CALCULATING THE CARBON FOOTPRINT OF SHRIMP FARMING IN VIETNAM: THE CASE STUDY IN PHU VANG DISTRICT, THUA THIEN HUE PROVINCE

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Abstract: *Shrimp farming is one of the most rapidly growing aquaculture, which globally has been associated with considerable revenue for farmers. In Vietnam, shrimp aquaculture is now one of the most important aquaculture practices in terms of area, production, employment and foreign exchange generation. However, they were also guilty of polluting the environment with greenhouse gas emissions. This study represents an attempt to estimate the carbon footprints of shrimp farming systems* based on *farm data. Phu Vang District of Thua Thien Hue Province was selected as a case study. The primary data was obtained from fieldwork and interviews with the different actors involved in the selection of shrimp production. The strength of the approach does not lie in producing exact carbon footprints, but in providing a range in which the footprints could fall. Overall, the results of this study demonstrate that the annual carbon footprint of shrimp farming in Hue province is 0.0021 tCO2e or 2.1 Kg CO2e/Kg of shrimp weight. In which, feed consumption contributes most to total greenhouse gas emissions of shrimp farming activities; while energy use such as electricity, diesel oil and human labor also play important roles. The results also indicate the significant differences among farming types in terms of farming productivity and carbon footprint contribution. The on-sand farming system produced the highest yield of shrimp per hectare, however, it has about twice as much greenhouse gas emission per kg shrimp than those grown in high-tide and low-tide farming systems. More sustainable farming practices should be implemented to reduce the carbon footprint or amount of greenhouse gas emissions from shrimp farming activities.*

Keywords: *Carbon footprint, shrimp farming, greenhouse gases.*

1. Introduction

Over the past two decades, Vietnamese fisheries sector in general and aquaculture in particular has made important contributions to the national economy, and poverty alleviation. However, the boom in aquaculture production has generated great concerns over its negative environmental impacts on aquatic ecosystems and human livelihoods in coastal areas. These impacts include biodiversity depletion, eutrophication, land

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modification, and food insecurity. Another notable one is increasing the global warming potential through releasing significant amount of greenhouse gas emissions during production activities every year.

According to Research Institute for Aquaculture (RIA), in 2010, the Aquaculture sector recorded an output of 2.8 million tonnes, but they also produced about 4.33 million tonnes of Carbon dioxide, experts estimated. They also estimated that the sector's greenhouse gas emissions would reach 6.66 million tonnes by 2015 and 8.33 million tonnes by 2020 if farming conditions are unchanged [1].

As a part of aquaculture, shrimp farming emits a significant volume of greenhouse gases. These gas sources associated with shrimp farming include direct use of fossil fuels in production activities, indirect fossil fuel use, conversion of natural ecosystems or agricultural land, stock respiration and waste decomposition.

The climate change phenomena related to global warming is one of the greatest social, economic and environmental challenges of our time. Human activity is causing the climate to change. This, in turn, is having an impact on rainfall, temperatures, bushfire frequency, health, heritage and biodiversity for current and future generations.

This brief report sets out the results and findings of a survey of 30 shrimp farms in Phu Vang District, Thua Thien Hue Province, which tries to measure the Carbon Footprint of shrimp farming activities.

2. Methodology

2.1. Site selection

The main shrimp farming areas in Vietnam are in the coastal regions of the Mekong Delta and central provinces. In this study, the selected shrimp aquaculture areas are in Phu Vang District of Thua Thien Hue (Phu Xuan and Vinh An Commune).

2.2. Data collection

The data and information consists of primary and secondary data collected through a survey from July 1st 2017 to July 25th 2017.

2.2.1. Primary data

The primary data was obtained from fieldwork and interviews with the different actors involved in the selection of shrimp production. Interviews with 30 small-scale shrimp farmers in two communes (14 high-tide farms in Quang Xuyen and 13 low-tide farms in Ba Lang Village of Phu Xuan Commune and 3 on-sand farms in Vinh An Commune). The data was supplemented by secondary data.

2.2.2. Secondary data

Secondary data was collected from literature, including public documents, journals, articles, statistical agencies, and keynote speeches.

2.3. Data Analysis

Aggregating and analyse the survey results to determine the carbon footprint of shrimp farming following below process:

(1) Determining the shrimp culture process (the major stages of a shrimp culture process) at study sites.

(2) Determining the major source of greenhouse gas emissions in the whole process of commercial shrimp farming activities:

Shrimp farming's carbon footprint calculation consists of emissions from the following sources: the consumption of shrimp feed, electricity, oil, water, labor, fertilizer, antibiotics, post-larvae stocking, wastewater discharge, transportation, etc.

In this research, because a lack of field data (e.g. Most farms throw out wastewater into the water body without treatment, thus we can't measure carbon footprint from wastewater discharge activity) and Emission conversion factors for some farming activities (e.g. post-larvae shrimp production); Therefore, we just only focused on calculating amounts of greenhouse gases emission from four main farming activities which release a large amount of greenhouse gases, include: Feed consumption, electricity consumption, oil consumption, and labor use.

(3) Estimation and comparison of the carbon footprint of the shrimp farming activity among different kinds of shrimp farming systems in Hue Province.

(4) Estimation of the annual carbon footprint of one Kg of commercial shrimp in Hue Province in general (t CO2e/kg/y):

The calculating formula of carbon footprint (CF) of each input item of shrimp farming:

CF of input supplied (tCO2e) = Volume of input supplied x relevant emission conversion factor (kg CO2e/unit) x 0.001

The calculating formula of carbon footprint of shrimp farming:

CF of shrimp farming (tCO2e) = $\sum$ CF of inputs supplied

The detail carbon footprint calculating formula for each input item:

Shrimp feed consumption:

***Table 1**. Estimating the Carbon footprint of 1 metric ton of shrimp feed production*

Raw materials	Amount spent by product category (kg)	Total kg CO2e/ kg	Total kg CO2e
Fishmeal[1]	422 [a]	0.76	320.7
Wheat flour/gluten	[a]	0.135[b]	35.1
Core starch (Beet pulp)	126 [a]	0.675 [b]	85.05
Soybean meal	64 [a]	0.8 [b]	51.2
Mineral predix	15 [a]	0.8 [b]	12
Systhetic amino acid	30 [a]	3.6 [b]	108

Electricity	kWh	Total kg CO2e per kWh	
Feed production	2.646 [a]		
Waste treatment	0.343 [a]		
Total electricity	2.989	0.541[c]	**1.62**
TOTAL			**613.2**

(1): Carbon emission factor of fishmeal is calculated as fish product (Annex 4:1.27 Kg CO2e per £ of fish product); The price of fishmeal: 566-629 £/tone, average 597.5 £/tone or 0.5975£/kg fishmeal (Annex 3).

(a) Annex 1[2]

(b) Annex 2 and [3]

(c) *Table 1:* Emission conversion factors for fuels required (Converting from fuel use to carbon dioxide equivalent emissions) [4]

So, we have following formula:

CF of Feed Consumption (tCO2e) = the amount of shrimp feed used (tonnes) x 613.2 (kg CO2e/tonnes) x 0.001

Farm Electricity consumption:

CF of Electricity Consumption (tCO2e) = the amount of electricity used (kWh) x 0. 5764 (kg CO_2 e/ kWh) (*) x 0.001

(*)Emission factor for Vietnam electricity system is 0.5764 tonne CO_2 eq/ MWh [5]

Farm oil consumption:

CF of Diesel Oil Consumption (tCO2e) = the amount of oil used (liters) x2.639 (kg CO2eq/liter) (* *) x 0.001

(* *) Emission conversion factors for fuels required (Converting from fuel use to carbon dioxide equivalent emissions) [4].

Labour use during farming operation:

CF of Human Labor Consumption (tCO2e) = amounts of working days x 5.75 (kg CO2 e/ capita/day) (***) x 0.001

(***)Per capita greenhouse gases emission of Vietnamese in 2005 is 2.1 tonnes of CO2 e. That means: kg CO2 e/ capita/day = $\frac{2.1 \text{ x } 1000}{365}$=5.75(Note: 1 year= 365 days) [6].

4. Limitation

There are some limitations in the study due to the lack of facilities and short period of the survey. The study only focused on small-scale shrimp farming in Phu Vang Districts. For further studies on this field, the study should randomly investigate shrimp farming in all coastal Districts in Thua Thien Hue province in order to obtain a comprehensive view of the carbon footprint of Hue shrimp farming.

Another limitation is the lack of materials and former studies in national, even international scope which invoveled in calculating carbon footprint of shrimp farming, in other words, the data on greenhouse emissions from aquaculture fields in general is not available.

3. Results and discussions

3.1. The commercial shrimp culture process (the major stages of a shrimp culture process) at study sites

Fig.1. *The process of commercial shrimp farming operation*

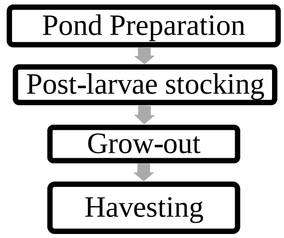

Table 2. *Different stages of shrimp farming and type of main input energy*

Stages of farming operation	Type of input energy
Pond preparation	Human labor
Post-larvae stocking	Human labor
Grow-out	Human labor + Electricity+ diesel oil + Shrimp feed used.
Harvesting	Human labor

Among these stages, the Grow-out stage accounts for the highest amounts of greenhouse gas emissions due to the consumption of shrimp feed, electricity, and diesel oil used for operating the aeration machine and light, the labor for management of the shrimp farming system.

3.2. Estimation and comparison of the annual carbon footprint of shrimp farming activities among different kinds of shrimp farming systems in Hue Province:

Table 3. *Average amount of Shrimp Farming Inputs supplied to produce 1 Kg of commercial shrimp*

No	Kinds of shrimp farming System	Labor Use (Working days/year)	Amount of used Shrimp feed (tonne/year)	Amount of used electricity (kWh/year)	Amount of used diesel oil (liters/year)
1	High-tide	0.105	0.001	0.041	0.191
2	Low-tide	0.085	0.001	0.031	0.123
3	On -sand	0.0145	0.0012	4	0

Table 4. *Carbon footprint calculation for High-tide shrimp farming activity (t CO2e/kg/y).*

No	Input Items	Unit	Amount of consumption per year	Carbon convertion factor(Kg CO2 eq/unit)	Carbon footprint (t CO2 eq/y)	Percentage (%)
1	Human Labor	Working days	0.105	5.75	0.000604	34.6

2	Shrimp feed	tonne	0.001	613.2	0.000613	35.1
3	Electricity	kWh	0.041	0.5764	0.000024	1.4
4	Diesel oil	liters	0.191	2.639	0.000504	28.9
5	Total				0.00174	100

Table 4 shows the contributions of four major farming activities, including feeding, electricity, diesel oil and human labor use to the carbon footprint of each kilogram of commercial shrimp in high-tide farming systems. In which, human labor (34.6%) and shrimp feed (35.1%) are the major contributors to carbon footprint of this farming system. Diesel oil used for aeration and water pumping also adds a significant volume, about 28.9% and only 1.4% is attributed to electricity consumption. The total annual carbon footprint of high-tide farming activities is 0.00174 tCO2e or 1.74 kg CO2e/kg of shrimp.

Table 5*. Carbon footprint calculation for Low-tide shrimp farming activity (t CO2e/kg/y).*

No	Input Items	Unit	Amount of consumption per year	Carbon convertion factor(Kg CO2 eq/unit)	Carbon footprint (t CO2 eq/y)	Percentage (%)
1	Human Labor	Working days	0.085	5.75	0.000489	3.83
2	Shrimp feed	tonne	0.001	613.2	0.000613	42.5
3	Electricity	kWh	0.031	0.5764	0.0000179	1.2
4	Diesel oil	liters	0.123	2.639	0.000325	22.5
5	Total				0.00144	100

Table 5 indicates the distribution of total carbon footprint of each kilogram of shrimp production among the main farming activities in low-tide farming systems. In which, shrimp feed is the greatest carbon footprint contributor of this farming system (about 42.5%; human labor and diesel oil consumption (used for aeration practice) account for 33.8% and 22.5%, respectively. For electricity, like in high-tide system, is only used for light, thus has a low percentage contribution. The total annual carbon footprint of low-tide farming activities is 0.00144 tCO2e or 1.44 kg CO2e/kg of shrimp weight.

Table 6*. Carbon footprint calculation for On-sand shrimp farming activity (t CO2e/kg/y).*

No	Input Items	Unit	Amount of consumption per year	Carbon convertion factor(Kg CO2 eq/unit)	Carbon footprint (t CO2 eq/y)	Percentage (%)
1	Human Labor	Working days	0.0145	5.75	0.0000834	2.7
2	Shrimp feed	tonne	0.0012	613.2	0.000736	23.5

3	Electricity	kWh	4.0	0.5764	0.0023056	73.8
4	Diesel oil	liters	0.0	2.639	0.0	0.0
5	Total				0.00312	100

Table 6 demonstrates the contributions of four major farming activities to the carbon footprint of each kilogram of commercial shrimp in on-sand farming systems. Shrimp raised in this system are grown under crowded conditions that require lots of electricity for aeration and water pumping as well. Therefore, this type of farming input contributes the most to carbon footprint of this farming system (73.8%), while shrimp feed and labor account for 23.5% and 1.7%, respectively. The total annual carbon footprint of on-sand farming activities is 0.00312 tCO2e or 3.12 kg CO2e/kg of shrimp weight.

Fig.2. *Distribution of total shrimp production among three kinds of faming systems*

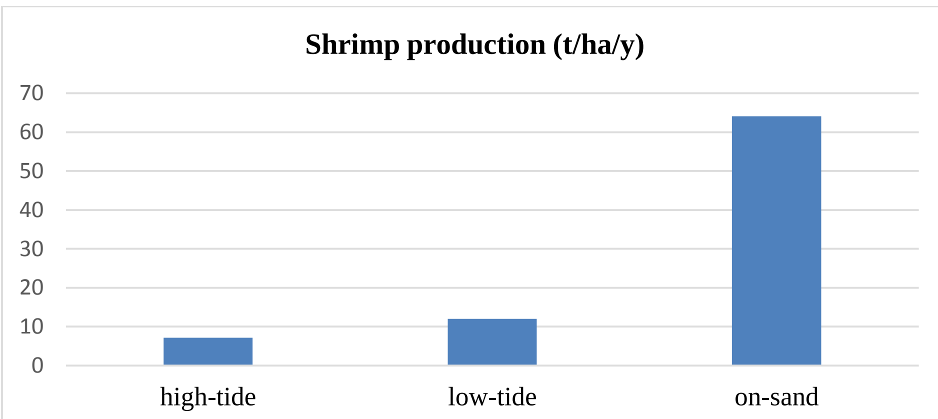

Fig.3. *Distribution of total carbon footprint among three kinds of faming systems*

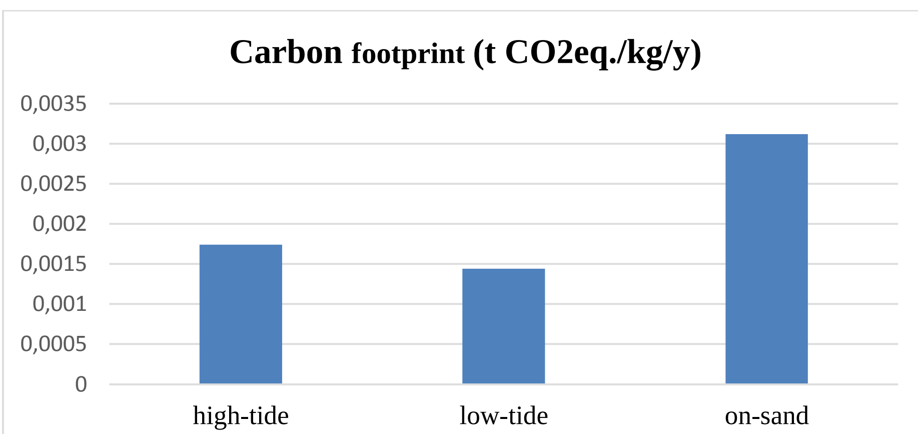

Figure 2 and figure3 show that the on-sand farming system, which is known as intensive shrimp farming, achieved the highest yield of commercial shrimp per hectare compared with other systems. Each hectare of on-sand farming areas produces 64.12 tonnes shrimp/year, while high-tide and low-tide produce only 7.15 and 11.98

tonnes/year, respectively. However,on-sand farm has about twice the environmental impact or carbon footprint per kg shrimp (about 49%) than those grown using less intensive methods such as high-tide (28%) and low-tide (23%) farming systems.

3.3. Estimation of the annual carbon footprint of one Kg of commercial shrimp in Thua Thien Hue Province (t CO2e/kg/y)

Table 7. *The annual carbon footprint of one Kg of commercial shrimp in Thu Thien Hue Province (t CO2e/kg/y)*

No.	Input Items	Carbon footprint of High-tide system		Carbon footprint of Low-tide system		Carbon footprint of On-sand system		Average carbon footprint	
		t CO2 eq./kg/y	%	t CO2 eq./kg/y	%	CO2 eq./kg/y	%	t CO2 eq./kg/y	%
1	Human Labor	0.000604	34.6	0.000489	33.8	0.0000834	2.7	0.000392	23.7
2	Shrimp feed	0.000613	35.1	0.000613	42.5	0.000736	23.5	0.000654	33.7
3	Electricity	0.000024	1.4	0.000018	1.2	0.0023056	73.8	0.000783	25.5
4	Diesel Oil	0.000504	28.9	0.000325	22.5	0.0	0.0	0.000276	17.1
5	Total							0.00210	100.0

Fig.4. *Distribution of total carbon footprint among shrimp farming activities*

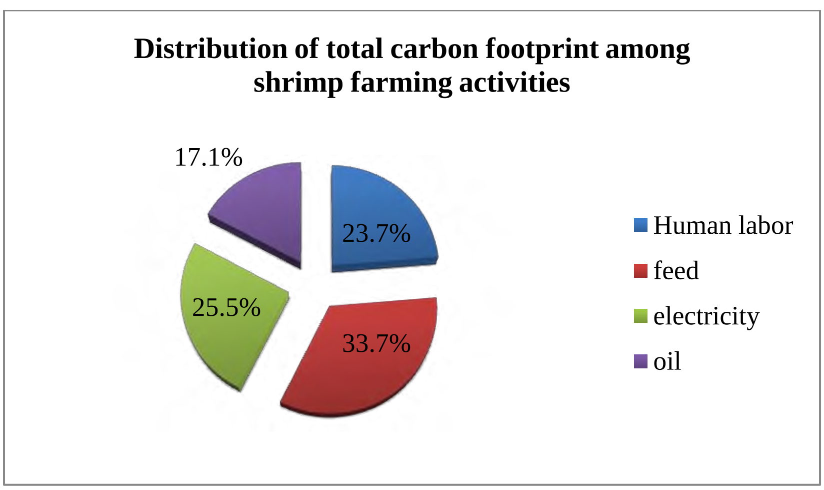

Table 7 indicates that the annual carbon footprint of one Kg of commercial shrimp production in Hue Province is 0.0021 tCO2e or 2.1 Kg CO2e. In which, feed consumption accounts for 33.7% total carbon footprint, thus, is the biggest contributor to environmental impacts of shrimp farming activities. Electricity, Human labor and Diesel Oil account for 25.5%, 23.7% and 17.1% total carbon footprint, respectively (Figure 4).

4. Conclusion

Overall, the results of this study shows that the annual carbon footprint of shrimp farming in Thua Thien Hue province was 0.0021 tonnes CO2e or 2.1 Kg CO2e/Kg of shrimp weight.

The on-sand farming system produced the highest yield of commercial shrimp per hectare, however, it has about twice as much greenhouse gas emission or carbon footprint per kg shrimp than those grown using less intensive methods such as high-tide and low-tide farming systems.

This study also shows the contributions of major farming activities (Feeding, Electricity, Diesel Oil and Human Labor Use) to the carbon footprint of each kilogram of commercial Shrimp weight. Shrimp Feed consumption accounts for greatest contribution (33.7%) to greenhouse gas emissions or carbon footprint of shrimp farming activities. The next is electricity consumption, about 25.5% total carbon footprint, especially accounts for highest percentage of energy use as well as greenhouse gas emissions in on-sand farming systems. The human labor and diesel oil are about 23.7 and 17.1% total carbon footprint of one Kg of commercial shrimp, respectively.

Raising an understanding of the carbon footprint of farming systems as well as implementing the *official* research and statistics to *calculate* annual greenhouse gas emissions from shrimp farming activities are necessary to determining the environmental impacts of those. It is through that, having the suitable and effective strategies to finally reach to sustainable development.

More sustainable farming practices should be implemented to reduce the carbon footprint or amount of greenhouse gas emissions from shrimp farming activities.

5. Recommendations

The first recommendation would be to increase the understanding of carbon footprint of food production in general and farming systems in particular, which might impact the production practices to reach sustainable development.

Besides, *the* awareness of shrimp farming impact on the environment is very important, thus, it is necessary to have the official research and statistics to *calculate* annual greenhouse gas emissions from shrimp farming activities.

Another recommendation would be for shrimp farmers and stakeholders that more sustainable farming practices should be implemented to reduce the carbon footprint or amount of greenhouse gas emissions from shrimp farming activities such as:

Develop and use feed that contains less fishmeal- a major constituent of shrimp industrial feed, which has the highest contribution to carbon footprint of shrimp feed production. One idea is to switch to plant-based feed or feed - formulations that use greater amounts of vegetable protein and less fishmeal. However, these new formulas would need to be evaluated for their ability to support healthy shrimp growth and their own environmental impacts.

Increasing energy efficiency would help to reduce energy consumption. However, a major, national-level change in energy production policy would be needed to significantly cut greenhouse gas production due to shrimp farming.

Switching to renewable energy supplies, e.g. bio-diesel.

Improving production efficiency and farm management.

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