peso invested, shiitake mushroom production is expected to generate a return of PHP 48.33, showcasing excellent profitability. The researcher also computed its payback period to about nine (9) years. On the other hand, the shiitake mushroom production is not sensitive to various shocks/uncertainties based on the result of the sensitivity analysis showing positive values (〈Table 12〉).

〈Table 11〉 Results of the financial analysis of honeydew melon and netted melon production in WESVIARC

	Base scenario	Increase in expense		Decrease in revenue	
		+5%	+10%	-5%	-10%
FIRR	-4%	-5%	-5%	-5%	-6%
FNPV	(4,392,051.65)	(4,813,099.05)	(5,234,146.45)	(4,593,496.47)	(4,794,941.29)
BCR	0.51	0.48	0.46	0.48	0.46
ROI	2.75%	2.43%	2.14%	2.41%	2.08%

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center; FIRR, Financial Internal Rate of Return; FNPV, Financial Net Present Value; BCR, Benefit-Cost Ratio; ROI; Return on Investment.

〈Table 12〉 Results of the financial analysis of shiitake mushroom production in WESVIARC

	Base scenario	Increase in expense		Decrease in revenue	
		+5%	+10%	-5%	-10%
FIRR	19%	18%	17%	18%	17%
FNPV	27,380,670.20	26,554,683.49	25,728,696.78	25,185,649.98	22,990,629.76
BCR	2.82	2.68	2.56	2.68	2.54
ROI	48.33%	45.65%	43.22%	45.52%	42.71%

Note: WESVIARC, Western Visayas Integrated Agricultural Research Center; FIRR, Financial Internal Rate of Return; FNPV, Financial Net Present Value; BCR, Benefit-Cost Ratio; ROI; Return on Investment.

6. Financial Feasibility Indicators of NMACLRC

For the strawberry production, all the provided financial metrics shows a weak financial viability. The FIRR of 1% suggests that the returns are minimal and likely insufficient to cover the cost of capital. The negative FNPV shows that it will generate significant net loss. The BCR of 0.76 further indicates that for every peso invested, it will generate only PHP 0.76 in benefits which signifies that it is not financially viable. While a positive ROI of 5.81% indicates some level of profitability, it is still relatively low and might not be sufficient to justify the investment, especially when considering the low FIRR, negative FNPV and low BCR and a payback period of about 19 years (〈Table 13〉).

A similar scenario with the strawberry production was generated for the cherry tomato production. The low FIRR and ROI, combined with the negative FNPV and low BCR, suggest that the cherry tomato production is not expected to generate sufficient returns to justify the investment (〈Table 14〉).

〈Table 13〉 Results of the financial analysis of strawberry production in NMACLRC

	Base scenario	Increase in expense		Decrease in revenue	
		+5%	+10%	-5%	-10%
FIRR	1%	0%	0%	0%	0%
FNPV	(3,226,218.65)	(3,789,681.48)	(4,353,144.31)	(3,628,370.55)	(4,030,522.45)
BCR	0.76	0.72	0.69	0.72	0.68
ROI	5.81%	5.28%	4.80%	5.25%	4.70%

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex; FIRR, Financial Internal Rate of Return; FNPV, Financial Net Present Value; BCR, Benefit-Cost Ratio; ROI; Return on Investment.

〈Table 14〉 Results of the financial analysis of cherry tomato production in NMACLRC

	Base scenario	Increase in expense		Decrease in revenue	
		+5%	+10%	-5%	-10%
FIRR	1%	0%	-1%	0%	-1%
FNPV	(1,390,379.35)	(1,736,993.59)	(2,083,607.83)	(1,667,474.62)	(1,944,569.89)
BCR	0.85	0.81	0.77	0.81	0.76
ROI	5.95%	5.25%	4.62%	5.22%	4.48%

Note: NMACLRC, Northern Mindanao Agricultural Crops and Livestock Research Complex; FIRR, Financial Internal Rate of Return; FNPV, Financial Net Present Value; BCR, Benefit-Cost Ratio; ROI; Return on Investment.

V. CONCLUSION AND RECOMMENDATION

1. Conclusion

The establishment of smart greenhouses in the Philippines is one of the Department of Agriculture's initiatives to modernize and transform the agriculture sector into a technology-based, advanced and competitive industry. While this technology may be promising for Filipino farmers, it is still at its infancy stage and there are numerous considerations still needed to look into.

This study is aimed at assessing the projected costs and benefits of adopting smart greenhouse technology and evaluating its profitability. The costs associated with setting up smart greenhouses can vary widely depending on several factors, including the size of the greenhouse, the level of automation and technology integration, geographic location, and the specific requirements of the crops being cultivated. The findings highlighted the significant initial investment needed to establish these facilities for cultivating high-value crops such as honeydew melons, netted melons, shiitake mushrooms, strawberries, and cherry tomatoes. The cost of land is a significant portion of the total investment for smart greenhouses, especially in WESVIARC. Investments in greenhouse equipment and the physical structure also make up substantial parts of the total costs. Technologies such as smart systems also represent crucial but costly investments. It is worth mentioning that both the materials used in building the physical structures of the greenhouses and the equipment procured are imported, which contributes to the considerable investment expenses. In addition, annual depreciation represents a significant portion of the total production costs, indicating substantial initial capital investments. Labor and input costs (like seeds, fertilizers, and growing media) also form a considerable part of the production costs across all examined crops. Investment and production cost also varies across countries, even in terms of distribution across the cost items. The Philippines' bulk of investment for tomato production is on construction of the physical structure of the greenhouse while in Spain and Hungary is on tangible assets and labor. In terms of production costs, the Philippines spends the highest on inputs and labor compared to Hungary where the highest spending is on fertilizers and energy.

Moreover, the operation of these smart greenhouses has experienced delays and challenges, resulting in their full capacity utilization and benefits not yet being fully realized and maximized. The Project implementers are also exploring alternative ways to further maximize its potential benefits and impact on productivity and sustainability. Despite this uncertainty regarding its potential for high yields, the ability to cultivate multiple cropping cycles annually and/or continuous year-round harvest presents promising opportunities for its future optimization.

Not realizing the facilities maximum benefits had a notable impact on the outcomes of the financial analysis conducted in this study. The financial analyses shows a big difference in the viability of all examined crops. Melon production, as indicated by the negative FIRR and FNPV and a BCR of less than one, is not financially viable. In contrast, shiitake mushroom production demonstrates a robust financial profile with a high FIRR of 19%, a positive FNPV, and a BCR of 2.82. This indicates strong profitability, substantial returns over costs, and a payback period of nine years. Strawberry and cherry tomato productions exhibit weak financial metrics similar to melon production, with low FIRRs, significant net losses (negative FNPVs), and BCRs below one. These indicators suggest that the returns from these crops are insufficient to cover the costs and investment risks, with long payback periods further diminishing their attractiveness.

2. Recommendation

Based on the findings of this study, the following initiatives are recommended that could be applied:

1) To improve profitability, use of locally sourced materials and machineries and equipment is recommended instead of imported. This will greatly improve the viability of the establishment of greenhouses by significantly reducing investment costs. It is also best to conduct continuous study to optimize the use of inputs (like fertilizers and pesticides) and labor to reduce production costs. The use of this cost-benefit analysis (with already established parameters in this paper) will further help in attaining profitability through maximizing production with the least cost;
2) The baseline data developed can be used as basis for Project implementers in conducting follow-up project evaluations and return on investment analysis in smart greenhouse facilities;

3) Use the result of this cost-benefit analysis to aid in the decision making of the farmers whether to invest in smart farms and in the future help them decide on what crop combinations will provide the best and sustained profit. This is because, part of the GOP/DA obligations in this smart greenhouse Project is to convince local farmers to adopt smart greenhouse technology for commercial production and link them to the Department's funding facility. The high investment requirement may compel the Government to build the facility and allow interested farmers to pay the reasonable rent or a shared service facility where the Government build the facility and will be offered to farmers for its operation and maintenance; and,
4) Lastly, use the result of this study in crafting relevant policies and guidelines in order to encourage and accelerate the local development and adoption of smart agriculture ICT-based technologies in the Philippines.

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