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Protected Cultivation with Drip Fertigation Is a Feasible Option for Growing High-Value Vegetables in Samoa: A Case Study

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Abstract

Protected structures with drip fertigation systems have allowed many countries around the world to grow high-value vegetables, such as tomatoes and bell peppers year round, particularly under adverse edaphoclimatic conditions. This paper evaluates the feasibility of tomato and bell pepper cultivation in Sunshine Pacific Limited. Farm in Tanumalala, a commercial farm in Samoa, under a protected cultivation system with drip fertigation. The yield, water use efficiency, establishment and maintenance costs, and the average return per hectare of production were analyzed. Additionally, economic feasibility indicators were estimated using the discount factors of 6.5% and 11%. Results showed that the annual yield of tomatoes (163,500 kg/ha) was higher than bell peppers (103,500 kg/ha). The water use efficiency (WUE) and product water use (PWU) of these two crops in this study were less efficient compared to what was observed in other countries, as indicated by the value of the respective WUE and PWU: 8.38 kg/m^3 and 0.12 m^3/kg for tomatoes while 5.31 kg/m^3 and 0.19 m^3/kg for capsicum. Despite the high initial establishment cost, all economic feasibility parameters indicated that the system is profitable, having a BCR ratio of more than 2, and feasible under Samoa conditions, mostly due to the high market price. Thus, this system of cultivation could be an option for growing high-value vegetables in Samoa. However, further research is needed to improve the yield and water use efficiency.

Keywords: protected structure; drip fertigation; economic feasibility; tomato; bell pepper

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1. Introduction

Agricultural production in Pacific Island Countries and Territories (PICTs) such as Samoa is limited by several factors, including space, climate, pests and diseases, and cost of production, while demand for food is increasing due to a growing population [1,2]. Only 27% of the total land area in Samoa was used for agriculture in 2015, or about 106,423 acres in 2019 [3]. The recent Samoa Agriculture Census recorded an increase in the production of taro, ta'amu, yam, banana, and breadfruit, while a decrease in vegetable production, such as cabbage and tomatoes. Thus, Samoa, like most other PICTs, relies on imported foods, including high-value vegetables such as tomatoes and bell peppers, among other products [2–5]. Understandably, imported goods are expensive. However, it also poses other serious threats to the importing countries, such as biosecurity issues [6], including plant pests and diseases. For instance, diseases such as Pepino mosaic virus (PepMV) and potato spindle tuber viroid were detected in tomato plants at commercial tomato-growing greenhouse facilities in New Zealand in 2021 and 2023, respectively [7,8], posing threats to Samoa's small but thriving tomato farms. Additional port measures were implemented to mitigate this threat, requiring new technology [9] and experts to detect and prevent exotic pests and diseases from entering. However, the small Pacific Island countries and territories often lack the necessary experts and resources. Additionally, in 2020, the COVID-19 pandemic forced border closures to prevent the spread of the virus, including Samoa, although its first case was not recorded until 2022 [10]. The pandemic severely impacted imported agricultural products, such as fruits and vegetables, which rely on air freight. The air freight capacity drastically decreased, while freight costs increased due to the cessation of flights [11] carrying tourists in the country, increasing the prices of these commodities.

This biosecurity threat and supply shortage can be minimized to some extent by locally producing these high-value vegetables. Cultivation of high-value crops in protected structures with drip fertigation presents a potential solution to mitigate such challenges in PICTs. The protected structure is designed to modify the environment in which plants are grown, such as greenhouses, screen houses, and tunnel houses [12]. It is also known to increase crop yield and quality by altering the environment [13,14]. In the case of Samoa, a protected structure could protect the plants from unfavorable weather conditions, particularly during the wet season. It is used in many countries to grow crops with improved quality out of season [15]. This allows year-round production and a steady supply of high-value crops in the market. This system of vegetable cultivation is well-established and popular in countries where agricultural land is limited and weather conditions are challenging. The Netherlands is recognized as the matriarch of the greenhouse industry, with approximately 12,000 ha. England has around 400 ha, Canada approximately 800–1000 ha, Australia about 1000 ha, and the largest in Spain, with approximately 40,000 ha [16]. In Samoa, the Australian Centre for International Agricultural Research (ACIAR) introduced protected structures in 2010 to allow farmers to grow high-value vegetables all year round. The design was tailored for warm conditions and used wood to lower costs [17]. In 2022, the Samoa–China Agricultural Technical Aid Project (SCATAP) distributed 200 protected structures to farmers intending to stabilize vegetable supplies and prices in Samoa [18].

Drip irrigation or fertigation systems, particularly for soilless cultivation, are commonly used in protected structures. Studies have shown that drip fertigation increases water and nitrogen use efficiency while reducing nitrogen leaching and over-fertilization compared to conventional flood irrigation systems [19,20]. It is an efficient way to attain a 12% yield increase, 26.4% water productivity, and 34.3% NUE [20]. It also decreased irrigation water input for tomatoes by 20% and nitrogen input by 21% [20]. Despite the information that protected structures with drip fertigation offer a considerable solution to the challenges of limited space, scarcity of labor, high market price, and high demand for these high-value crops in Samoa, the profitability and sustainability of such cultivation remain a challenge. No comprehensive research on the profitability, sustainability, and water use efficiency of growing vegetables under protected structures with drip fertigation has been conducted under Samoan socio-economic and climatic conditions. Thus, this study was conducted to determine the yield potential, water use efficiency, and economic feasibility of growing 'Heat Master' tomatoes and 'California Wonder' bell peppers, under a protected structure with a drip fertigation system in prevailing weather and socio-economic conditions of Samoa.

2. Materials and Methods

The study was conducted at Sunshine Pacific Limited Farm in Tanumalala, Samoa (Latitude: 13°53′34.22″ S, Longitude: 171°56′31.86″ W). It belongs to tropical weather, with an annual average temperature of 27.8 ± 1.04 °C and total yearly rainfall between 2986 and

4171 mm (Figure 1). In Samoa, April to October is comparatively cooler with less rainfall, called the dry season, while the rest of the period (November to March) is the wet season.

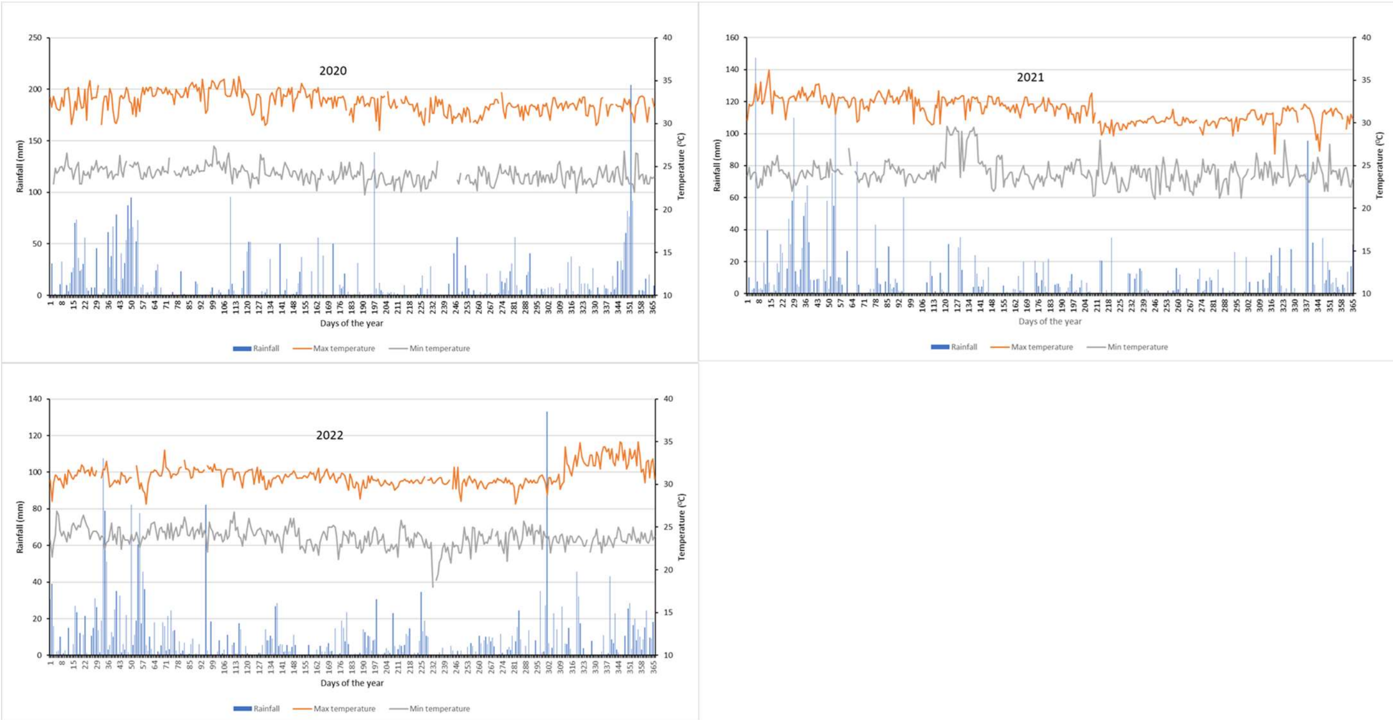

Figure 1. Annual average temperature and rainfall from 2020 to 2022 in Samoa [21].

Transplanting of seedlings was done in March 2020, and harvesting commenced in June 2020. Hybrid seeds of 'Heat Master' tomato and 'California Wonder' bell pepper were grown in semi-open protected structures following good agricultural practices while keeping the whole area pesticide-free. Seeds were germinated in trays using rock wool. Trays were kept in the nursery and watered regularly until the seeds had germinated. Seedlings at 20–25 days for tomato and 30–35 days for bell pepper were transplanted to the Coco coir grow slabs. Tomatoes and bell peppers were grown on Coco coir grow slabs (Brown Grow, Universal Solar). The planting distance for tomato and bell pepper plants was 25 cm × 100 cm in 12 rows × 25 grow bags × 4 plants per grow bag, with 1200 plants per 18 m × 28 m greenhouse. Coco coir was replaced after three crop cycles of 120 days. Water and nutrients were managed by an automated open-drip fertigation system, with an irrigation controller, fertilizer dispenser, fertilizer tanks, filters, tubes, and emitters. Each emitter, having a discharge rate of 3 L h^{-1}, was placed at the root system of each plant. The irrigation schedule was automatically controlled by a controller (Hunter, Pro-C, Hunter Industries, Tijuana, Mexico, which ran for two minutes during the first 2/3 weeks and then three to five minutes on its 4th week onward at eight to ten cycles daily. A pre-mix fertilizer was used with an NPK ratio of 9:1.5:17 (Pure Hydroponics, Ltd., Rotorua, New Zealand). The fertilizer dispenser (Bluelab, PeriPod L3, Bluelab Corporation Limited, Tauranga, New Zealand) maintained the nutrient concentration and pH of the irrigation water.

The yield in kilograms was recorded every harvest time to determine the yield potential of tomatoes (*S. lycopersicum*) and bell peppers (*C. annuum*) grown in a protected structure under a drip-fertigation system. Only marketable fruits were considered in this study. The gross returns were calculated by multiplying the total production of tomatoes and bell peppers by the respective prices received. The average market price used in this analysis from 2020 to 2022 for tomato and bell pepper was 9 WST/kg and 16 WST/kg, respectively. The net returns were calculated by subtracting the gross returns from total production costs. The water use of this system of cultivation was also evaluated by calculating the Water Use Efficiency (WUE, kg/m^3) and Product Water Use (PWU, m^3/kg), using the equations below [22,23].

$$WUE = \frac{Y}{I}$$

where Y is the yield of fresh fruits (kg ha^{-1}), and I is the amount of irrigation water (m^3 ha^{-1}).

$$PWU = \frac{I}{Y}$$

where I is the amount of irrigation water (m^3 ha^{-1}), and Y is the yield of fresh fruits (kg ha^{-1}).

We conducted business analyses to determine the profitability of growing tomatoes (*S. lycopersicum*) and bell peppers (*C. annuum*) under a protected structure with a drip-fertigation system. All analyses were based on the actual costs incurred by the farm and were classified into fixed and variable costs. Land rates and interest rates on fixed and working capital were based on the prevailing rents (4400 WST/ha/year) and rates (11%) in Samoa. The labor was credited according to the actual wage rates given by the farm. The cost of purchased planting materials, fertilizers, and other farming inputs was based on the actual cost paid by the farm. Irrigation and electricity were calculated based on the cost incurred. Pay Back Period (*PBP*), Net Present Value/Worth (*NPV*), Benefit Cost Ratio (*BCR*), and Internal Rate of Return (*IRR*) were used to evaluate the feasibility of growing tomato (*S. lycopersicum*) and bell pepper (*C. annuum*) under protected structure with drip fertigation system for one hectare greenhouse structure in a commercial farm. A projected lifespan of six years was assumed for both the greenhouse and equipment for the drip fertigation system to estimate the depreciation costs of the greenhouse structure. Depreciation was calculated using the equation below.

$$D = (I - S) \div N$$

where D is the depreciation, I is the initial cost of the asset, S is the junk/salvage value, and N is the expected life of the asset.

Payback Period (*PBP*) is considered the time required for the project to pay for itself. This will be performed by successively deducting the initial investment from the net returns until the initial investment is fully recovered using the following formula below.

$$PBP = \frac{E}{I}$$

where PBP is the payback period, I is the initial investment, and E is the sum of the projected net cash flow per year from the investment.

The Net Present Value/Worth (*NPV*) criterion states that investments in greenhouses and equipment for drip-fertigation systems can be considered economically viable if the present value of benefits is greater than the present value of costs [24].

$$NPV = \sum_{t=1}^{n} \left(\frac{Bt}{(1+r)t} - INV \right)$$

where INV is the initial investment, and in the case of a series of investments remade over the years, the present value of such costs [$\sum \frac{Ct}{(1+r)t}$] should be computed and used. B_t is the cash flow at the end of the year t, n is the life of the project, and r is the appropriate discount rate. Since the *BCR* and *NPV* are linked together, the former was obtained by dividing the present worth of the benefit stream by that of the cost stream, which was determined by following the formula below.

$$BCR = \frac{\Sigma \frac{Bt}{(1+r)t}}{\Sigma \frac{Ct}{(1+r)t}}$$

If the *BCR* is >1, then the investment in greenhouses and equipment for the drip fertigation system can be considered economically viable, indicating that the *NPV* of the benefit stream is higher than that of the cost stream.

On the other hand, the *IRR* is the discount rate that makes the *NPV* of the cash flow zero and was determined following the formula below.

$$IRR = \Sigma \frac{Bt}{(1+r)t} - \Sigma \frac{Ct}{(1+r)t} = 0$$

The project with an *IRR* greater than the cost of capital should be selected.

A sensitivity analysis was conducted to assess how changes in variable costs, such as labor and materials, affect the different economic indicators. We assumed a 10% and 15% increase, and the resulting net cash flows were discounted using an 11% discount factor.

3. Results

3.1. Crop Yield and Water Use Efficiency

The annual yield in kilograms per hectare and the water use of tomato and bell pepper grown in a protected structure with a drip fertigation system are calculated and presented in Table 1. The average yield of tomatoes was recorded at 163,500 kg/ha per year during the 2020–2022 production period, while the bell pepper yield was lower at 103,500 kg/ha per year. The water use efficiency (WUE) of these two crops showed an opposite trend, having a higher WUE for tomato (8.38 kg/m^3) than bell pepper (5.31 kg/m^3). Generally, between tomatoes and bell peppers, the former recorded a higher yield and required less water (120 vs. 190 L) to produce one kg of fresh fruit weight compared to the latter.

Table 1. Annual yield per hectare of tomato and bell pepper, water use efficiency (WUE), and Product Water Use (PWU) under protected cultivation based on the 2020–2022 production.

Crop	Yield (kg/ha)	WUE (kg/m^3)	PWU (m^3/kg)
Tomato	163,500 ± 42	8.38 ± 0.42	0.12 ± 0.02
Bell Pepper	103,500 ± 31	5.31 ± 0.34	0.19 ± 0.03

3.2. Economics of Protected Structure with Drip Fertigation System

Growing vegetables, such as tomatoes and bell peppers, in a protected structure with drip fertigation is a capital-intensive technology that needs a sizeable initial investment. Table 2 shows the establishment cost for a one-hectare greenhouse structure in Samoa. The total establishment cost for both crops was 1,502,609 WST for each. Almost half of this cost (42.25%) went to the greenhouse structure, which includes materials and installation costs; 38.40% was allocated to the drip fertigation equipment; and 8.03% and 11.32% were spent on crop establishment and maintenance costs, respectively.

Table 2. Crop-wise establishment cost of protected structure with drip fertigation in growing tomatoes and bell pepper for a 1-hectare greenhouse structure in Samoa.

	Amount (WST)	% Total
1. Greenhouse structure	634,920	42.25
2. Drip fertigation equipment	576,995	38.40
3. Crop Establishment/Land Development	120,655	8.03
4. Maintenance cost (1st Year Crop cycle 1)	170,039	11.32
5. Total establishment cost	1,502,609	100.00

The maintenance cost of growing tomatoes and bell peppers in a protected structure with drip fertigation is shown in Table 3. In each year, crops were grown using the same Coco coir grow slabs for more than one cycle, two (2) cycles in Year 1, and three (3) cycles thereafter. Considering two cycles of tomato in Year 1, the fixed and variable costs were 40,888 WST (8.63) and 432,936 WST (91.37%), with a total maintenance cost of 473,824 WST. The return was 832,000 WST, and the net return was 358,176 WST. However, in Years 2 to 6 with three cycles, the net returns increased by almost double. The variable cost increased to 738,690 WST (94.76%), but gross returns also increased to 1,427,225 WST, resulting in a net return of 647,647 WST. A similar trend was observed for bell peppers, with an increase in variable cost from Year 1 (417,104 WST) to Year 2 (714,941 WST) and net returns of 462,884 WST and 673,547 WST, respectively. This is slightly higher than in tomatoes.

Table 3. Estimated crop-wise total maintenance costs in WST (Year 1–Two Cycles and Year 2 to 6–Three cycles) returns of growing high-value vegetables under a protected structure with drip fertigation for a one-hectare greenhouse structure in Samoa.

Cost/Return Components	Tomato (Amount in WST)				Bell Pepper (Amount in WST)			
	Year One (Two Cycles)	%	Year Two to Six (Three Cycles)	%	Year One (Two Cycles)	%	Year Two to Six (Three Cycles)	%
Fixed Cost	40,888	8.63	40,888	5.24	40,712	8.89	40,712	5.39
Variable Cost	432,936	91.37	738,690	94.76	417,104	91.11	714,941	94.61
Total Cost	473,824	-	779,578	-	457,816	-	782,653	-
Returns	832,000	-	1,427,225	-	920,700	-	1,456,200	-
Net Return	358,176	-	647,647	-	462,884	-	673,547	-

3.3. Feasibility Analysis of Protected Structure Cultivation of High-Value Crops

Table 4 shows the cash flow from growing both crops in a one-hectare protected structure with drip fertigation for 6 years. During years two to six, the estimated cash inflows from bell pepper production were slightly higher (1,456,200 WST) compared to the cash inflows from tomato production (1,427,225 WST). During year one, the estimated cash outflows from bell pepper production were also observed slightly lower (457,816 WST) than from tomato production (473,824 WST). The net cash flows (WST) in Year 1 from bell pepper and tomato were observed as 998,385 WST and 953,401 WST, respectively. During years 2 to 6, cash outflows increase in both crops, amounting to 755,653 WST in bell pepper and 779,578 WST in tomato production. With this change in years 2 to 6, the net cash flows decreased to 700,547 WST from bell pepper and to 647,647 WST from tomato. During six years of production, the average net cash flow from bell pepper and tomato was estimated as 750,187 WST and 698,606 WST, respectively. Tomato production using a protected structure with drip fertigation attracted slightly more cost than that of bell pepper.

Table 4. Cash flow from growing tomatoes and bell peppers in a one-hectare protected structure with drip fertigation in Samoa for six years.

SI. No.	Bell Pepper			Tomato		
	Cash Inflow	Cash Outflow	Net Cash Flow	Cash Inflow	Cash Outflow	Net Cash Flow
1	1,456,200	457,816	998,385	1,427,225	473,824	953,401
2	1,456,200	755,653	700,547	1,427,225	779,578	647,647
3	1,456,200	755,653	700,547	1,427,225	779,578	647,647
4	1,456,200	755,653	700,547	1,427,225	779,578	647,647
5	1,456,200	755,653	700,547	1,427,225	779,578	647,647
6	1,456,200	755,653	700,547	1,427,225	779,578	647,647
Total	8,737,200	4,236,078	4,501,122	8,563,350	4,371,714	4,191,634
Ave.			750,187			698,606

Economic feasibility indicators, such as NPV, BCR, IRR, and PP, were calculated for both crops (Table 5). The net cash flows were discounted using 6.5% and 11% discount factors. Analysis shows that growing capsicum and tomato in a protected structure with drip fertigation is economically feasible and profitable. This technology is capital-intensive; thus, it requires a huge investment. Using the prevailing bank interest rate in Samoa at 6.5%, the net present value (NPV) for the six years of growing bell pepper was observed as 2,175,012 WST with a benefit-cost ratio (BCR) of 2.44, while the NPV of tomato was observed to be relatively lower at 1,925,888 WST with a BCR of 2.28. Even at a higher discount factor of 11%, growing bell pepper and tomato in protected structures with drip fertigation remained economically feasible and profitable, although the values have reduced. The NPV for six years of growing bell pepper at an 11% is 1,721,755 WST, with a BCR of 2.14. For tomatoes, the NPV at 11% for six years was 1,505,638 WST, with a BCR of 2. The IRR in bell peppers was slightly higher at 11.9% compared to tomatoes at 11.86%. Both crops are expected to have an IRR of more than the set discount factor of 11%.

Table 5. Economic feasibility of growing tomato and bell pepper in a one-hectare protected structure under drip fertigation in six years.

SI No.	DF (6.5%)	Present Value (WST)		DF (11%)	Present Value (WST)	
		Bell Pepper	Tomato		Bell Pepper	Tomato
1	0.94	938,482	896,197	0.90	898,546	858,061
2	0.88	616,481	569,929	0.81	567,443	524,594
3	0.83	581,454	537,547	0.73	511,400	472,782
4	0.78	546,427	505,165	0.66	462,361	427,447
5	0.73	511,399	472,782	0.59	413,323	382,112
6	0.69	483,377	446,876	0.53	371,290	343,253
Total	-	3,677,621	3,428,497	-	3,224,364	3,008,247
Net Present Value (NPV)		2,175,012	1,925,888	-	1,721,755	1,505,638
Benefit Cost Ratio (B:C)		2.44	2.28	-	2.14	2.00
Internal Rate of Return (IRR)				-	11.9	11.86
Pay Back Period (PP) in years		2.0	2.15	-	2.0	2.15

The payback period, either at 6.5 or 11%, was found to be 2 and 2.15 years for bell peppers and tomatoes, which is estimated to be at least six (6) production cycles. This denotes that, within two years, the total initial establishment cost of 1,502,609 WST for a one-hectare protected structure with a fertigation system will be fully regained by the investor. The superiority of bell pepper over tomato across all feasibility indicators was due to the higher market price of bell pepper than tomato.

A sensitivity analysis was performed with an increase in variable costs by 10 and 15% considering that labor and input costs might increase over time (Table 6). It was observed that under increased variable costs, an 11% discount factor will affect the different economic indicators, such as the NPV, B:C, and PP. However, despite the decrease in the NPV and BCR, the drip-fertigation systems will remain economically viable for growing bell pepper and tomato. A similar trend will be observed between bell pepper and tomato; the NPV of the former will be relatively higher than the latter due to the difference in the market price of the two vegetables. At a 10% increased variable cost, the NPV for six years of growing bell peppers will be 1,072,532 WST with a BCR of 1.58. This value is relatively higher than the NPV and BCR of tomato, which will be 847,033 WST and 1.46, respectively. At a 15% increased variable cost, the NPV for growing bell pepper will further be reduced to 926,492 WST, and the BCR will be more or less the same at 1.50. The NPV of growing tomatoes for 6 years will be significantly lower at 696,301 WST, with the BCR of 1.37. The payback period will also be affected if labor and materials costs are increased by 10 and 15%. For bell pepper, almost one year will be added before the total initial establishment cost for a one-hectare protected structure with a fertigation system is fully regained by the investor. While in tomato, an additional three (3) months at 10% and five (5) months at 15%.

Table 6. Sensitivity of the different economic indicators to the increase in variable costs of growing tomato and bell pepper in a one-hectare protected structure under drip fertigation.

Economic Indicators	Bell Pepper				Tomato			
	Present Value	NPV	B:C	PP	Present Value	NPV	B:C	PP
-	3,224,364	1,721,755	2.14	2.0	3,008,247	1,505,638	1.62	2.66
10%	2,932,288	1,072,532	1.58	2.74	2,706,785	847,033	1.46	2.97
15%	2,786,244	926,492	1.50	2.88	2,556,053	696,301	1.37	3.16

4. Discussion

Using the information gathered from Sunshine Pacific, Limited, in establishing a protected structure with a drip fertigation system to grow tomatoes and bell peppers, evidence indicating the production, water use, feasibility, and profitability of the system in a commercial farm in Samoa is provided. The average yield in Samoa is lower than the reported yield in leading countries such as the Netherlands, Spain, Britain, Canada, Sweden, and Australia. In Samoa, the yield of tomatoes was only 16.35 kg/m^2 a year, in other countries it ranged from 20 to 74 kg/m^2 a year. Canada has the highest yield per m^2 a year, with 55 to 74 kg, while Spain and Australia were at the bottom with 28 to 30 kg/m^2 and 20 to 50 kg/m^2 a year, respectively. The bell pepper yield estimate in Samoa was only 10.50 kg/m^2 a year, while in Britain it recorded the highest production of 25 to 35 kg/m^2 a year, and the rest ranged from 20 to 25 kg/m^2 a year [16]. This is logical, as the climatic condition in Samoa is tropical, and the production system used here is a semi-protected system that was not equipped with a temperature and air-controlling system. In Cambodia, having similar weather conditions to Samoa with an average temperature of 29.43 °C, the average fruit yield of the 'KK1', a local cultivar of tomato grown under greenhouse conditions, was 7.35 kg/m^2 a year [25]. However, Samoa's production conformed with these countries, showing that tomato production grown in hydroponic greenhouses is higher than bell peppers. This is attributed to many factors, such as high-water content and high Harvest Index of tomatoes [26]. Further, in Samoa, the coco coir slabs were used for three (3) cycles, maximizing the utility of the material to compensate for its cost, showing a steady decline in yield from the first to the third cycle.

The water use in both crops in Samoa is less efficient than in other parts of the world, using a protected structure with a drip fertigation system. The PWU of tomatoes in the Netherlands varies from 12.5 to 20 L/kg [26] while in Samoa, the PWU is 119.27 L/kg. This difference can be attributed to the higher transpiration rate in plants growing in a low-technology greenhouse in Samoa compared to modern greenhouses in the Netherlands. Crops in hot climates transpire more water than crops in cooler climates [26]. In tomatoes, the PWU (L/kg) in the tropics ranged from 200 to 900 [19]; it was about 170 in an arid country like Saudi Arabia [27], ranged from 68 to 90 in Mexico [28], and was 77 in Arizona, USA [27], while in cooler regions it ranged from 8 to 150 L/kg [26]. High temperature increases leaf temperature, which results in more evaporation of water to cool its surfaces; thus, more water is lost [29]. The largest water loss in plants is by transpiration, with about 10 times more water being transpired than is stored in the biomass. Crop transpiration consumes 90% of the water taken up by the crop [30,31]. The average ambient temperature inside the protected structure used in this study was 29 °C, and the ambient temperature outside was 27.8 °C [21], while in the Netherlands, the annual ambient temperature was 10.6 °C [32]. Greenhouses in the Netherlands are a modern design that provides a high degree of climate control and protects indoor crops from unfavorable changes in ambient conditions, such as temperature [33]. In arid regions such as Riyadh (KSA), the PWU of a tomato plant improved to as low as 4.2 L/kg when grown in greenhouses fitted with sufficient mechanical cooling capacity that also allows water recovery after transpiration. In an environment where there are no water escapes theoretically, the minimum PWU of tomato is 1.25 L/kg [22,27].

The huge amount in the initial establishment cost was attributed to importing major materials, such as greenhouse structure and drip fertigation equipment from China and New Zealand, respectively. High fuel and energy prices have direct impacts on operating and establishment costs, particularly in the cost of plastics, and transport is one of the major challenges for protected cropping industries around the world [16]. Despite this, the system is found to be profitable and feasible. This might be due to the high price of the product. The average market price of tomato and bell pepper from 2020 to 2022 was 9 WST/kg and 16 WST/kg, respectively; however, these prices were much lower than those of imported tomato (18.10 WST/kg) and bell pepper (26.40 WST/kg). A notable benefit of using the drip fertigation system was the reduced number of farm workers involved, reducing the labor cost to only 0.30% of the 8.03% crop establishment costs due to the automation of water and nutrient application systems. The use of drip fertigation in annual crops, such as bell pepper and tomato, in Israel has achieved significant results. The use of this technology is key for the development of high-yield, efficient, and high-quality agriculture [34]. One of the major challenges in small PICTs like Samoa is the cost of goods, most of which are imported, and the cost of labor due to a shortage caused by the seasonal workers' scheme to Australia and New Zealand. The sensitivity analysis showed that even increasing these two key factors in the drip fertigation system by 10 and 15% the investment will remain profitable and feasible.

These are critical pieces of information to encourage farmers and investors to grow high-value vegetables, such as bell peppers and tomatoes, in protected structures with drip fertigation systems. This approach can help meet the demand in Samoa and reduce the import volume of these commodities, lowering the prices in the market and making these commodities accessible and affordable for the common masses. The current production in Samoa is lower than in other countries, while the establishment cost is higher, suggesting a need for continuous improvement in the system most suitable for Samoan conditions.

Opportunities are available to minimize production costs, for instance, harvesting rainwater as the average yearly rainfall in Samoa varies from 3500 mm–5500 mm [21] and utilizing solar energy to generate power. Temperature inside the structure will be optimized by installing a cooling pad, which will incur additional costs of USD8500 and maintenance costs for electricity to operate. Based on the sensitivity analysis, even with the additional costs of cooling pads, the systems will remain feasible. Availability of information and sharing are the most important advantages for growers in the industry. Despite the large-scale investment in this system of growing vegetables, the success in the Netherlands, Spain, Canada, Britain, and Australia is a testament to its value and long-term future, which offers substantial labor and set-up efficiencies [16].

These findings, although conducted in a commercial farm and only one location, reflect the reality of Samoa. This limitation could suggest variation in the results if the study were conducted in multiple locations, but given the size of arable land on the island and the number of commercial farmers in Samoa, the variation will be insignificant. This result is considered the first attempt to understand the economic feasibility of the drip fertigation system under a protected structure and is valuable information to encourage local investors. In this study, we only focus on the economic analysis but do not give much emphasis to social and environmental issues, as initially we were afraid that it would not be economically feasible in a remote island country, Samoa, due to the very high installation cost of the system. On the other hand, there was a dire need for such a production system in those remote island countries when the supply chain was totally disrupted due to COVID. As the system is now considered economically feasible and the commercial entity has successfully run the system for the last five years, it is time to look at other aspects, such as social and environmental sustainability. In our next study, we shall address those issues.

5. Conclusions

Based on the average yield per hectare from 2020 to 2022, the production is lower than the average worldwide and requires more water to grow tomatoes and bell peppers in a commercial farm in Samoa under protected structures due to the high temperature inside the structure, which increases the transpiration rate in plants. Options to address the problem of high temperature are available, such as installing mechanical cooling equipment, which will increase the current initial establishment costs and maintenance costs for electricity in the cooling equipment thereafter. The additional costs to improve production and water use are worth exploring in the future, including the impact of this production system on individual well-being and societal development of small island countries like Samoa. The impact on the environment is also another crucial aspect to explore to mitigate potential negative effects. At the moment, despite the current low yield, low water use efficiency, and high establishment costs, growing bell peppers and tomatoes in a protected structure with a drip fertigation system is feasible and profitable in Samoa, even with an increase of variable costs by 10 and 15%, due to the high market prices. These findings have limitations, such as being studied only in a commercial farm at one location and not addressing social and environmental aspects; however, this is the first attempt to understand the economic feasibility of the drip fertigation system under a protected structure and is valuable information to encourage local investors. This system of cultivation allows island countries like Samoa, with limited arable land, vulnerable to climate change, high incidence of pests and diseases, and high cost of labor, to produce fresh high-value crops like tomatoes and bell peppers for a steady supply in the market that most of the Samoans can afford.

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