Applied aquaponics to culture high value local species and ultimately reused and recycle the local materials to build the green and sustainable agriculture

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Abstract. Aquaponics is not a new technology including a wide variety of systems, but the interest has grown rapidly in recent years, especially in developing countries. Each system has different types and levels of costs and interest. Aquaponics can be implemented using low-cost materials making it more attractive farmers to diversify their incomes. This article examined the profitability of applied aquaponics in thoroughly reused, recycle local materials and the local species. Three sources of data were considered for the study: (1) commercial local species farms, (2) applied aquaponics farms and (3) published research. The first analysis compares the economics of local farms, traditional aquaponics and applied aquaponics systems under similar operations. Results suggest that the traditional aquaponics system requires higher investment and operating cost compared with the applied aquaponics system and local farms. The second analysis constructed on the aquaponics production of fish and plants as well as the returns. The study found that at the small scale of 1-year operation, applied aquaponics is the most profitable model ($1991.34) at 36 percentage of interest. It is more advantage to develop the economic, social by building environmental sustainability of agriculture to maximize food production through applied aquaponics. The economic efficiency of applied aquaponics in using multiple use of resources, primarily water and nutrients, and recycle certain infrastructural, management and labor costs will keep the aquaponics lasting and expanding to social life.

1. Introduction
The current world population is nearly 7.7 billion and will intimately reach 8.6 billion in 2030 and hit to 9.8 billion in 2050 and over 11 billion people by 2100 with more than 75 percentage of population living in urban area [1]. Food security will be stress when global population growing and increasing demands of animal protein [2]. The blooming of population is rising to more than 60% demands of food compare to current demand by 2050 [3-4]. It will cause heavily stress on water resources, land usage for forest destroy and soil degradation and ecosystems [5-6]. Therefore, agriculture in the next centuries are challenging to produce more food to feed a continuously growing population with shrinking agricultural area, fluctuating energy and oil costs, changing climate and decreasing of...
constrained freshwater supplies [7-8]. Most of food sources are contributing from developing countries where need to adopt more efficient and sustainable production methods and technologies adapting to climate change. This challenges to researchers to ultimate the benefits of using cycled and reusable and local materials into the necessity to compensate existing sustainability deficits in agricultural farming systems and agricultural available area.

During the last century, for enhancing food production to meet the global food demands and to achieve the success of intensive farming, farmers have used pesticides and agrochemical productions to be an important factor to increase in crop yields and food agriculture systems [2, 9-10]. These chemicals are used for many purposes and at different stages of the production cycle. Chemicals are used to prevent or treat the diseases that can prevent large crop losses. Therefore, they will continue to play an important role in agriculture. However, overdoses of chemicals in agricultural cultivation causing significant contamination of terrestrial ecosystems and poisoning human foods [11-12]. According to the report of WHO, 2017 [13], the causes of more than 200 diseases (diarrhea and cancers) are coming from unsafe food containing harmful bacteria, viruses, parasites or chemical substances. It is estimated that food poisoning kills 420,000 people a year worldwide [14].

Aquaponics is a combined model of growing vegetable with fish to achieving more for less by designing the two systems to benefit one another [15]. It is now seen as a potentially sustainable fishery/ agricultural model in terms of: (1) Enhance the productivity that gains on the same acreage and cost savings for two systems in one: Fish and vegetables but only cost food for the fish, vegetable fertilized from fish wastewater; seedlings are high densities grown before transferring to vegetable bed where vegetables can grow to market size in few weeks. (2) Safe and friendly to environment: The mechanical process of the model is based on biological filtration rules: vegetables grown is fed by wastewater from aquariums (containing wastewater) without synthetic fertilizers or pesticides; vegetable bed act as a circulating biological filtration system: they absorb waste from the aquarium and supplies clean water return to the fish tank. (3) Moreover, this model also saves water that is great model adapting to climate change: applied in shortage water area. The system is a closed loop recirculating system that never suffer from water stress. Aquaponics also advantages in reducing the input resources: water, energy, nutrients, area, labour, chemicals, pesticides, etc., to produce very high yield of safety food or organic food [16-18]. However, the cost to set up an aquaponics system is still very much expensive, high electrical use, and sensitivity of output prices to get profits especially the small aquaponics enterprises mainly incurred losses [19-23]. It is expensive system in developing countries where is producing the most food products to feed the world. Moreover, degradation of land area, soil and water scarcity are current problems of agricultural production, especially in the developing countries suffering from scarcity of resources under climate changes. Therefore, we need to make aquaponics more sustainable and cheaper by incorporating it into ultimately the local materials, local species and reusable as well as recycle materials in setting up the applied aquaponics in developing countries and eventually leading to different techniques. It will contribute to keep aquaponics long last and reality to farmers. In this paper we will initially analyze the costs and benefits of applied aquaponic systems in using the recycled and reusable materials as well as local materials and species. Potentials of the mobile apply in the small area to pursue the goals: saving the areas and water resources, investigating costs efficiency, providing clean and safe food to consumers and increasing food products in the arc of land effectively.

2. Methodology

The data were collected from three sources. First, data from currently local farms of snakehead. The data cover the cost of infrastructure, production costs, selling price and profits as well as the environmental impact. Second, the experiment conducted data was recorded at applied aquaponics at Tra Vinh University and Saphenix farm. Third, the source was coming from the published research in aquaponics. Some of data from published research were used as the parameters. The first analysis compared the initial investment of local farms, traditional commercial aquaponics and applied aquaponics under similar operations. The second analysis focused on the aquaponics production of fish and plants as well as the returns based on the sources of collected data. The purchase price and
installation costs for construction of the infrastructure and production units were estimated to understand the capital requirements of the farms at the rate of current country setting up the systems. We constructed the scenarios for representative farms to analyze price and investment sensibility. Each model was including 100m³ of fish tank and 200m² of vegetable systems. The presentative local species was snakehead that was value fish to culture in developing countries with high nutrient, high yield and high market requirement flavor [24-26]. Fish in traditional aquaponics was red tilapia. Fish were growing at density of 70 fish/m³ for 12 months. The survival ratio (%) of fish were 70, 90 and 90 (commercial fishpond: CP, traditional aquaponics: TA and applied aquaponics: AA). The FCR were 1.6 (CP), 2.2 (TA) and 1.2 (AA). After 12 months of culture, fish got the market size at 1.2 kg (CP), 1.0 kg (TA) and 1.4 kg (AA). The vegetable growing in aquaponics was water spinach which was loving water vegetables and highly local market demand.

3. Results and discussion

3.1. The general materials and benefits to construct commercial snakehead pond, traditional aquaponics and applied aquaponics

Table 1 is showing some of the key differences at materials and benefits to construct commercial snakehead pond, traditional aquaponics and applied aquaponics. The differences among 3 models stem directly from the farming methods and materials during food’s production. The commercial fish farm and traditional aquaponics usually locate outdoor and use big space, the applied aquaponics is mobilizer with flexible in sizes and easier to apply at household, school, balcony or roof top. Figure 1 are showing the reality of models on: scale, location, materials, operation. The applied aquaponics is using cheap and available local materials as coconut peat, rice husk, water hyacinth roots, bamboo tree, Styrofoam, canvas, etc., to reduce investment cost and culture the locally high value species as snakehead to increase the income to local farmers. The most importance of applied aquaponics is ultimately reused and recycled local materials to reduce initial investment cost and culture local high value species to increase the potential profits that strongly attract farmers investment.

![Figure 1. (a) Locally Commercial fishpond; (b) Commercial fish in cement tank; (c) Commercial Aquaponics system design; (d) Commercial Aquaponics system; (e, f) Applied aquaponics ultimate local materials (Saphenix Co, Ltd. And Tra Vinh University); (g, h) Applied aquaponics at household scale.](image-url)
Table 1. The general materials and benefits to construct commercial snakehead pond, traditional aquaponics and applied aquaponics [4, 20-22, 27].

| Materials          | Commercial snakehead pond | Traditional aquaponics                        | Applied Aquaponics             |
|--------------------|----------------------------|-----------------------------------------------|-------------------------------|
| Tanks/ponds        | Earthen pond               | Composite/                                 | Styrofoam box                 |
| Cages              | Composite/                 | Plastic box/ bottles                        |                               |
| Cement tanks       | Concrete                   | Plastic floating pond                       |                               |
| Vegetable bed      | Wooden tray                | Styrofoam box/Plastic box                   | Bamboo/Trash timber/tree      |
| Soils/filter bed   | Clay pebbles               | Coconut peat/Rice husk/ash                  | Water-hyacinth roots          |
| Size/volume        | >500 m$^3$                 | Mobilized depending on the available space  |                               |
| Location           | Outdoor                    | Outdoor/ Indoor                             | Rural/Urban                   |
| Rural area         | Greenhouses                | Outdoor/ Indoor                             | Rural/Urban                   |
| In farm/ garden    | In office/kitchen/Ornamental | Balcony/The roof tops                      |                               |
| Rural/Urban        | In office/kitchen/Ornamental | Balcony/The roof tops                      |                               |
| Management         | Easier for kids and elders operate |                               |                               |
| Education          | Yes                        | Yes                                           |                               |
| Fish               | Local value species        | Yes                                           | High value local species      |
|                    | Tilapia                    | Snakehead/ Catfish/Trout                    | White leg shrimp/Prawn/etc.   |
| Climate change     | Yes                        | Yes                                           |                               |
| Chemical free food | Yes                        | Yes                                           |                               |
| Recycle water and wastewater | Yes                       | Yes                                           |                               |

3.2. Investment cost of building the commercial snakehead pond, traditional aquaponics and applied aquaponics

Table 2 shows the initial cost to build 100m$^3$ of aquaculture tank and 200m$^2$ of hydroponics. The local commercial farm is the cheapest investment at $1120 of aquaculture component, applied aquaponics costing $1448 and traditional aquaponics costing $6365. The cost to invest the aquaculture system in traditional aquaponics is 5 times expensive. The vegetable system in applied aquaponics is ultimately reused and recycled the local materials that familiar to farmers to set up costing $2340 while vegetable system in traditional aquaponics costing $13745. The total building cost of traditional aquaponics is 5.3 times expensive to compare with initial constructs applied aquaponics and 18 times of higher cost to invest for locally commercial fishpond.

3.3. Operational cost of commercial snakehead pond, traditional aquaponics and applied aquaponics

Table 3 indicates the operation cost of 3 models for 12 months. The fish feed is the highest cost during the farming process account approximately 50% of operation cost. The second largest operational cost is labour. The labour cost in traditional and applied aquaponics is higher than labour cost in commercial fishpond because of extra payment for take care the vegetable systems as plantation and harvesting. The remarkable in both aquaponics systems are using less chemicals just for treating water before pouring to culture tanks (river supplying water to systems). In commercial fish farms, chemicals are used to treat water and treat the disease that are current problems to fish quality and wastewater releasing to environment. During snakehead commercial farming, average water is exchanging at least 70% - 90%/ (1-3 times/day) [28-29], it costs twice for electricity to pump water out and in every day. In aquaponics systems, electrical cost just saves for water cycle flows and
The volume of water exchange in traditional fish farm is 250 times to compare with water need to fill in aquaponics systems because of water evaporating, leaking or fish flashing (30% - 50% water adding). It is extremely necessary to build industrial fish farms by applied aquaponics to well develop the green and sustainable agriculture adapting to climate changes and water more crisis.

3.4. Annual Production and Sales Income

Table 4 shows the annual production and sales income. We take the average price of fish and vegetables. Snakehead is more advantage in price to compare with tilapia in Vietnam that is leading the annual income in farming snakehead ($1046.304: CP and $3157.056: AA) higher than in farming tilapia ($409.5: TA). During culture periods, snakehead in applied aquaponics systems is no disease, higher survival ratio to increase in yield and the price of snakehead in applied aquaponics is double in price that help increasing the annual income as 3 times higher to price of snakehead in local commercial farms.

Table 2. Total initial investment for commercial snakehead pond, traditional aquaponics and applied aquaponics (the average long life of commercial snakehead system: 3 years; the average long life of traditional aquaponics system: 10 years and the average long life of applied aquaponics system: 5 years) (Cost is calculating for setting up in the same time and location).

| Item                                      | Commercial snakehead pond | Traditional aquaponics | Applied Aquaponics |
|-------------------------------------------|---------------------------|-----------------------|-------------------|
| Aquaculture component                     |                           |                       |                   |
| 100m$^3$ fish tank (1.4m x 6m x 12m)      | $300                      | Composite cement tanks| $5217             |
| Water pumps                               | $100                      | $100                  | $100              |
| Electrical systems                        | $150                      | $300                  | $200              |
| Plumbing                                  | $100                      | $200                  | $200              |
| Environmental water measure               | 470                       | 470                   | 470               |
| Electrical Timer                          | $10                       | $10                   | $10               |
| Air pumps                                 | $50                       | $50                   | $50               |
| Air stones                                | $18                       | $18                   | $18               |
| **Sub total**                             | **$1120**                 | **$6365**             | **$1448**         |
| Vegetable systems                         |                           |                       |                   |
| 200m$^2$ Plants beds (wooden tray)        | $7745                     | Styrofoam plastic box/| $600              |
| Vegetable beg                             | $2000                     | Bamboo trash timber   |                   |
| 300 m$^2$ net house                       | $3000                     | Stone 1x2             | $300              |
| Aquaponic installation cost               |                           | Stone 3x4             | $140              |
| **Total**                                 | **$1120**                 | Coconut peat          | $50               |
| **Depreciation/ year**                    | **$373.3**                | Rice husk             | $20               |
|                                          |                           | Net                   | $30               |
|                                          |                           | Net house             | $900              |
|                                          |                           |                       | $300              |

*Note: Price is updating at current location ($1USD = 23000VND).
### Table 3. Operational cost of commercial snakehead pond, traditional aquaponics and applied aquaponics (Duration: 12 months). (Cost is calculating for setting up in the same time and location).

|                     | Commercial snakehead pond | Traditional aquaponics | Applied aquaponics |
|---------------------|---------------------------|------------------------|-------------------|
|                     | Total ($USD)              | Total ($USD)           | Total ($USD)      |
| Labor               | 600                       | 1000                   | 1000              |
| Electricity (kW)    | 2880                      | 374.4                  | 2520              |
| Water (m³)          | Free of charge            | 50                     | Free of charge    |
| Seed (kg)           | Snakehead                 | 12                     | 12                |
| Fish fingerlings    | 156.5                     | Red tilapia            | Snakehead         |
| Fish Feed           | 40% protein               | 30% protein            | 40% protein       |
| Water treatment     | 200                       | 693                    | Water treatment   |
| Diseases            | 200                       | 0                      | 0                 |
| **Total**           | **2575.9**                | **2293.8**             | **2808.1**        |

*Note: Price is updating at current location ($1USD = 23000VND).*

### Table 4. Annual Production and Sales Income.

|                    | Commercial snakehead pond (CP) | Traditional Aquaponics (TA) | Applied Aquaponics (AA) |
|--------------------|--------------------------------|------------------------------|-------------------------|
| Species            | Snakehead                      | Tilapia                      | Snakehead               |
| Price ($USD/kg)    | 1.73                           | 1.3                          | 3.48                    |
| Annual production  | 604.8                          | 315                          | 907.2                   |
| (kg/ 12 months)    | 604.8                          | 315                          | 907.2                   |
| Annual sales income($USD) | 1046.304                  | 409.5                        | 3157.056               |

*Note: Price is updating at current location ($1USD = 23000VND). The yield of vegetable in both aquaponics systems are proposed the same.*

### 3.5. Annual profit

The study found that at the small scale of 1-year operation, applied aquaponics is the most profitable model ($1991.34) at 36 percentage of interest (Table 5). For commercial fish farm and traditional aquaponics can increase the profit when operation in the big scale [22]. Based on the previous research on the economics of aquaponics, many aquaponics operations were not profitable because of high initial investment costs, labor cost, high use of electricity, and sensitivity of profits to output price [21]. Applied aquaponics system to increase productivity and reduce the construction cost of the structure though simplicity, easy management and low equipment cost make this system an interesting solution to increase food production as advantage in reducing vulnerability from shrinking of land, lack of water and pollute to environment. Applied aquaponics also increase resilience of the farming households with ponds towards climate change in the coastal area.

### Table 5. Annual profit.

|                        | Commercial snakehead pond | Traditional Aquaponics | Applied Aquaponics |
|------------------------|---------------------------|------------------------|-------------------|
| Annual sales /income ($USD) | 1046.304                  | 2809.5                 | 5557.056          |
| Annual cost ($USD)     | 2949.2                    | 4304.8                 | 3565.7            |
| Profits ($USD)         | -1902.9                   | -1495.3                | 1991.34           |
| Percentage of interest | -1.82                     | -0.53                  | 0.36              |
4. Conclusion
This paper presented an initially economic analysis among commercial fishpond, traditional aquaponics and applied aquaponics systems by using the recycled and reusable materials as well as local materials and species. The cost to invest the aquaculture system in traditional aquaponics is 5 times expensive. The vegetable system in applied aquaponics is ultimately reused and recycled the local materials that familiar to farmers to set up costing $2340 while vegetable system in traditional aquaponics costing $13745. The total building cost of traditional aquaponics is 5.3 times expensive to compare with initial constructs applied aquaponics and 18 times of higher cost to invest for locally commercial fishpond. The volume of water exchange in traditional fish farm is 250 times to compare with water need to fill in aquaponics systems. Snakehead is more advantage in price to compare with tilapia in Vietnam that is leading to the annual income in farming snakehead ($1046.304: CP and $3157.056: AA) higher than farming tilapia ($409.5: TA). The study found that at the small scale of 1-year operation, applied aquaponics is the most profitable model ($1991.34) at 36 percentage of interest. Cost effective in applied aquaponics is compatible with the conservative livelihoods of farmers in developing countries. The applied aquaponics not only cheaper in investment cost but also enhance the quality and the quantity of food products in the same land area. Applied aquaponics also solve the problem on maintaining and protecting the green environment. It is more green and sustainable farming systems adapting to climate change by taking full advantage of all the natural resources: recycle local materials, agricultural scrap, reused and treated wastewater through closed recirculating systems. Moreover, applied aquaponics is mobilized and it is potential to be a great model to educate kids at home or school about green agricultural system. The model also gives a job to women or retired people can take part in feeding fish, harvesting and collecting vegetables.

In conclusion, based on our findings, economic performance of applied aquaponics is promising. This suggests a strongly potential for next deep research on applied aquaponics industry and for technology to help applied aquaponics developing and playing larger role in producing both vegetable and fish in the developing countries to increasing as much as the healthy food to blooming world population. Therefore, applied aquaponic is more than just a method of food production; it is a way of nourishing communities, increasing economic of developing farmers and creating a better sustainable future.

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