Mangrove and Production Risk in Aquaculture in the Mekong River Delta, Vietnam[1]

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ABSTRACT. *Utilizing survey data in aquaculture activities in 2014 from the Mekong river delta-Vietnam, this paper aims to examine the impact of mangrove forests on profit and profit variability in extensive and semi-intensive aquaculture farms (mostly shrimp farms). The Just-Pope framework for a stochastic short-run profit function is applied to examine the impacts of inputs on both the deterministic component and the stochastic component of profit. The most crucial characteristics of mangrove forests such as the area of mangrove forests in farm, the density of mangrove trees per 100 square meter, and the area of mangrove forests within 500, 1000, and 2000, are utilized in this paper. The main estimation method is the Maximum likelihood (ML) estimator for the log-likelihood function employed to investigate the relationship between mangrove forests and profit as well as its variability. Apart from the ML estimator, other estimation methods (including FGLS, Robust S.E, and SUR) are also employed to test robustness of the regression results. The results show robust evidences that mangrove forests have negative effect and variance-reducing effect on profit in extensive and semi-intensive aquaculture farms. From these results, it implies that when converting more mangrove into water surface area, farmers earn higher profit at higher risk, and that a risk-averse farmer will plant more mangrove forests in farm than the risk-neutral farmer.* (JEL Q12, O13, Q22, Q23)

Keywords: Mangrove forests, Production risk, Aquaculture, Profit function.

Abbreviations: FGLS - Feasible Generalized Least Squares; ML - Maximum Likelihood; OLS - Ordinary Least Squares; SUR - Seemingly Unrelated Regressions; WRI - World Resources Institute.

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1. INTRODUCTION

Mangrove forests are primary ecosystems along coastlines, riverbanks in the tropical and subtropical regions of the world. They provide protection to deal with extreme climate problems such as storms, floods, and tsunamis. About 30 mangrove trees per 100 square meters with the depth of 100 meters may prevent the damage of a tsunami up to 90 percent (Hiraishi and Harada, 2003). Based on biodiversity, mangroves also provide good habitats as well as nutrients to flora and faunal species, for instance birds, monkeys, and snakes. Moreover, mangrove forests can alleviate erosion of riverbank shoreline and alleviate the rising of sea level with allowable and reasonable cost (e.g. Khail, 2008; Paola, 2012). In addition, mangrove forests contribute a significant part to income of households who live nearby mangrove forests. Barbier (2007) found that people could earn $12,392 per hectare of mangrove forest, economic annual value, from wood products, fishery and non-wood products (e.g. honey, nipa palm).

Nowadays, the area of mangrove forests have been significantly shrunk worldwide since the mid-twentieth century. Specifically, over one-fifth of mangrove forests have been lost since 1995 (Spalding, Kainuma, & Collins, 2010), and most of mangrove forests decrease occur in Southeast Asia and Latin America. For example, 70 percent of the mangrove forest was diminished in the period from 1920 to 1990 in Philippines, while this rate in Malaysia was around 17 percent during the period of 1965-1985 (WRI 1996). The area of mangrove forests in 1993 have existed about 54 percent in comparison with this one in 1975 in Thailand (Sathirathai, 1998).

In Vietnam, the rapid reduction of mangrove forests occurred in the last century. Do (2005) showed that the mangrove forests area was as much as 400,000 ha in Viet Nam in 1940s, but this area was reduced to only 170,000 ha in 2010 (Phan and Quan, 2012). There are many reasons for the decrease in mangrove forest areas such as conversing of forest land to economic activities, harvesting timber products, and increasing in population; whereas the major factor is the expansion of aquaculture ponds into mangrove forests (Spalding, Blasco, and Field., 1997; Lewis et al., 2003). Besides, the deforestation of mangrove forests has significantly increased in recent years in South Asia due to the use and scale of forest products of local users (Giri et al., 2011).

From the beginning of 1995, in the South of Viet Nam, mangrove forests have been distributed and contracted to households for the purposes of livelihood and conservation. Some parts of the allotted mangrove forests, under this policy, can be converted (depending on each province's policy) to economic activities comprising aquaculture, agriculture and other fields. In more detail, households can convert a certain part of mangrove forests in farms to areas utilized for shrimp farming or crops cultivation. However, the area of mangrove forests allotted to households was over-exploited because of the poor enforcement of regulations in Vietnam. This over-exploitation has brought some serious problems to social as well as household's welfare, for instance floods, hurricanes, and storms. Therefore, the existence of mangrove forests in production area has contributed to household's welfare and helped to alleviate the damage caused by natural disasters in production process.

Researchers have recognized the importance of mangrove forests and the reality of deforestation. Hence, most of studies have focused on calculating of the value of mangrove forests or finding a good way to reduce mangrove deforestation. Furthermore, some studies attempt to investigate the behavior of households towards the conversion of some area of mangrove forests into other land uses. Nevertheless, whether the existence of mangrove forests have effects on household production activities in the area of aquaculture or agriculture is still an open question.

Therefore, this paper aims to investigate the effects on household production in aquafarming of mangrove forests in the Mekong river delta through estimating the profit function for various types of aquaculture comprising extensive, intensive and semi-intensive culture. The proposed hypothesis is that mangrove forests will improve or mitigate risks in aquaculture production through reducing cost of water treatment, mitigating damage of climate changes, etc. Since mangrove forests are often planted inside and outside extensive and semi-intensive aquaculture farms (including mangrove forests and surface water), this thesis concentrates on analyzing the impacts of mangrove forests on profit and profit variability in these farms. As a result, the study will provide information local farmers and authorities about the advantage of mangrove forests and propose recommendation to policy makers these kinds of aquaculture often contain a certain area of mangrove forest either into or around farms.

2. THEORETICAL BACKGROUND

This section briefly reviews theories about the ecological functions of mangrove forests and their role in the production process. Additionally, the theory of production risk is also reviewed in this part. To demonstrate these theories, this paper also represents empirical studies which are analyzed the impacts on economic activities of mangrove forests and estimated the effects of inputs on production risk.

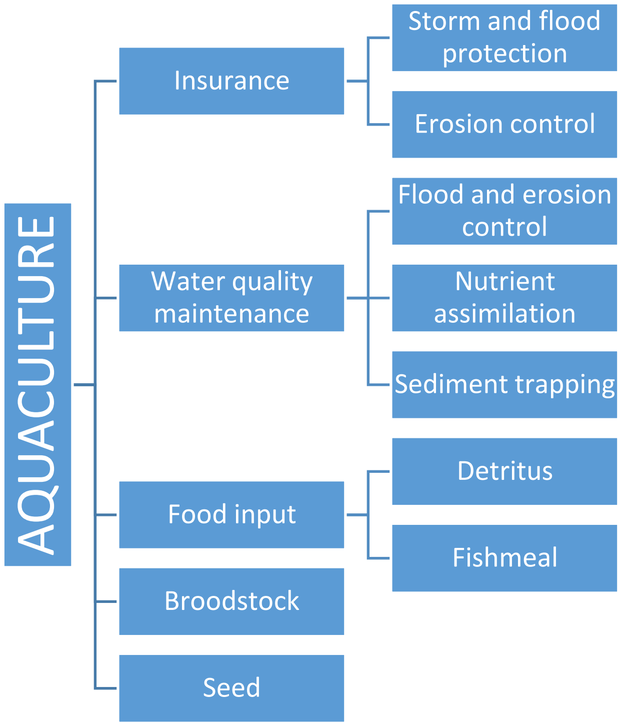
2.1 The ecological functions of mangrove forests

Mangroves are diverse huge and pervasive categories of trees and shrubs that live in the tropical and subtropical regions of the world. They can easily adapt to difficult environmental conditions and are one of important plants in the ecosystem that have brought a high productivity. “Mangroves provide a wide range of ecological services like protection against floods and hurricanes, reduction of shoreline and riverbank erosion, maintenance of biodiversity, etc.” (Rönnbäck, 1999). These functions help maintain economic activities in coastal areas and in the tropical region such as the Southeast Asia. Besides, mangrove ecosystems provide local economic activities with natural products which are directly harvested, for example wood, aquatic products, and birds.

In terms of aquaculture production, the mangroves support some diverse services for production activities through the mechanisms in Figure 2.1. Above all, mangrove forests play an important role in alleviating the turbulences of environmental conditions which can destroy aquaculture production in coastal areas such as floods, hurricanes, and storms.

Secondly, mangrove forests help to sustain the quality of water. This function helps to decrease levels of pollutants, mitigate variation in salinity and turbidity, etc. Larsson et al. (1994) and Kautsky et al. (1997) imply that the existence of mangrove forests in semi-intensive farms for shrimp production is necessary to maintain the water quality. Mangrove forests are also a safe habitat for predators as well as a good habitat for mollusk species to seek food through this tangled root system (Nagelkerken et al., 2008). In addition, mangrove forests provide nutrients to the coral reef and flora communities. This root system also reduces the flow of tidal water, causing the deposition of sediment which may filter out and treat toxins. It is easy to see that the value of wastewater treatment via mangrove forests is better than the expense to set up a new wastewater treatment system. Hence, the integrated shrimp-mangrove farming is being encouraged in recent years.

Figure 2.1. The ecological functions of mangrove forests are in seafood production



Source: Rönnbäck (1999)

Moreover, mangroves can produce and supply food inputs to aquatic organisms in aquaculture activities (Nagelkerken et al., 2008; Hong and San, 1993). The first, organic material and nutrients may be directly served as a food input to fauna species in the mixed shrimp-mangrove farms (e.g. extensive and semi-intensive aquaculture). Furthermore, they can be exported to specialized production areas (e.g. intensive aquaculture). Larsson et al. (1994) found that the area of semi-intensive farm covers approximately 25% of the area of mangrove forests, whereas it provides about 70% the quantity of shrimp food in compared with a semi-intensive farm without mangroves. And the rest of shrimp food is from the bacterial and fungal films on mangrove leaf detritus. The last one is fish and mollusk species producing from mangrove forest systems can be used as a direct input food or a component in formulated foods in aquaculture.

Finally, the natural seed production in mangrove forests perhaps express the crucial relationship between mangroves and aquatic organism farming. The developing of juvenile fishes and shrimps in mangrove system can be explained by reasons such as the wealth nutrition, diminished water force caused by the shallow water ecosystems, and sophisticated tangible composition in mangroves (Beck et al., 2001). These features can affect natural hatcheries for fish and shrimp cultivation, extend density, and maintain the level of growth as well as the survival of seed. Furthermore, the availability of seed is low in mangrove forests can reduce the productivity of aquatic organism cultivation (Menzel, 1991). Kautsky et al., (2000) claimed that mangrove forests have directly affected on the productivity and sustainability of shrimp cultivation. Consequently, these advantages of mangrove forests can affect the mangrove forest conservation behavior.

Apart from the advantages of mangrove forests, many empirical studies have shown evidences of adverse effects of mangrove forests on aquaculture. In reality, three systems which combines mangroves and aquaculture are integrated, associated, and separated mangrove-aquaculture farming systems. Johnston et al., (2000a and 2000b) with technical evidences from the mixed mangrove-shrimp systems proposes that pond design, poor water quality and management technique are crucial factors in declining shrimp outputs in those systems. Moreover, water quality and biodiversity in ponds have been affected directly from mangrove forests.

In particular, the leaf-litter fall have crucial role to survival and growth of shrimps (Johnston et al., 2000b), and each species of mangrove brings different effects to aquatic organisms in farms (e.g. Basak et al., 1998; Tran and Yakupitiyage, 2005). First, dissolve oxygen was consumed significantly in decomposition process of leaf litter. The decomposition rate of leaf litter also varies with species and different environmental conditions, and this happens faster in ponds than on lands (e.g. Ashton, Hogarth and Ormond, 1999; Dick and Osunkoya, 2000). Second, the high of leaf litter loadings in ponds have contributed negative effects to aquatic organisms via reduced water quality, sediment quality, and body weight of shrimp (Fitzgerald, 2000 cited by Tran and Yakupitiyage 2005). In this way, it leads to decrease of natural food production in aquatic ponds (Lee, 1999). In ponds without aeration, aquatic organisms even died within 2 days if the loading rate of leaves is more than 0.5 g DM L-1 (Tran and Yakupitiyage, 2005). Finally, the low levels of dissolve oxygen in ponds can cause physiological inhibition which leads to low productivity in extensive farming. In fact, survey on water quality in the mixed shrimp-mangrove forests systems found that the level of dissolve oxygen is low and ranges from 0,3 to 3,9 ppm (Roijackers and Nga, 2002).

In fact, compounds extracted from mangrove trees will have negative effects on survival and growth of aquatic organisms. In particular, tannic acid extracted from mangrove leaves is the main poison which causes profit from aquiculture to reduce, especially Rhizophora leaves (Inoue et al., 1999 cited by Primavera 2000). According to Madhu and Madhu (1997, cited by Tran and Yakupitiyage 2005), besides, aquatic organisms (e.g. shrimp and crab) have been seriously damaged by compounds extracted from other aspects of mangroves trees such as root, bark and stems.

In addition, the age of mangrove trees, the density of mangroves, and the mangroves coverage in farm may induce damage to aquatic organisms. Binh, Phillips, and Demaine (1997) implies that the age of mangrove trees in farms which is older than 7 years will decrease shrimp profit owing to less nutrients producing when the trees are older. Meanwhile, high-density of mangrove forests decrease fish yield due to creating a good habitat to attract predators (e.g. birds and snakes) and reducing of plankton and benthic algae (Burbridge and Koesobiono, 1984 cited by Primavera 2000).

To sum up, the ecological functions of mangrove forests mayhap bring both advantages and disadvantages to household and social welfare. Despite the opposition of many farmers to mangrove forests, there were compelling evidences suggest that mangroves forests play important role to deal with the unexpected changes of natural conditions which can damage production means (e.g. ponds, seeds). Nevertheless, in terms of economics, the role of mangrove forests in aquaculture has still existed many shortcomings. Therefore, specified mangrove-aquaculture models will bring various economic benefits to farmers.

2.2 The theory of production risk

Production risk may be caused by many reasons like natural disasters, human mistakes, misapply technologies, etc. This may lead to a variability of output or revenue target in production process. Hence, production risk have attracted significant attention from researchers and policy makers recently. Most researchers cope with production risk by employing Just and Pope (1978) framework. In the paper of Just and Pope (1978), they introduced eight postulates which satisfy the utilization of specifications for stochastic production function incorporating risk. Several postulates of Just and

Pope (1978) force restrictions on the mean function are similar to the usual deterministic function. Other postulates are flexible conditions for an output variance function. The key significance in their specification is marginal risk in input use may be positive, zero or negative. Namely, inputs are permitted to be either risk-increasing or risk-reducing. As a result, they imply shortcomings on popular production specifications in production studies such as $y = f(x)e^{\varepsilon}$ with ε is a stochastic disturbance ($E(\varepsilon) = 0$; $V(\varepsilon) > 0$). For such specifications, there are often positive in marginal risk. Besides, for an additive specification $y = f(x) + \varepsilon$, marginal risk is frequently zero.

To overcome the shortcomings above, a stochastic production function includes the mean and variance (risk) function, should satisfy eight postulates in the Just and Pope framework; then the impacts of inputs on each function is specified. The Just and Pope framework seems to be a prior theory on production risk, so it affects most of later theoretical as well as empirical studies. The Just and Pope framework for a stochastic production function is presented as:

$$y = f(x) + h^{\frac{1}{2}}(x)\varepsilon$$

Where $f(\cdot)$ is the mean function, $h^{\frac{1}{2}}(\cdot)$ is the risk function, and ε is production shock with mean of zero and variance of σ_{ε}^2. The vector of inputs is represented by x in the mean function, though the risk function contains not only identical inputs as the mean function but also some other elements.

It is easy to see that the effects of inputs on output and variability of output are separated. In particular, inputs can exert a positive effect on output, but not necessary to be a positive effect on variability of output. Thus, the sign of marginal risk and marginal effect of input use on marginal productivity variability depend on the effect of input on variability of output. These marginal effects are verified now:

$$\frac{\partial V(y)}{\partial x_i} = h_i(x)\sigma_{\varepsilon}^2$$

$$V\left(\frac{\partial y}{\partial x_i}\right) = \frac{h_i^2(x)\sigma_{\varepsilon}^2}{4h(x)}$$

and

$$\frac{\partial V(\frac{\partial y}{\partial x_i})}{\partial x_i} = \frac{h_i\sigma_{\varepsilon}^2[h(x)h_{ii}(x) - h_i^2(x)]^2}{2h^2(x)}$$

Based on the Just and Pope framework, moreover, it is obvious to see that the risk function seems to be a disturbance term. It is described as:

$$y = f(x) + u$$

where u is the error term, $var(u) = h(x)\sigma_{\varepsilon}^2$, and mean of zero. According to the theory of heteroskedasticity, results in estimated parameters are still consistent but not efficient due to bias in estimated standard errors. To settle this problem, empirical studies have employed some estimation methods to estimate the mean function and risk function together such as Maximum Likelihood, SUR, or FGLS.

2.3 Empirical studies

This part briefly reviews empirical papers of the impact of mangroves on aquaculture production. In fact, the studies of this issue in the economic field are limited. Meanwhile, the impact of mangroves on household's production has been studied from a biological perspective.

2.3.1 Integrated shrimp-mangrove farming systems in the Mekong delta of Vietnam (Binh et al, 1997)

To investigate the integrated shrimp-mangrove system in Ngoc Hien district, Binh et al (1997) used a sample of 161 households (living on the west and east coast) who operate shrimp farming and directly took part in the culture. The authors collected primary and secondary data about economy, environment and technology from the interview survey at Ngoc Hien district (the Forestry Fisheries Department, the Provincial Fisheries Department, the Provincial Forestry Department, and the State Forestry Fisheries Enterprises). They find that the negative effects of mangrove density, pond age, and pH on shrimp yields existed on the east coast, but the same did not occur on the west coast. In terms of economics, farming systems with about 30%-50% mangrove area in a pond will give the highest return. On the other hand, a pond with the cleared mangroves will give the lowest annual return. These results imply that the integrated mangrove-shrimp farming system will get a better economic return, if mangrove forests are maintained.

2.3.2 Effect of an integrated mangrove-aquaculture system on aquacultural health (Peng et al, 2009).

Based on experiment method, Peng et al (2009) tried to find out whether the traditional method or integrated mangrove aquaculture farming is better. They classified nine experimental aquaculture ponds and one control pond without mangrove forests, then all ponds fed two fish species in the first year and additional crab species in the following year. Through that approach, they can observe for a period of three years the differences between experimental ponds and control pond in terms of water quality, production of aquatic organisms, and growth of mangroves in integrated mangrove-aquaculture farming systems. Their findings imply that water quality of experimental ponds is better than the control ponds while Aegiceras corniculatum is the best type for improving water quality compared with the rest. In general, the experimental ponds had higher yield more than the control pond with 19% in the first year. Particularly, the experimental ponds planted with Kandelia obovata and Aegiceras corniculatum brought a higher seafood yield than the experimental pond planted with Sonneratia caseolaris. Moreover, they found that if an aquaculture pond had 15% of its area planted with Aegiceras corniculatum, the pollutants in production process would be reduced and aquaculture production quality would be improved.

3. RESEARCH METHODS

3.1 Model specification

As mentioned in the literature review above, the economic activities are being effectively protected and supported by the ecological services of mangrove forests system, then the economic value of that ecological functions are proved to be evaluated by an indirect approach. Although the worth of these services is principally non-marketed, the surrogate market valuation can be employed to value mangrove forests. Travel cost, hedonic pricing methods are standard techniques used to evaluate a non-marketed good basing on the information of marketed goods that is related to that goods. In particular, those methods find out the derived demand of consumers for the ecological functions of mangrove forests.

Another approach utilized to evaluate the ecological services of mangrove forests is the production function approach. The procedure of this approach consists of two steps which examine the physical impacts of ecological services on economic activities and the impacts of ecological changes on the change of corresponding economic activities' output. Thus, this implies that the ecological services of mangrove may act as an input in the production function, and it could be a proxy for productivity in the function (e.g. Barbier, 1994; Barbier, 2000).

Under assumption of constant absolute risk aversion ($\alpha > 0$), Coyle (1992 and 1999) suggests that the utility function of farmers is a function of farmer's risk preferences:

$$U = \bar{\pi} - (\frac{\alpha}{2})\sigma_{\pi}^2$$

where $\bar{\pi}$ is expected profit and σ_{π}^2 is profit variance.

As mentioned previously in the literature review, the Just and Pope stochastic restricted profit function is utilized to investigate the effects of mangrove forests on profit and variability of profit in extensive and semi-intensive aquaculture farms. The profit function and the Just-Pope production function are:

$$\pi = py - wx$$

$$y = f(x) + h^{\frac{1}{2}}(x)\varepsilon$$

The mean and variance of profit are:

$$\bar{\pi}(x) = p\bar{y} - wx = pf(x) + ph^{\frac{1}{2}}(x)\varepsilon - wx$$

$$\sigma_{\pi}^2(x) = p^{\mathbf{2}}\sigma_{y}^2 = p^2 h(x)\sigma_{\epsilon}^2$$

Based on the previous findings in the primal approach and properties of profit function, moreover, the proxies for the existence of mangrove forests in aquaculture areas are treated as an input into the short-run profit function. Besides, the variance function in this research will be specified as Harvey (1976), and the important property of Harvey's formulation is that the variability of output should be positive. The model specification for the restricted profit function and its variance function are illustrated below:

$$\pi_i = f(p_i, w_i, x_i) + u_i \qquad var(u_i) = h(z_i) = \exp(z_i\beta_i)$$

where i subscript denotes ith farm; p and w is a vector of output prices and input prices, respectively; x is a vector of fixed inputs in the short-run; and z is a vector of inputs in the risk function. Particularly, empirical variables utilized in this paper will be described in Table 3.1.

Table 3.1 Data matrix

Key concepts	Empirical variables	Unit	Notation
Profit	Profit per square meter in farm	VND	*properm2*
Output price	Selling price of aquatic products in farms	VND/kg	*prioutput*
Fry price	Buying price of fry inputs (e.g. shrimp seed)	VND/ind	*pribreed*
Chemical price	Buying price of chemical inputs	VND/kg	*pripes*
Labor family	The amount of hours worked of labor family	Hours	*hourlf*
Total cultivated area	Total area includes mangrove area and surface water area	m2	*sumarea*
Age of household head	Age of household head	Years	*age*
Education of household head	Schooling years of household head	Years	*schyears*
The characteristics of mangrove forests	The ratio of mangrove area to total cultivated farm (= mangrove area/total cultivated area)	%	*mangratio*
	The density of mangrove trees in farm	Trees/100 m2	*mangdens*
	The area of mangroves in the radius of 500, 1000, and 2000 meter	m2	*mang500; mang1000; mang2000*
Production scale	Total cost of producing aquatic products	Million VND	*Costm*

The linear and linear quadratic functional form for the short-run profit function will be employed in this study, as described below:

Firstly, a linear mean unrestricted profit function and the risk function are:

$$properm2_i = \alpha_0 + \alpha_1 prioutput_i + \alpha_2 pribreed_i + \alpha_3 pripes_i + \alpha_4 hourlf_i + \alpha_5 sumarea_i + \alpha_6 age_i + \alpha_7 schyears_i + \alpha_8 (mangratio_i/mangdensity_i/mang500_i/mang1000_i/mang2000_i) + u_i \quad (3.6)$$

$$\text{var}(u_i) = exp(\beta_0 + \beta_1 costm_i + \beta_2 (mangratio_i/mangdensity_i/mang500_i/mang1000_i/mang2000_i)) \quad (3.7)$$

Secondly, a linear quadratic mean unrestricted profit function (3.6 and 3.8) is simply presented with m input factors (explanatory variables include input prices (*prioutput, pripes, pribreed*), fixed input amounts (*hourlf* and *sumarea*), farmer characteristics (*schyears* and *age*), and the characteristics of mangrove forest). Also, the risk function (3.7 and 3.9) is described with n risk inputs (including cost and the characteristics of mangrove forest) with the dependent variable of profit variance ($var(u_i)$), which is predicted from the mean profit function.

$$properm2_i = \alpha_0 + \sum_k \alpha_k m_{k,i} + \frac{1}{2}\sum_k \sum_j \alpha_{kj} m_{k,i} m_{j,i} + u_i \qquad (3.8)$$

$$var(u_i) = exp(\beta_0 + \sum_k \beta_k n_{k,i} + \frac{1}{2}\sum_k \sum_j \beta_{kj} n_{k,i} n_{j,i}) \qquad (3.9)$$

3.2 Data collection method

3.2.1 Data requirement

The survey data is required to examine the research objective. The survey types include face to face, mail, telephone, and internet survey, whereas the most efficient type is face to face survey. Though other types of survey are easy to carry out, survey results may be less reliable. Therefore, to get reliable survey data, a face to face survey was chosen.

After the questionnaire had been completed, a pilot survey with a small sample size of farmers was conducted afterward to test the reasonability of the questions. Then, the questionnaire was revised before conducting the proper survey. All enumerators were carefully trained by experts in production economic field. Data was collected over a period of two months. To ensure the high response rate and the willingness to participate in the research, respondents received an amount of VND 50.000 for completing the questionnaire. Although the larger sample size will take higher accuracy of estimation, data was collected as much as possible within the constraint of cost and time.

A cross-sectional data is obtained in the survey. The questionnaire consists of two parts. The first part consists of general questions about respondent such as schooling years, age, experience years, and so on; the second one includes information of aquaculture activities last year. For instance, cost, revenue, input and output prices are mentioned and described in questionnaire (outlined in Appendix A). On the other hand, questions about mangrove forests are make up the main in part two, and they will be discussed hereafter in more detail.

3.2.2 Data for mangrove forests

As noted in the literature review above, local residents cultivate aquatic organisms by combining mangrove plants through the mixed mangrove-aquaculture farming systems such as integrated, associated, and separated. In the integrated system, mangroves are planted along canals within farms. In the associated system, mangroves are planted concentrated on surface of ponds. In the separated system, mangroves are planted outside ponds. These systems is depicted in more detail in Figure 2.2. Based on the research objective as well as those systems, therefore, the paper will use variables that reflect the impacts of mangrove forests on household's production in aquaculture (mostly shrimp farming), as follow:

- The (self-reported) density of mangrove trees in the area of aquaculture farm (trees/100 m2).
- The (self-reported) area of mangrove forests in the sum area of aquaculture farm (m2).

- The calculation mangrove forests in the radius of 500, 1000, and 2000 meter using GIS map (m2).

3.3 Estimation methods

In this section, tests for production risk known as heteroskedasticity tests that will be applied to this paper; are Goldfeld-Quandt, Breusch-Pagan-Godfrey, White's General Heteroskedasticity, and Breusch-Pagan LM tests. If heteroskedasticity is detected, the estimation methods which can deal with heteroskedasticity and examine the effects of mangrove forests on profit as well as profit variability will be applied.

Moreover, the main estimation method which is used to address research questions, is the Maximum Likelihood estimator for the log-likelihood function. This method is proved to be more consistent than FGLS (Harvey, 1976 and Saha et al., 1997). Additionally, Wang and Schmidt (2002) also advocated the use of MLE due to the biasness of two-step estimation. However, other estimation methods (i.e. FGLS, SUR, and Robust S.E) will be also employed to estimate the models in order to clarify the fundamental concern of non-robustness of the regression results.

Based on previous studies (Saha et al, 1997; Isik and Devadoss, 2006), the log likelihood function in this paper is presented as:

$$lnLF = -0.5\left[N * \ln(2\pi) + \sum_{i=1}^{N} \frac{(\pi_i - f(x_i, \alpha))^2}{\exp(z_i, \beta)} + \sum_{i=1}^{N} \beta x_i\right]$$

All equations for the profit function and the risk function will be in turn substituted to the log likelihood function. As mentioned above, the unknown coefficients (α, β) with given π_i will be estimated simultaneously in one-step estimation via ML estimation. This leads to a better estimator than separated estimator of each function. Since statistical software packages for the log likelihood function in this paper are unavailable, the authors will have to program a ML estimator ourselves in STATA 13.

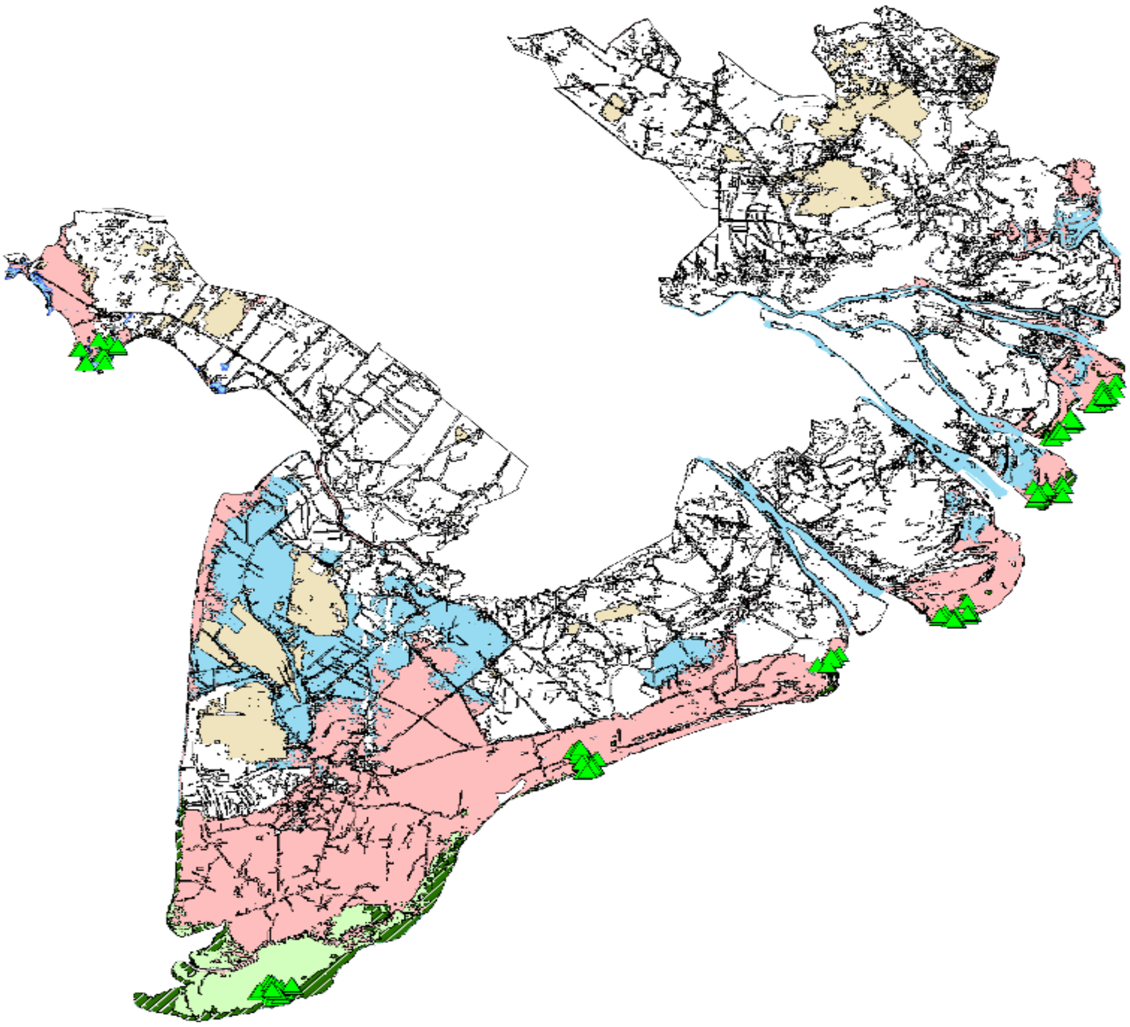
4. RESEARCH RESULTS

4.1 Descriptive statistic

A data survey was conducted in the Mekong river delta, and a total of 278 aquaculture farms (mostly shrimp farms) under extensive and semi-intensive cultures was collected. Figure 4.1 presents the area utilized in agriculture and aquaculture in the Mekong delta. Generally, the area of aquaculture depicted as the pink areas (including intensive and extensive culture) is larger than other regions of the whole country. The zones of green-white stripes denote the area of coastal mangrove forests. Observed aquaculture farms were distributed across the pink areas and the green-white stripes areas as green triangles.

Due to inadequate or absent data on production details, some observations cannot be analyzed. In addition, farms with an outstanding proportion in factors seem to be potential outliers in the sample, those observations were dropped from the sample. As such, a total of 205 observations with completed information about the ratio of mangrove forests in farms and the density of mangrove forests per 100 square meter were defined in the final analysis. Nonetheless, the number of observations with completed data for the mangrove area in 500, 1000, and 2000 meter are 194.

Figure 4.1 The distribution of observed aquaculture farms



The descriptions of data presenting the mean, standard deviation, minimum, and maximum values for each variable is showed in table 4.1. From the table, a mean value of profit per a square meter in aquaculture is 3,111.65 VND; whereas about 25 percent of observed farms in the sample got loss in the last season. The average value of output price, chemical price, and fry price (including shrimp, crab, fish, and blood cockle) is approximately 190,000 VND/kg; 30,000 VND/kg; and 538 VND/ind; respectively. The average area including surface water area and mangrove area is roughly 27000 square meter, whereas the minimum area is about 1000 square meter and 17 hectare for the maximum area. The mean number of household's working hours is about 99 hours for the equivalent to 12 days, whereas some aquaculture farms have not attention of households in production process. Most of the education level of operators is very low, even illiteracy. Other collected information including the characteristics of mangrove forests are the ratio between mangrove area and total area, the density of mangrove trees in farm, and the area of mangrove forests around farm (e.g. 500, 1000, and 2000 meter). The average value of mangrove ratio, mangrove density, and mangrove area around farm is approximately 31 percent, 88 trees, as well as 57,000, 190,000 and 550,000 square meter, respectively. Generally, the degree of variation in the data sample is quite well over the observed area.

Table 4.1 Descriptive statistics of the variables in the sample data

Variables	No. Obs.	Mean	Std. Dev.	Minimum	Maximum
properm2	205	3,111.65	5,228.62	-5,100.83	33,042.86
Input and Output prices					
prioutput	205	189,577.90	56,287.27	44,813	368,678
pripes	205	29,770.95	18,075.52	1,300	118,462
pribreed	205	537.40	846.28	20	6,514
Fixed inputs					
sumarea	205	26,064.42	20,946.59	1,000	100,000
hourlf	205	98.47	189.72	0	1,120
The management ability					
age	205	49.73	11.99	23	83
schyears	205	6.04	3.32	0	16
The characteristics of mangroves					
mangratio	205	29.65	27.31	0	88.89
mangdens	205	74.78	137.21	0	900
mang500	194	54,816	155,331.70	0	759,038
mang1000	194	183,530	482,494.70	0	2,208,348
mang2000	194	536,244.10	1,162,627	0	5,593,181
Production scale					
costm	205	22.43	19.93	0.36	157.75

4.2 Bivariate analysis

4.2.1 Mangrove forests versus profit

The characteristics of mangrove forests including the ratio and density of mangroves within extensive and semi-intensive farms, and the area of mangroves within 500, 2000 meter are employed to examine the impact of mangrove forests on profit in aquaculture activities. Figure 4.2 represents scatter diagrams of profit per square meter by the ratio of mangrove area, the density of mangrove trees in 100 m2, and mangrove area in the radius of 500 and 2000 meter. Graphically, profit per square meter in extensive and semi-intensive farms tends to decrease with the ratio of mangrove forests and mangrove tree density in farms. Most the ratio of mangrove areas in farm that have high profit per square meter is minimal. Moreover, the trend line suggests the uncompelling evidence of negative relationship between profit and the ratio of mangrove forests in farm. The graph also shows the majority of farms with zero percentage of mangrove forests. This is simply because many farmers tend to violate the regulation of mangrove conservation, which resulted in the destruction of mangrove in extensive and semi-intensive farms.

In addition, from a glance of this figure, we can see that most farms concentrate in the quadrant which mangrove trees density is less than 100 trees and VND 5,000 for profit per square meter. Interestingly, farms with high density of mangrove trees per 100 m2 will be less profitable compared to farms with low density of mangrove trees. The trend line also confirmed the negative association between profit and mangrove trees density. This relationship is not special and similar to the relationship between profit and the ratio of mangrove forests in farm. On the other hand, the trend between profit and mangrove area in the radius of 500 and 2000 meter may be positive. Most farms have no mangrove forests within as well as outside cultivated area. Visually, these relationships are unclear, and there seems to be no impact of mangrove forests on profit in aquaculture production.

4.2.2 Mangrove forests versus profit variability

Figure 4.3 illustrates the relationship between production risk and the ratio of mangrove area, the mangrove tree density, and the mangrove area in the radius of 500 and 2000 meter. There is no graphical evidence showing that high ratio of mangrove area in farms will take higher production risk. Interestingly, production risk tends to decrease as the ratio of mangrove forests in farm increases. This tendency is quietly reasonable because of the presence of ecological services of mangrove forests for mitigating the damage of natural disasters and human mistakes. Furthermore, the trend line implies the negative impact of mangrove area in farm on profit variability. However, this negative correlation between profit and mangrove ratio is not conclusive.

Furthermore, the mangrove density of most farms concentrate in the range from 0 to 100 mangrove trees per 100 square meter. Besides, the association between production risk and mangrove trees density is unclear though the trend line is slightly downward. Nevertheless, the relationship between production risk and the area of mangrove forests in the radius 500 and 2000 meter is not negative. Visually, farms that have large mangrove area in the radius 500 and 2000 meter take higher risk than others. The trend line of those scatter diagrams also implies the positive relationship between production risk and mangrove area in the radius 500 and 2000 meter. Besides, production risk tends to be less fluctuated for large mangrove areas around farms.

These scatter diagrams above were provided an initial view about the association between mangrove forest and production risk (profit variability) in aquafarming. Visually, the relationship between production risk and the ratio of mangrove area and mangrove trees density in farm are negative, whereas the positive relationship between production risk and the area of mangroves in 500 and 2000 meter potentially exists. Nevertheless, all relationships above need to be confirmed via the regression analysis to determine causal effects.

Figure 4.2 Mangrove characteristics versus Profit per square meter

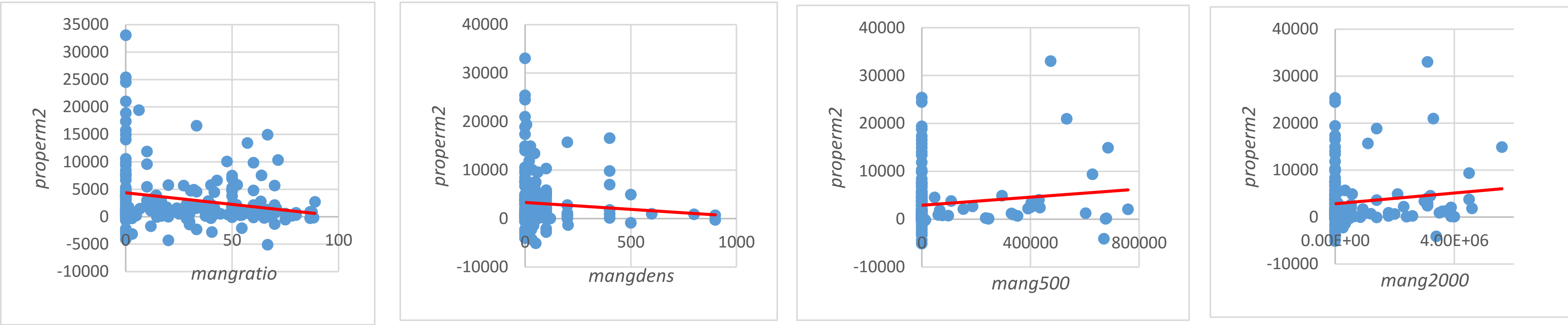
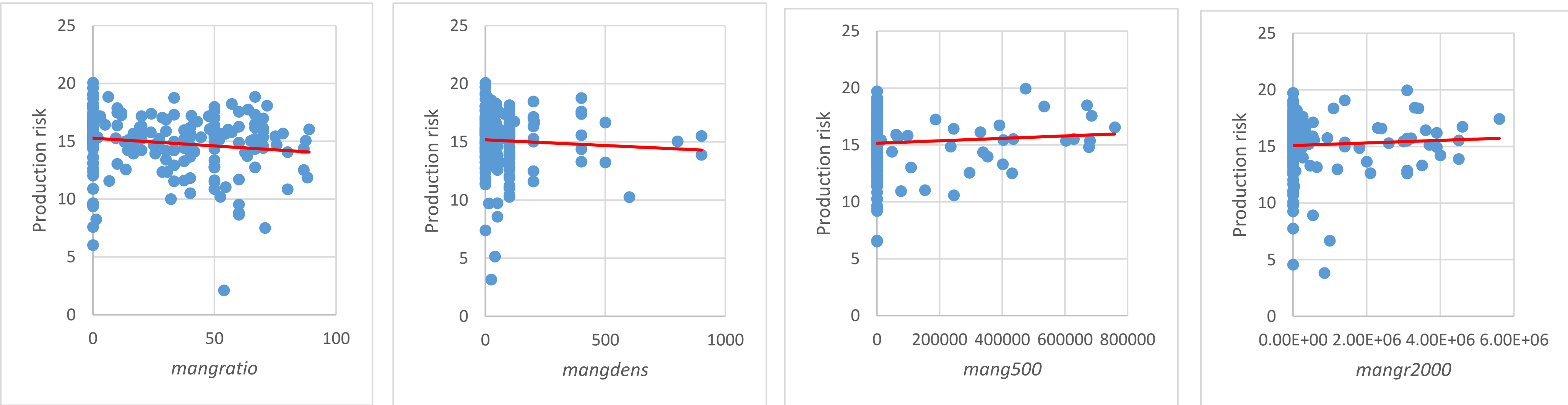


Figure 4.3 Mangrove characteristics versus Profit variability



4.3 Estimation results

Initially, the restricted profit function is specified by a linear and linear quadratic functional form, but most of coefficients on most of the square and cross-product terms in a linear quadratic functional form are not statistically significant to be a difficult to explain in this case study. Thus, empirical results for a linear functional form will be interpreted and discussed instead of a linear quadratic functional form in this section.

4.2.3 Testing for production risk

The models will be firstly regressed by OLS, then the presence of heteroskedasticity will be tested. Most of tests for heteroskedasticity indicate that the null hypothesis for constant variance was rejected in the models (as represented in Table 4.2). The 5% significance is adopted to conclude heteroskedasticity problem.

Table 4.2 Heteroskedasticity tests with the models

Heteroskedasticity tests	Model 1	Model 2	Model 3	Model 4	Model 5
White's test	93.55 (0.0000)	84.87 (0.0000)	96.63 (0.0003)	95.81 (0.0004)	114.08 (0.004)
Breusch-Pagan-Godfrey test	120.66 (0.0000)	31.44 (0.0001)	33.24 (0.0001)	32.14 (0.0002)	35.98 (0.0002)
Goldfrey-Quandt test**					
• **1/10 central observation omitted**	1.17 (0.05)	1.13 (0.05)	1.15 (0.05)	1.15 (0.05)	1.17 (0.05)
Breusch-Pagan LM test	98.85 (0.0000)	95.24 (0.0000)	98.78 (0.0000)	87.24 (0.0000)	95.41 (0.0000)
HET problem*	Yes	Yes	Yes	Yes	Yes

Note: F denotes the heteroskedasticity tests which fail to reject the null hypothesis of homoscedasticity.
The p-value is in the brackets
*conclusion at the significant level of 5%.
**the F-statistic

4.2.4 Regression results for the effect of mangroves on profit per square meter

At least one coefficient from each regression models is statistically significant due to the highly significant of Wald chi-squared coefficients at the 1% level (presented in Table 4.3). Both sign and value of coefficients are similar in the regression results of all model. As such, the results of models with difference of variable quantity are robustness.

All of compulsory variables such as *prioutput*, *pribreed*, and *pripes* are statistically significant in all model; and their sign are as expected. The positive effect of price of aquatic products on profit is recognized through the models, whereas the negative effects of input prices (including fry and chemistry) are obtained at the significant level of 1 percent. In particular, the coefficient of *prioutput* in the models is about 0.013, it means that an increase of 100 VND in the output price will raise by 1.3 VND in profit per square meter, ceteris paribus. The price of fry increases by 100 VND, profit per square meter will decline by 62.7 VND whereas an increase of 100 VND in the chemical price will lead to a decrease of 5.1 VND in profit per square meter, other things equal. As such, these effects are suitable in the properties of profit function as well as in the practice under competitive market.

Table 4.3 Regression results of mangrove forests and profit per a square meter (MLE)

Variables	**MLE**				
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
prioutput	0.013** (0.005)	0.013** (0.005)	0.013*** (0.005)	0.012** (0.006)	0.012** (0.005)
pribreed	-0.627*** (0.227)	-0.710*** (0.210)	-0.633*** (0.223)	-0.754*** (0.198)	-0.687*** (0.247)
pripes	-0.051*** (0.015)	-0.055*** (0.018)	-0.051*** (0.015)	-0.051*** (0.016)	-0.048*** (0.014)
hourlf	1.714 (2.613)	4.220 (3.332)	1.638 (2.585)	1.015 (2.504)	-0.132 (2.044)
sumarea	-0.042*** (0.014)	-0.058*** (0.016)	-0.042*** (0.014)	-0.056*** (0.016)	-0.042*** (0.014)
age	-23.166 (21.056)	-24.604 (25.006)	-23.5334 (21.915)	-39.562 (28.223)	-29.112 (21.198)
schoolingyears	108.682 (77.113)	140.062 (85.536)	104.315 (75.970)	140.938 (97.383)	85.495 (84.029)
mangratio	-30.828*** (10.824)	-	-30.538*** (11.538)	-	-33.917*** (12.234)
mangdens	-	-2.144 (1.698)	-0.333 (1.777)	-	-0.315 (1.416)
mang500	-	-	-	0.002 (0.007)	0.005 (0.003)
mang2000	-	-	-	0.0002 (0.001)	-0.0003 (0.0002)
Cons	4828.033*** (1696.291)	4296.14** (2000.367)	4896.151*** (1783.091)	4824.296** (1889.945)	5717.691*** (1863.356)
No. Obs	205	205	205	194	194
Wald chi-sq	49.38	43.56	51.15	51.67	60.35

Note: * denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%
Robust standard errors are shown in brackets

Furthermore, the relationship between the total cultured area and profit is found in this paper. At the significant level of 1 percent, the total cultivated area including the total area of surface water and mangrove forests in pond has negatively impact on profit per square meter. The coefficient ranges from -0.042 to -0.058 interpreting that if the total cultured area increases by 1000 square meter, profit per a square meter declines from 42 to 58 VND, ceteris paribus. This result reveals that a pond with larger area is more costly than smaller ponds due to higher management cost, fry cost, pond rehab cost, etc. As such, profit will be reduced. This result once supports the theory of production and empirical studies in agriculture (e.g. Sidhu and Baanante, 1981).

The characteristics of mangrove forests including the ratio of mangroves in farm, the density of mangroves in farm, and the area of mangroves within 500, 2000 meter are employed to examine the impact of mangrove forests on profit in aquaculture activities. Specifically, the impact of the mangrove ratio in farm and the density of mangrove trees per 100 square meter on profit are negative, which imply that a farm with high area of mangrove forests or high density of trees may lessen space, sunlight penetration and increase decaying leaves. This will increase production costs or reduce the quantity of output. The relationship between the area of mangrove forests within 500 as well as 2000 meter and profit is positive meaning that profit per a square meter may be increased if the mangrove area in a range of 500 and 2000 meter raises. However, table 4.3 represents that the only ratio of mangrove forests within pond is statistically significant at the 1% level in the relationship with profit, whereas the other proxies are not significantly statistic. The coefficient ranges from -30.538 to -33.917 explaining that an increase of one percent in the ratio of mangroves in farm, profit per 1000 square meter will decrease from 30,538 to 33,917 VND. This negative effect is complying with empirical studies in biological field (e.g. Primavera, 2000; Alongi et al, 2000; Johnston et al, 1999, 2000a and 2000b).

All the proxies of management ability which are age (*age*) and education (*schyears*) of the operator are considered as productive assets in aquaculture; nevertheless, the results do not support this relationship. Both *age* and *schyears* are statistically insignificant. However, the sign of *schyears* coefficient meets the expectation while age does not.

The number of household's working hours has positive impact on profit in aquaculture. The result can be interpreted that if members in family spend more time to monitor, guard, and rehabilitate pond, profit in aquaculture will increase. However, this effect is statistically insignificant in the models. This can be explained by the difficulty in measuring the number of household's working hours, due to the peculiarity of family workers and non-collectability of arbitrary family working hours.

Table 4.4 reports the regression results of the models using other methods (i.e. SUR, FGLS, and Robust S.E) used to test robustness of the regression results in Table 4.3. Preliminary examination of three testing estimation methods portrays the consistency in sign and magnitude of compulsory variables' coefficients compared with the ML estimation such as *prioutput, pribreed*, and *pripes*. The variable of interest represented by the ratio of mangrove forests within pond (*mangratio*) which shows the same results with the MLE. The rest proxies of mangrove forests (*mangdens, mang500*, and *mang2000*) are also not statistically significant, and these results are similar to results of the main method. Furthermore, the total cultivated are (*sumarea*) has estimated coefficient with the sign as the ML estimator, but the magnitude of the coefficient is not the same in the estimation methods.

Table 4.4 Regression results of mangrove forests and profit per square meter (FGLS and Robust S.E)

Variables	FGLS					Robust S.E					SUR				
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
prioutput	0.007** (0.003)	0.007** (0.003)	0.006* (0.003)	0.005 (0.003)	0.008** (0.004)	0.013** (0.006)	0.012** (0.006)	0.013** (0.006)	0.011* (0.006)	0.012** (0.006)	0.013** (0.006)	0.013** (0.006)	0.013** (0.006)	0.013** (0.006)	0.013** (0.006)
pribreed	-0.549*** (0.209)	-0.601*** (0.110)	-0.539*** (0.207)	-0.556*** (0.193)	-0.659*** (0.140)	--0.765*** (0.216)	-0.741*** (0.203)	-0.768*** (0.217)	-0.837*** (0.238)	-0.805*** (0.247)	-0.701* (0.382)	-0.513 (0.387)	-0.693* (0.382)	-0.721* (0.413)	-0.647 (0.408)
pripes	-0.019** (0.009)	-0.017* (0.010)	-0.020** (0.009)	-0.023** (0.011)	-0.021** (0.010)	-0.057*** (0.016)	-0.056*** (0.018)	-0.057*** (0.016)	-0.059*** (0.017)	-0.061*** (0.017)	-0.047** (0.019)	-0.049** (0.019)	-0.048** (0.019)	-0.055*** (0.020)	-0.053*** (0.019)
hourlf	5.464* (2.781)	6.473** (2.682)	5.133* (2.762)	6.836** (2.941)	4.969 (3.097)	4.260 (3.518)	4.887 (3.576)	4.247 (3.533)	4.619 (3.999)	4.075 (4.038)	3.724* (1.763)	4.202** (1.767)	3.709** (1.762)	3.794* (1.969)	3.408* (1.957)
sumarea	-0.008 (0.008)	-0.013* (0.008)	-0.012 (0.008)	-0.018** (0.007)	-0.015* (0.008)	-0.052*** (0.015)	-0.061*** (0.016)	-0.052*** (0.015)	-0.064*** (0.017)	-0.055*** (0.016)	-0.046*** (0.016)	-0.051*** (0.016)	-0.045*** (0.016)	-0.053*** (0.016)	-0.048*** (0.016)
age	-22.035 (18.050)	-22.773 (18.248)	-22.108 (18.134)	-23.708 (18.569)	-28.898 (18.386)	-24.122 (25.530)	-24.381 (27.099)	-24.710 (26.215)	-24.747 (28.379)	-23.243 (27.463)	-20.786 (27.772)	-22.555 (28.189)	-21.243 (27.834)	-22.219 (28.885)	-19.324 (28.605)
schyears	42.464 (61.957)	80.168 (63.179)	53.401 (62.803)	29.464 (71.616)	63.562 (63.708)	220.165** (98.448)	179.020* (95.329)	220.721** (98.450)	161.433 (99.193)	208.421** (104.143)	218.039** (101.261)	162.679 (101.165)	218.863** (101.177)	133.211 (104.027)	216.045** (104.497)
mangratio	-25.811*** (8.365)	-	-26.545*** (8.678)	-	-24.891*** (8.697)	-32.908*** (12.448)	-	-34.067** (13.188)	-	-32.841** (14.421)	-35.124*** (12.554)	-	-36.225*** (13.329)	-	-35.431** (14.040)
mangdens	-	-0.150 (1.523)	1.832 (2.066)	-	1.068 (1.933)	-	-1.520 (1.961)	0.654 (2.131)	-	0.331 (2.143)	-	-1.886 (2.423)	0.507 (2.533)	-	0.182 (2.573)
mang500	-	-	-	-0.001 (0.003)	-0.0003 (0.003)	-	-	-	0.0007 (0.004)	0.001 (0.004)	-	-	-	0.0005 (0.004)	0.0006 (0.004)
mang2000	-	-	-	0.0002 (0.0004)	0.0001 (0.0004)	-	-	-	0.0004 (0.0004)	0.0002 (0.0004)	-	-	-	0.0004 (0.0005)	0.0002 (0.0006)
Cons	3519.299*** (1299.847)	2593.066** (1269.36)	3663.748*** (1295.467)	3664.955*** (1348.26)	3900.202*** (1348.471)	4528.933** (2031.2)	4166.042** (2077.76)	4576.725** (2081.82)	4499.646** (2166.7)	4838.177** (2214.10)	4046.846** (1911.861)	3501.921* (1936.02)	4011.243** (1918.656)	3741.467* (1984.66)	4141.58** (1974.21)
No. Obs	205	205	205	194	194	205	205	205	194	194	205	205	205	194	194

Note: * denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%. White heteroskedasticity consistent standard errors are shown in brackets in Robust S.E

4.2.5 Regression results for the impact of mangrove forests on the profit variability

Table 4.5 reports the results of the models using the ML estimator, whereas the results using the other methods are shown in Table 4.6. The variables represent the mangroves coverage in ponds (i.e. *mangratio* and *mangdens*), which have a risk-reducing effect on profit in aquaculture activities of extensive and semi-intensive farms. Nevertheless, only *mangratio* is statistically significant at the significant level of 1 percent. Furthermore, the sign and magnitude of *mangratio* remain consistent when adding various proxies of mangrove forest. The *mangratio* coefficients of 0.011 in the models suggest that if the area of mangrove forests increases by 1 percent, the variability of profit per square meter will reduce by 0.011 percent, ceteris paribus. This result is in accordance with the mangrove ecological functions of preventing disaster consequences (e.g. flood, erosion, and hurricane).

Table 4.5 The impact of mangrove forests on the profit variability (the variance of profit - $var(u_i)$)

Variables	**MLE**				
	Model 1	Model 2	Model 3	Model 4	Model 5
mangratio	-0.011*** (0.005)	-	-0.010*** (0.003)	-	-0.011*** (0.004)
mangdens	-	-0.001 (0.001)	-0.0003 (0.0007)	-	-0.0002 (0.001)
mang500	-	-	-	1.9e-6 (1.6e-6)	2.6e-6 (1.6e-6)
mang2000	-	-	-	-1.3e-7 (2.4e-7)	-3.4e-7 (2.5e-7)
costm	0.0003 (0.004)	-0.001 (0.004)	0.0002 (0.004)	-0.006 (0.004)	-0.001 (0.004)
Constant	8.662*** (0.137)	8.535*** (0.136)	8.674*** (0.144)	8.513*** (0.149)	8.744*** (0.165)
No.Obs	205	205	205	194	194

Note: * denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%
The robust standard errors are shown in brackets

On the other hand, the rest of mangrove proxies are the area of mangroves within 500 and 2000 (i.e. *mang500* and *mang2000*) having different effects on the variance of profit. Particularly, *mang500* has a variance-increasing effect on profit in aquaculture while a variance-decreasing effect on profit is found in *mang2000*; nonetheless, neither attains statistical significance. Meanwhile, the scale effect has no statistical significance in the models.

Table 4.8 The impact of mangrove forests on the profit variability using other methods (FGLS, Robust S.E, and SUR)

Variables	FGLS					Robust S.E					SUR				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
mangratio	-0.014** (0.007)	-	-0.015** (0.007)	-	-0.014** (0.007)	-0.014* (0.007)	-	-0.015* (0.007)	-	-0.014* (0.008)	-0.014** (0.007)	-	-0.015** (0.007)	-	-0.014** (0.007)
mangdens	-	-0.001 (0.001)	0.001 (0.001)	-	0.0004 (0.001)	-	-0.001 (0.001)	0.001 (0.001)	-	0.0004 (0.001)	-	-0.001 (0.001)	0.001 (0.001)	-	0.0004 (0.001)
mang500	-	-	-	6.5e-7 (2.2e-6)	1.4e-6 (2.2e-6)	-	-	-	6.5e-7 (1.7e-6)	1.4e-6 (1.8e-6)	-	-	-	4.8e-7 (2.2e-6)	1.3e-6 (2.1e-6)
mang2000	-	-	-	3.7e-8 (2.9e-7)	-1.3e-7 (2.9e-7)	-	-	-	3.7e-8 (2.2e-7)	-1.3e-7 (2.1e-7)	-	-	-	5.7e-8 (2.9e-7)	-1.1e-7 (2.9e-7)
costm	0.001 (0.009)	-0.001 (0.008)	0.002 (0.009)	-0.001 (0.009)	-0.010 (0.009)	0.001 (0.010)	-0.001 (0.009)	0.002 (0.010)	-0.0005 (0.010)	-0.010 (0.015)	0.004 (0.009)	0.003 (0.008)	0.005 (0.009)	0.004 (0.009)	-0.006 (0.009)
Constant	15.259*** (0.336)	15.202*** (0.263)	15.262*** (0.331)	15.078*** (0.291)	15.60*** (0.354)	15.259*** (0.343)	15.202*** (0.246)	15.262*** (0.342)	15.078*** (0.304)	15.599*** (0.421)	15.175*** (0.334)	15.111*** (0.259)	15.178*** (0.326)	14.969*** (0.286)	15.508*** (0.347)
No.Obs	205	205	205	194	194	205	205	205	194	194	205	205	205	194	194

Note: * denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%

The standard errors are shown in brackets in FGLS, SUR

White heteroskedasticity consistent standard errors are shown in brackets in Robust S.E

Table 4.6 presents the results of the models using other estimation methods (including SUR, FGLS, and Robust S.E) adopted to test robustness of the regression results in Table 4.5. These estimation methods yield the similar results to the ML estimator, but the levels of significance of variables are different. Throughout the results of those methods, the sole proxy of mangrove forest which is the ratio of mangrove forests coverage in farm (*mangratio*) is statistically significant and have a risk-reducing effect on profit. Specifically, *mangratio* is statistically significant at the level of 5% in the SUR estimation, and the coefficients of approximately 0.014 implies that an increase of 1 percent in the ratio of mangrove forests coverage in pond will lead to decrease by 0.015 percent in the variability of profit, ceteris paribus. Meantime, the coefficients of *mangratio* are identical in the FGLS and Robust S.E estimation; however, the standard error in the FGLS estimation is not adjusted to correct for heteroskedasticity.

5. CONCLUSION AND POLICY IMPLICATION

Based on the empirical results from the previous chapter, this chapter will present the conclusion remarks of the study, from which implication will be inferred from. Some limitations of the research will also be articulated, and then suggestions to improve for further research will be introduced last.

5.1 Conclusion remarks

Four main findings deriving from the models using the estimation methods can be outlined as follow:

First, the negative relationship between the ratio of mangrove forests in farm and profit per square meter in aquaculture production is statistically significant at the significant level of 1 percent. However, the rest proxies of mangrove forests are statically insignificant in the models. These results are consistent in all estimation methods and in the line with some paper in biological field (e.g. Alongi et al, 2000; Johnston et al, 1999, 2000a and 2000b).

Second, mangrove forests have a risk-decreasing effect on profit. Thus, the ratio of mangrove forests coverage in farm has an important role to mitigate the variance of profit in aquaculture. This is complying with the natural conditions and geographic in Southwestern of Vietnam where usually confront with natural disasters (e.g. flood, hurricane, and erosion). Mangrove forests have been evaluated as a good insurance in aquafarming for households to alleviate the damage of those problems (Rönnbäck, 1999). Therefore, a risk-averse farmer chooses to plant more mangrove forests in farm than a risk-neutral farmer.

Third, the larger the extensive and semi-intensive aquaculture farms are, the lower the profit per square meter in aquaculture activities achieved. This is compatible with the reality because these farms are usually larger than 2 hectare, and this is difficult for households to control and manage issues related to production process such as providing adequate food for aquatic organisms and adopting shrimp protection.

Finally, the management ability of the operator have negligible effect on profit in aquaculture production in extensive and semi-intensive farms. Since the exchange of information and farming techniques is almost perfect, new entrants may imitate old ones to cultivate aquatic organisms in extensive and semi-intensive farms.

These results are important for risk-averse farmers who focus on not only the mean profit function but also factors have a variance-reducing effect and variance-increasing effect on profit. Therefore, they are expected to decide the optimal input levels that differ from risk-neutral farmers. Mangrove forests are one example. Even if mangrove forests are not statistically significant in the mean profit function, the increase of mangrove forest areas will decrease the variability of profit in extensive and semi-intensive aquaculture farms. Thus, the utility of households will increase.

5.2 Policy implication

The purpose of this study is to contribute empirical evidence of the benefits of mangrove forests in aquaculture activities, especially extensive and semi-intensive farming. Thence, farmers and local policy makers can make better-informed decisions on mangrove deforestation or reforestation. There are important policy recommendations as follow:

Above all, mangrove forests are a variance-reducing input on profit in aquafarming so that local authorities should encourage farmers to plant mangrove forests in the cultivated area for preventing production risk in aquaculture production.

Since total area (including mangrove forests) has a negative effect on profit in extensive and semi-intensive aquaculture farms, farmers should subdivide the cultivated area to manage and culture well, or policy makers should reduce allocated area for each household and increase the number of household contracted.

5.3 Limitations and further research

This study has some limitations that can be overcome in further researches. Above all, although three characteristics of mangrove forests are employed, this study does not consider other crucial characteristic of mangrove forests-the number of mangrove species. This characteristic represents biodiversity of mangrove forests and indicate which mangrove tree species bring benefits or drawbacks to aquatic organisms in aquaculture production. The second concern belongs to the lost information about the type of mixed mangrove-aquaculture farming systems each farm as each system will bring different effects to profit of extensive and semi-intensive farms, which is mentioned in Chapter 2. Finally, the restrictions of cross-section data are also a remarkable issue. Gujarati (2012) suggest that cross-section data is not the best selection to analyze complicated behavior models. It means that some inputs (i.e. mangrove forests) can be highly used to alleviate the effects of weather variation on production yield over time, so these effects cannot be accurately estimated using a cross-section data.

Above limitations are expected to be solve in further researches. Mangrove species should be taken into account when investigating the impact of mangrove forests on profit in extensive and semi-intensive aquaculture farms, and mangrove species data can be collected by interviewing operators directly. The limitation of types of mangrove-aquaculture farming systems may be solved by dummy variables which represent three popular types comprising integrated, associated, and separated systems. A panel data is necessary to test robustness of results in this paper. In this way, the impact of mangrove forests on profit variability using a panel data should be obviously examined in the further research.

Aside from further researches resolving these limitations, the way for future topics are also discussed. Firstly, the optimal ratio of mangrove forest areas in extensive and semi-intensive aquaculture farms, especially shrimp farms should be investigated to help policy makers. Secondly, further research should be not only determine the effects of mangrove forests on output levels and variability but also the covariance of output among aquatic organisms. Thirdly, further research should not identify and analyze the technical efficiency scores of extensive and semi-intensive aquaculture, operators have not invested any machines and applied techniques in production process.

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APPENDIX

Appendix A: Questionnaire

Code	Information		Answer choices
PART 1: GENERAL INFORMATION OF THE HOUSEHOLD			
B1	Type of farm entity		1. Subsistence; 2. Commercial
B2	Are you the head of the house hold?		1.Yes; 2. No - If the answer is "Yes", go straight to Question B5
B3	Age of the head of the household		Years
B4	Gender of the head of the household		1: Female; 2: Male
B5	Your age		Years
B6	Gender		1: Female; 2: Male
B7	Household size (of owner/manager of the farm)		Number
B8	Education of the head of the household (total years)		Years
PART 2: SEAFOOD FARMING			
S1	Farming area		Hectare
S2	Farming method		1. Intensive; 2. Extensive; 3. Semi-intensive
S3	Tenure type		1. Own land use; 2. Rented land from other person; 3. Rented land from government; 4. Unused land without ownership; 5. Other (specify)
S4	How many (average) number of years have you used these seafood farming area?		Years
S5	Total rent paid (per month) if plot is leased		Currency amount per month
S6	How many months do your seafood farming processes occur annually?		Months
S7	Annual output from seafood farming (shrimp, crab, fish, etc.)		Kg
S8	Average output from each rotation		Kg
S9	Average price for one kg of outputs		VND/kg
S10	Total value of annual output		VND

S11	Total value of outputs from one rotation		VND
S12	Number of working days per week		Days
S13	Average number of labors working on the field		Number of labors
S14	Daily average number of working hours (per labor)		Hours
S15	Average length of one seafood farming rotation		Days
S16	Value of seafood farming ponds, tools and machines?		VND
S17	Amount of seafood seed used in cropping in one rotation		Kg
S18	Average price for one kg of seafood seed		VND/kg
S19	Cost for seafood seed for one rotation		VND (Amount of seafood seed x Average price)
S20	Cost of antibiotics		VND
S21	Are your seafood farming activities area next to the mangrove site (within the distance of less than 100m)?		1. Yes; 2. No
S22	Are your seafood farming activities area covered by the mangrove?		1. Yes; 2. No
S23	Do you waste the sewage from the process into mangrove site?		1. Yes; 2. No