Farm Permits and Optimal Shrimp Management in Thailand: An Integrated Inter-Temporal and Spatial Planning Model

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By

Anantha K. Duraiappah
Adis Israngkura

Anantha K. Duraiappah
(Contact Author)
Senior Research Economist
Institute for Environmental Studies (IVM)
Vrije Universiteit
Boelelaan 1115, 1081 HV Amsterdam
The Netherlands
Tel. (work): 31 – 20 444 9524
Fax: (+31) 20 – 444 9553
E-mail: anantha@ivm.vu.nl

Adis Israngkura
Research Economist
Natural Resources and Environment Program
Thailand Development Research Institute
565 Soi Ramkhamhaeng 39 (Thepleela 1)
Ramkhamhaeng Road, Wangthonglang
Bangkok 10310 Thailand
Tel. (work): 66 2 718 5460
Fax: 66 2 718 5461-2
E-mail: adis@tdri.or.th

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ABSTRACT

Shrimp production in Thailand is characterized by boom and busts cycles. The busts are caused by production crashes. Many reasons have been cited for the cause of these production crashes with disease outbreaks been a prime suspect. A primary factor linked with disease outbreaks is poor water quality caused by farm management strategies. The major focus of existing studies has been at the farm level. We postulate that although farm management is a critical variable in determining sustainability for the sector, farm density plays an equally important role. In this paper, we address both factors. We begin by identifying the optimal combination of farm strategies. Once the farm management options have been identified, the optimal farm densities for three principal shrimp farming regions is computed. Spatial variation in the form of soil differentiation is taken into account in the analysis. Preliminary results suggest that water management and farm density are the two most critical variables determining sector sustainability.[1]

***Keywords**: Shrimps, disease, farm management, farm densities, optimal, Spatial, inter-temporal*

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1. INTRODUCTION

The shrimp sector has grown over the last decade to become a major export revenue generator for the Thai economy. Exports from the sector account for 3.5% of total export revenue in 1996 (Patmasiriwat *et al.* 1998) and approximately 1% of GDP in 1992 (FAO/NACA 1995). The Thai shrimp sector presently accounts for 20% of the world trade in shrimps and is the world's leading exporter of the Black Tiger prawn (Patmasiriwat *et al.* 1998). The sector is also looked upon favorably by international development agencies like the World Bank and the Asian Development bank for its social welfare profile. Unlike many other wealth generating sectors in many developing countries where an elite minority own a majority of the assets, the Thai shrimp sector is characterized by a large number of small owner operated farms. These statistics underscore the relative important role the sector has played and continues to play in the country's economic growth.

However, in spite of the impressive growth record of the industry, there have been many economic, socio-economic and environmental repercussions. The economic problems are related to the sustainability of the sector. The shrimp sector in Thailand has over the last 15 years witnessed a series of booms and busts. The first production crash came in 1990 when disease outbreaks wiped out approximately 90% of farms along the Inner Gulf of Thailand where the majority of farms were located (ibid.). However, unlike in Taiwan where a crash in 1987 basically wiped out the shrimp industry, the farmers in Thailand were able to migrate and expand from the Gulf to the Southern coasts (Prachuab Khiri Khan, Surat Thani, Nakhon Si Thammarat) and then across to the Andaman Coast.

But land is a finite commodity and at some point in time will become scarce. This scarcity has begun to materialize as production crashes caused by disease outbreaks along the South coast in 1996 caused a sharp decline in production (see Figure 1) while the production crash in 1990 had hardly any effect on production. This continuing decline of production if not addressed can only cause, one, a loss of valuable export revenue for the Thai economy and two, a loss of livelihood for a large number of people involved in the shrimp sector.

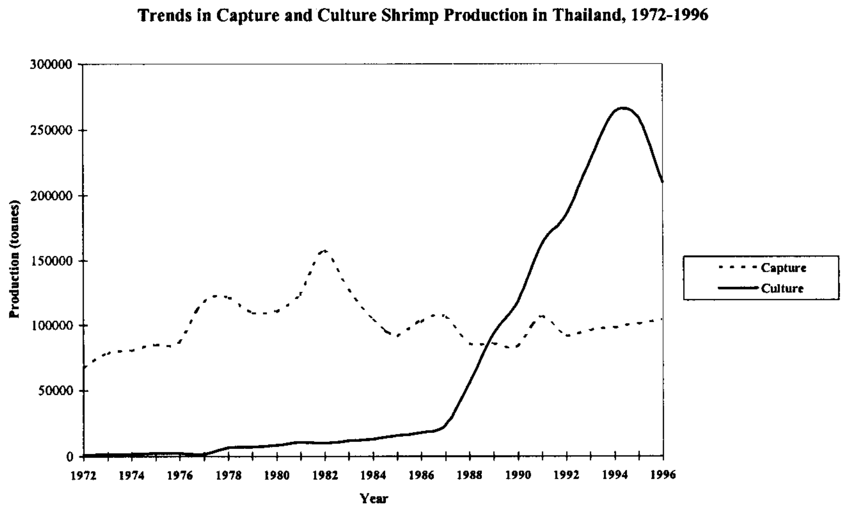


Figure 1. Trends in Capture and Culture Shrimp Production in Thailand, 1972-1996

Source: Department of Fisheries, Thailand.

Similar to its production sustainability record, the sector's environmental record has not been impressive. One of the most heavily cited environmental problem attributed to the shrimp sector is mangrove destruction. Although there is a certain amount of truth to the sector's role in destroying mangrove forests, the degree of its role may be questionable. A 1995 FAO/NACA (1995) report states that a large portion of mangrove land that has and is being used by shrimp farms were actually degraded mangrove lands. Moreover, Potoros (1995) and Paw (1991) find that only about 30 to 38% of mangroves destroyed can be attributed to shrimp farming. In 1996, a joint government study, comprising of the Department of Fisheries, Royal Forest Department, Land Development Department and the National Research Council of Thailand used remote sensing images to show clearly that 30% of the country's mangrove forest has been lost to date and of that amount approximately 31% was attributed to shrimp farming (Piamsak 1996).

Another environmental problem caused by the sector over which there is less controversy is coastal pollution (Thongrak *et al.* 1997; Tookvinas 1995; Dierberg and Kiattisimkul 1996; Midas Agronomics 1995). In a majority of cases, farms dispose their untreated water both during and especially after a harvest directly into the common water canals which eventually flow into the coastal waters. The open access characteristic of the water use and exchange system leads to massive pollution of the coastal waters and at rates that far exceed the natural systems regenerative capacity. Both the shrimp sector as well as other sectors dependent on coastal resources have suffered from this pollution. Ironically, the pollution caused by the shrimp farms have been cited as one of the principal causes for the frequent disease epidemics. Experts stress that if sustainability of the sector is to be achieved, this pressing issue of water quality must be addressed and resolved immediately.

The third and final environmental problem caused by the sector deals with salinization of land. Abandoned shrimp farms have very little alternative agricultural uses due to the high salinity levels in the soils. It normally takes about five to seven years before the land can be used again for other agricultural purposes. To make matters worse, the salinization process from the farms is not localized. Intrusion by surface and sub-surface saltwater from the shrimp farms to adjourning lands force many of the farmers working on these lands to also abandon their farms.

The economic and environmental externalities mentioned above have had serious socioeconomic repercussions for both the shrimp farmers as well as other communities living in the vicinity. The shrimp farmers are usually left with heavy financial debts leading to destitution when they are forced to abandon their farms after a series of disease outbreaks. The degradation of the coastal resources by the effluent discharge from the shrimp farms has caused many of the fishing communities to lose their source of livelihood. This in turn has caused many of these communities to migrate to the cities in search for employment. A similar turn of events face the rice and fruit farmers who have seen productivity of their land drop because of salt water intrusion into their farms.

Policymakers in Thailand have acknowledged both the importance of the sector as a revenue source on one hand and an environmental and socioeconomic "problem child" on the other hand. Many policies have been drawn up to address the issues mentioned above but to date have had limited success (Dierberg and Kiattisimkul 1996; Flaherty and Karnjanakesorn 1994; Thongrak *et al.* 1997). The majority of the policy responses have been regulatory in nature with very little attempt to use economic incentives. The Achilles heel of these policies has been the monitoring and enforcement of the policies; institutional and financial constraints have been cited as the primary reasons for failure of present regulatory policies (Flaherty and Karnjanakesorn 1994). Philips argues that what is needed are self-regulating mechanisms in which farmers have a personal interest to pursue activities which will help the shrimp sector become sustainable (Thongrak *et al.* 1997; M. Philips, personal communication).

The discussion above has highlighted many crucial issues ranging from production sustainability to socioeconomic repercussions to inadequacy of present policies. In this paper, we direct our efforts towards finding a sustainable strategy for the sector and some policy tools that can be used to motivate the sector to adopt these sustainable farming practices. The paper is structured as follows. In section 2, we provide a brief overview of the studies, which have been carried out and identify the gaps which we would like to address in this paper. In section 3, the main building blocks of the model developed for this study are presented (the detailed model is provided in appendix 1). Results from a number of simulation exercises using the model are presented in section 4. In section 5, we end the paper by providing a summary of the main findings together with a number of policy recommendations.

2. AN OVERVIEW OF THE THAI SHRIMP SECTOR

There have been two major production crashes to date, one in 1990 and the other in1996; both caused by disease outbreaks. The precise reason for the disease epidemics is still under debate although a growing consensus among experts points to deteriorating water quality (Briggs and Funge-Smith 1994; Phillips 1994; Chiu 1988; Wongsaengchan 1990; Boyd and Musig 1992). Water quality in turn is determined by a variety of factors ranging from farm management options to regional land use and planning strategies.

The main focus by a majority of the existing studies has been at the farm level and emphasis has been on farm management strategies and the options available for farmers to minimize water quality deterioration (Funge-Smith and Briggs 1994, Dierberg and Kiattisimkul 1996). For example, there have been numerous studies which have looked at how various combinations of stocking densities, feeding strategies, water exchange systems together with site locations based on soil types have had an impact on mortality rates (Briggs and Funge-Smith 1994; Dierberg and Kiattisimkul 1996; Primavera 1993). Closely related to this attention to farm level water quality, is the economic profitability of these management strategies and the economic consequences of failing to adopt these precautionary measures (Briggs and Funge-Smith 1994; Funge-Smith and Aeron-Thomas 1995; Thongrak *et al.* 1997). The information provided by these studies have been instrumental in guiding policymakers formulate appropriate responses to the growing problems faced by the farms.

However, a unique characteristic of the shrimp sector makes it imperative that a sectoral approach be adopted if sustainability of the sector is to be achieved. As mentioned earlier, the water use and exchange systems practiced by the sector gives it an open access character and rules governing its use are necessary if degradation is to be avoided. Both, Dieberg-Kiattisimkul (1996) and Potaros (1995) emphasize the importance of using an integrated approach to land use and planning for the control and maintenance of water quality for the individual shrimp farms. Our search of the literature failed to find any study which attempts to investigate the relationship among farm locations, farm management, farm density and water management with sustainability.

In order to address the gap mentioned above, we develop a sectoral land and water use planning model for the shrimp sector. The key questions we would like to find answers with the model are:

1) Do the number of farms or density of farms play a crucial role in making the sector sustainable. If yes, then what is the optimal number of farms or farm density within specified geographical boundaries.

2) Which factors determine farming density and which of these factors are dependent on natural properties and limits versus those which can be regulated through management activities?

3) What policy options should be used: regulatory, economic incentives or a combination of the two?

In the next section we describe the three main building blocks and the underlying dynamics of the model.

3. THE SHRIMP INTEGRATED ASSESSMENT MODEL (SIAM)

Three main systems make up the SIAM: (1) the land use and exchange system; (2) water use and exchange system; and (3) finally the economic system. Although an argument can be made that the land use and exchange system is part of the economic system, we felt that the critical role it plays in shrimp farming warrants it to be treated separately from the economic system. The three systems are described below.

3.1 Land Use Dynamics

One of the critical elements in shrimp farming is the type of land used. When shrimp farming first started, many farmers unknowingly sited their farms close to the coast to take advantage of the natural brackish conditions. In many cases, this turned out to be on mangrove lands. But mangroves are normally sited on high acidic sulfate soils which can retard growth of shrimps as well as reduce survival rates (Poernomo and Singh 1982). Moreover, the soft nature of the soil makes pond preparation expensive and time consuming. The remedies are costly and have environmental repercussions themselves in the long run (Dierberg and Kiattisimkul 1996). Land further inland is normally non-acidic and provides a more conducive environment for shrimp farming (M.Philips, Personal Communication). But as these are further away from the coast, additional costs are incurred for pumping in the water. Clearly, an analysis of trade-offs between the various soil types is necessary before any firm decision can be made on farm locations.

Another dimension to the land use question is the intensity of use. Some lands may have a higher carrying capacity than others. The carrying capacity of a site can be dependant on a number of factors, depending on the type of activity. In the case of shrimp farming the two critical parameters are the properties of the soil as well as the water bodies (Thongrak *et al.* 1997; Funge-Smith and Briggs 1994).

A third dimension, which is becoming an important issue, is abandoned shrimp farms. Many of these farms are not suitable to be converted for other agricultural activities and it is in only those rare instances that they can be converted for non-agricultural use. The rehabilitation of these lands is costly, time consuming and inefficient. A cost-benefit analysis of these costs should ideally be done before the decision to convert land for shrimp farming is made.

3.2 Water Exchange

A well-known fact in the shrimp literature is the important role water quality plays in the sustainability of the sector (Tookvinas 1996; Primavera 1993; Funge-Smith and Briggs 1994; Thongrak *et al.* 1997). Although experts are not sure of the degree of causality between water quality and disease and between water quality and farm productivity, they are unanimous in agreement on the high causality relationship between declining water quality, disease outbreaks and declining farm productivity.

The degree of control a farmer can have over the quality of water in his or her farm is largely dependent on the choice of water exchange system that is used in the farm. In the case of a closed system, the water quality during the grow-out period can be to a large extent controlled by the farmer. No exchange occurs with the common water channels and therefore no contact is made with pollutants which may have been produced by other farms.

In the case of a semi-closed or open water exchange system where there is continuous contact with the common water system, the probability of using disease-contaminated water is high. The choice of which particular water-exchange system to use comes with a cost. A closed system requires more land, as more ponds are needed for water storage and cleansing ponds. An open system does not require this investment. In order to decide on which option to adopt, an analysis of trade-off, similar to in the case of land use, is necessary before a decision on which particular water system should be adopted.

We now come to the water quality of the common water system. The deterioration of this water source has significant repercussions not only to the shrimp sector but also to other sectors, which rely on this water stream as input for their production activities. Sectors that come to mind immediately would be the coastal fishing and tourism sectors. Both these sectors are important in Thailand - tourism is a major foreign exchange source while the coastal fishing sector provides a source of income for a large population body. For the shrimp sector, irrespective of the water exchange system used, preventing the deterioration of this water source is vital for the long run sustainability of the sector. This is obvious for the semi-open and open water exchange systems but it also holds for the closed system because at some point in time, some form of water exchange needs to take place.

The critical factors, which determine the overall loading of the water systems, is the amount of effluents which are disposed into the system. This is turn is dependent on the following three factors: (1) the management strategies within each shrimp farm at the site; (2) the total number of shrimp farms; and (3) the total effluent discharge by other users. In this paper, we model the first two and assume the third factor is negligible because effluent discharge by other users is small in comparison to the shrimp farms in the specific geographical locations we use in this study.

3.3 Economic Dynamics

Revenues and costs form an important component in the shrimp sector. It is no understatement when we say that shrimp farming is a very lucrative business. High and quick returns on initial investment have been the driving forces for the rapid adoption of shrimp farming (Primavera 1991; Masae and Rakkheaw 1992). However, the degree of profitability is closely related to the intensity of farming: the higher the intensity, the higher the profit margins.

However, Primavera (1993) finds in her study that although intensive farms have a high rate of return, they have a high cost structure. Therefore, movements in shrimp prices can cause profits to fall drastically and in many instances to post negative returns. On the other hand, farms practicing extensive and semi-intensive farming strategy experience less vulnerability to price fluctuations due to the lower cost structure are lower which inevitably lowers their break-even points.

Because the sector is so highly sensitive to changes in costs and prices, it is imperative for policy makers to investigate how changes in any one item in these two categories can have an impact on the sector and the appropriate policy responses to cushion the detrimental effects. We do not attempt to find market-clearing prices for the sector. This would require us to model the demand side of the equilibrium equation, which is beyond the scope of this study. What we do instead is to use exogenous prices and then run sensitivity analysis to investigate the changes in management strategies that occur for price changes. In a similar construct, we analyze if and when policy measures are needed for these price fluctuations.

3.4 Model Dynamics

In this section, we describe the underlying dynamics of the model. As mentioned and stressed earlier, different types of soil have different characteristics and properties which play a crucial role in shrimp farming. Some are ideal whereas others need considerable changes before they can be used for shrimp farming. We also mentioned that certain soil types have better cleansing properties than others. All these different characteristics and properties translate to different cost structures and these differences play an important role in the final selection process.

Next, we have the different types of farming techniques or processes, which we shall term here as management options. There are many ways in which production systems can be modeled. We use activity analysis to model the production systems in this study. Activity analysis allows us to compare and contrast discrete management strategies, which differ according to spatial and technological properties. An integral component of activity analysis is the "technology" matrix. This matrix describes the inputs and outputs for a range of management strategies. For example, in the case of the shrimp sector, we would have one column which describes the various inputs needed for a farming management strategy using a technique calling for high stocking rates at 75 post larvae per square meter, an open water exchange system located in alkaline soil conditions. The columns also give a list of outputs produced by the process. In this way, we are able to keep track of the level of effluents produced by the respective processes.

In shrimp farming, one of the critical variables, which differentiate management strategy, is stocking or seed intensity. In this study we use the following seed intensity classification: (1) high intensive (100Pl/m^2; (2) mid-intensive (75pl/ m^2); (3) low intensive (50pl/ m^2) (4) high semi-intensive (15Pl/ m^2); (5) mid-semi-intensive (10Pl/ m^2); and (6) low semi-intensive (5Pl/ m^2). We exclude extensive farming as this strategy is not used extensively in Thailand and in all probability will not be considered as a candidate for choice due to its low profitability profile. By making the distinction first, between intensive and semi-intensive and second, within the two broad categories, we capture the differences in the following variables: (1) stocking densities; (2) feed strategies; (3) intensity of chemical use; (4) capital requirements; (5) labor use; (6) waste or sludge generation; and finally (7) potential yield.

The final dimension, which we think is crucial and needs to be defined explicitly, is the water management options farms can adopt. We specify two options: (1) closed; and (2) open. The differentiation in water management allows us to capture: (1) land use and scarcity; (2) interactions and inter-dependence among farms; and (3) water quality.

We close the model using a survival function. As the knowledge base on diseases is very limited, a detailed disease module is beyond the capacity of this paper. An econometric approach is therefore adopted whereby data from a farm survey is used to estimate a survival rate function. The survival rate is dependant on the variables mentioned above which form the basis of the various management strategies. In this manner, we capture the trade-offs that exist among management strategies and the respective survival rates. The survival rate is then used to adjust the potential yield to determine the final output level corresponding to the particular farm management used.

To summarize, we now have the following model resolution. We begin with the three regions. Next, within each region, the three soil types are classified. And within each of the three soil types, the six processes differentiated by seed intensity are defined. The last resolution then involves differentiating the two water exchange systems we use within the six processes. The reader is requested to refer to the mathematical model in appendix 1 to get a clearer idea of the resolution we use in the study.

The objective of the exercise is to maximize total discounted net benefits for the sector. The revenue stream comes from final shrimp production net of diseases. The cost stream has two components; (1) economic costs of production; and (2) environmental costs. The former is relatively straightforward and comprises primarily of raw material input costs and capital costs. Effluent disposal cost, opportunity costs of abandoned land and the opportunity costs of land converted to shrimp farming are the three main items under environmental cost. The environmental cost of water pollution is captured via a feedback relationship through the survival rate function – the higher the water pollution, the lower the survival rate.

In the optimization procedure, an analysis of trade-off is carried out in which the cost and benefits of various combinations of management strategies and farm densities are evaluated. The combination, which produces the highest net benefit over the time horizon, is then picked as the optimal sector design.

4. RESULTS

We report results from four experiments in this paper. A point to keep in mind when interpreting the results from these experiments is the optimality characteristics of the solution. The model solves for optimal solutions given the constraints specified in the model structure. It is, therefore, highly probable that we may get optimal solutions which may call for high rates of environmental degradation. We must also bear in mind that the results presented may or may not differ from the present status of the sector. If the model mimics closely the present situation, then the challenge is to investigate why the sector is pursing its present unsustainable strategy and identify policy initiatives to try stir it on a sustainable path. And if the model produces different results from present practices, then the challenge is to find plausible reasons, which explain the differences, and then again, to find policy instruments that will motivate the sector to move on to a sustainable path.

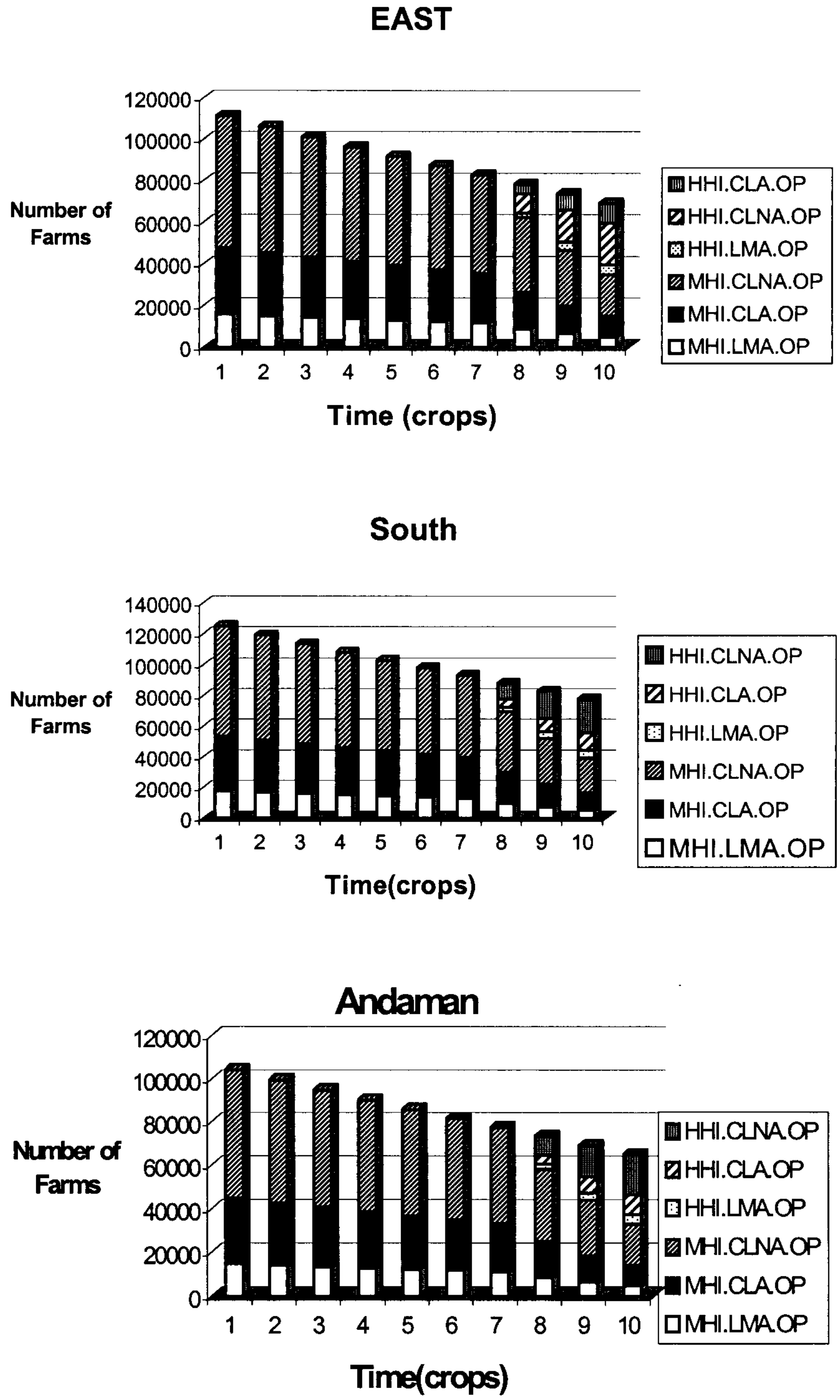
We call the first run Base and will use it as the point of reference for comparative static exercises. The second experiment is called IEE for reasons, which will become apparent when we explain the characteristics of the simulation. The third and fourth experiments are sensitivity test on: (1) price of shrimps; and (2) the opportunity cost of land.

4.1 BASE Simulation

Although there are official regulations governing the disposal of pond effluents, a majority of farmers do not adhere to these regulations and are known to dispose these effluents illegally (Dierberg and Kiattisimkul 1996). Moreover, this regulation applies only to farms larger than eight hectares. This in essence rules out 80% of farms in Thailand as most of these farms range from about one to 2 hectares (Tookvinas 1996). In order to mimic this behavior, we ran a scenario called BASE, in which environmental costs were excluded from the profit function.

We begin by looking at the farm techniques used and the total number of farms in operation. Figure 2 below clearly illustrates that in all three provinces, the open water system is the preferential choice. Dierberg and Kiattisimkul (1996) in their study on Thai shrimp farming support this observation when they remark that only in very rare instances did they find farmers using close-water exchange systems. An interesting result, which emerges, is the choice of medium high intensive ($75PL/m^2$) stocking rates for the first seven crops after which the high-high intensive ($100pl/m^2$)

option is also adopted. This particular choice of techniques over the five-year period[2] demonstrates and supports the observed myopic behavior of shrimp farmers (Thongrak *et al.* 1997).



HHI:	100PL/m^2
MHI:	75PL/m^2
CLA:	Clay Acidic
CLNA:	Clay Non-Acidic
LMA:	Loam Acidic
OP:	Open Water Exchange

Figure 2. Farm Techniques Adopted under BASE Strategy

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[2] The time horizon used in the model is 5 years with a total of 10 crops. The model was limited to 5 years due to computational complexities which makes the solution of longer time periods problematic at this point in time.

Farmers want to maximize short term profits and they do this by adopting high intensive stocking densities and allocating the maximum amount of land available for grow out ponds.

It is for the latter reason that they opt for the open water exchange systems. These systems do not need ponds to be set aside for water settlement and cleansing. The farmers also believe that the higher volume of shrimp produced (high stocking rate coupled with high acreage) compensates for the lower survival rates (high stocking rates and open-water systems) as shown in Figure 3.

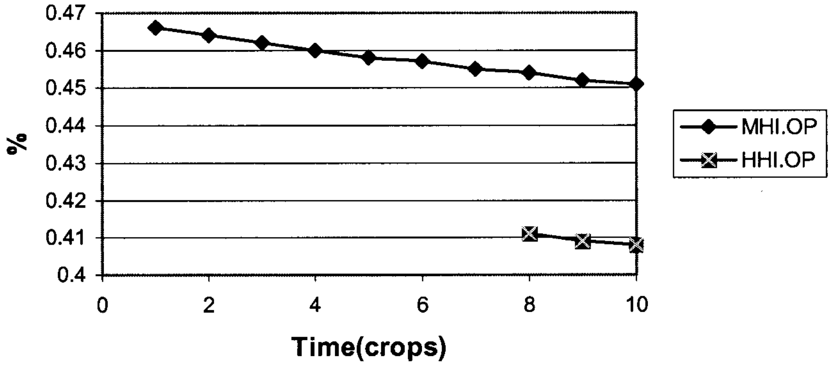

Figure 3. Survival Rates under BASE Strategy

Is the BASE sustainable? The decreasing farm density observed in Figure 4 suggests that it is not. The total area under shrimp farming is declining – caused by a rapid increase in land abandonment which in turn is caused by high(low) mortality(survival) rates.

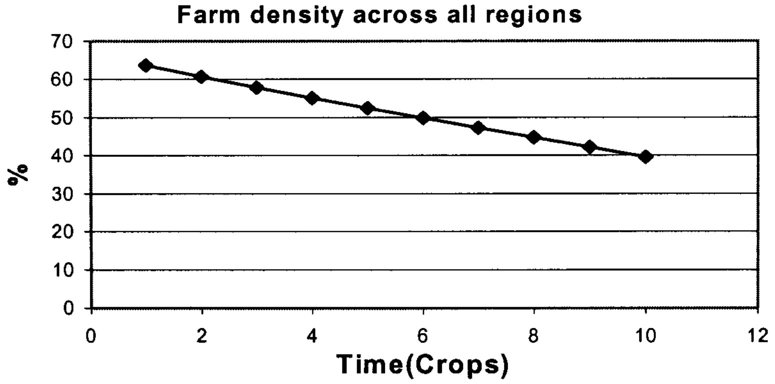

Figure 4. Farm Density under BASE Strategy

The farm density at the beginning of the time period is approximately 65%. But by the end of the time period, the farm density has dropped to 40%, with approximately, 41% of total land classified as abandoned. If the sector is allowed to operate under present conditions, a collapse is inevitable.

4.2 IEE (Internalization of Environmental Externalties) Strategy

In this scenario, the environmental costs caused by the shrimp sector are included in the profit function. In other words, the externalities caused by the sector are internalized. We observe a significant change in the techniques as well as in the number of farms across the three regions as compared to BASE solution. First, as Figure 5 illustrates, a closed-water system is used under the sustainable strategy in all sites except in the case of non-acidic clay soil on the Andaman coast.

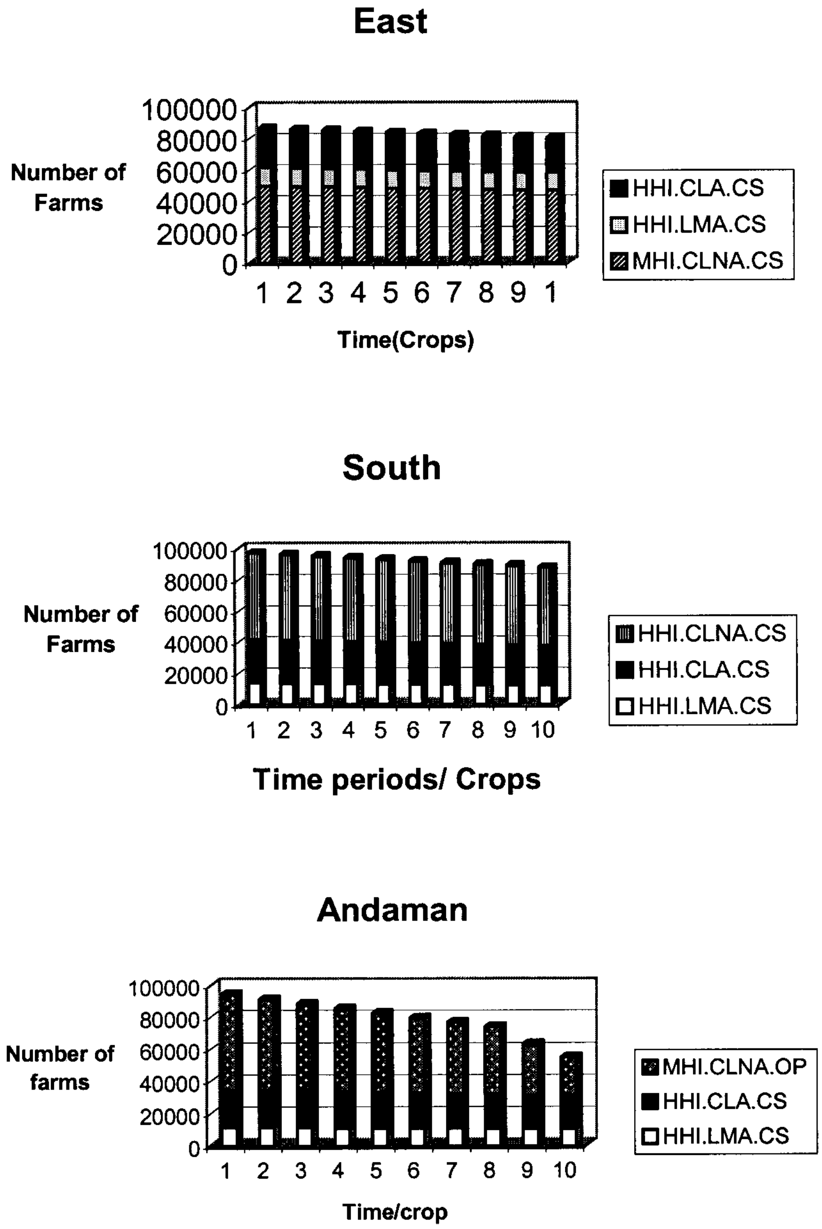

Figure 5. Farm Techniques Adopted under IEE Strategy

The primary reason for the switch to closed systems is that with the internalization of environmental costs, the need to minimize the rate of land abandonment is crucial. And in order to reduce the rate of abandonment, the mortality (survival) rate has to be decreased (increased) and one way of increasing survival rates is by using the closed water system. However, because closed-water exchange systems require larger tracts of land, the model prescribes a higher stocking rate (75 pl/m2 to 100 pl/m2) to compensate for production lost from lower acreage under production.

In the case of the Andaman coast, an open system was chosen for clay non-acidic lands with a lower stocking density of $75PL/m^2$. The main reason underlying this choice is the scarcity of land. Total suitable land available for shrimp farming is the lowest in the Andaman region. This scarcity of land forces the sector to choose techniques which maximize the acreage of land under shrimp cultivation. The survial rates shown in Figure 6 would attest to the fact that land scarcity plays a more pivotal role than survival rates in the maximization of profits. Although survival rates drop to about 45% for open systems as compared with 60% to 70% for closed systems, the final overall production would seem to be larger under the former system.

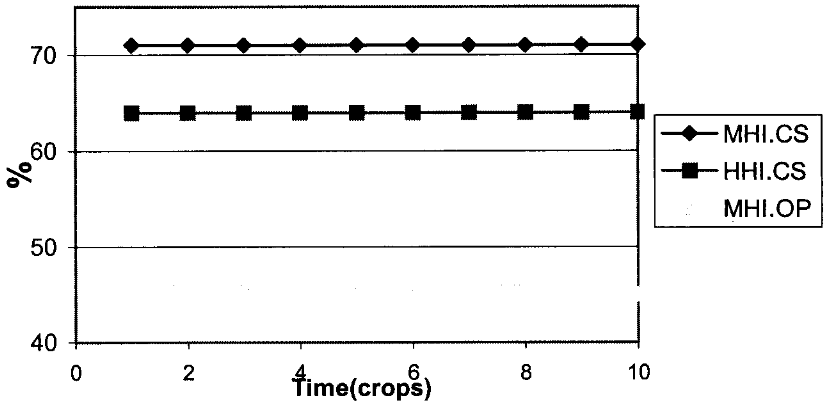

Figure 6. Survival Rate under IEE Strategy

The number of farms observed in IEE is lower than that seen in BASE – approximately 33% lower for the East and 25% lower for the South and the Andaman. This tells us that with internalization of externalties, there is pressure to reduce the total effluent production and the most cost-effective manner is by controlling the number of farms.

We begin to observe a pattern emerging from the two simulation runs above. There is a continuing trade-off between volume production on one-hand and survival rates on the other. For example, if total production under an open system with high intensive stocking rates produces 100 tons of shrimp but experiences a 40% survival rate, then final yield is only 40 tons. In another alternative, where a closed system is used with a high stocking rate produces 70 tons with a survival rate of 70%, then final yield is 49 tons. The decision in this case would be to choose the latter system.

This of course is a simplified explanation of the selection process. In the model, the choice set is much larger and the process of elimination far more complex.

The policy question we need to find an answer now is, how will the farmers be made accountable for the environmental costs they cause. A number of options are available. One alternative would be to implement an effluent emission tax on farms which pollute above a pre-specified emission limit. Subsidies can of course be given to farms that emit less than the limit. The draw back with this instrument is that it leaves open the following two critical issues: (1) environmental costs caused by soil salinization on both abandoned and adjourning lands; and (2) the number of farms within specified geographical boundaries.

A second option would be to introduce a system of price differentiated farm permits. Farm permits achieve two objectives. First, by specifying the total number of permits, authorities can control the actual number of farms within specified geographical boundaries. Second, the price of the permit can be set based on farm management practices as well as on soil characteristics, i.e., a differentiated permit price system based on spatial and technical properties.

Figure 7 below gives the permit price, which needs to be collected from the respective farms, based on soil type, stocking density and the water system adopted. However, as there was only one difference in site location under the IEE strategy, we have just presented the permit prices based on stocking density and water system.

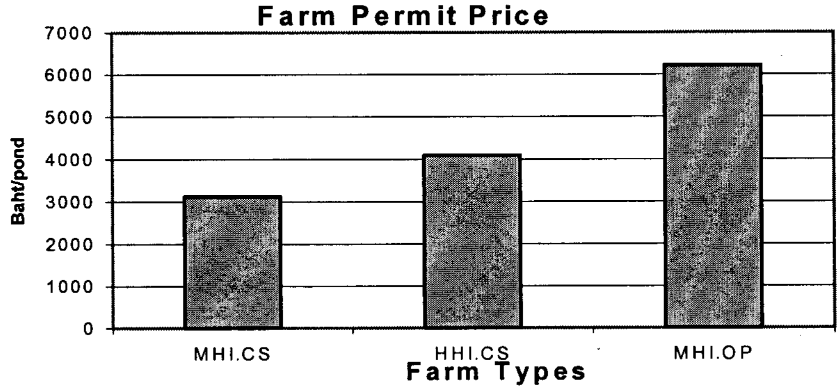

Figure 7. Farm Permit Price under IEE Strategy

Farms which adopt the open system pay the highest permit price, while farms which choose lower stocking rates combined with closed water systems pay the lowest permit price. All other combinations fall between these two ends of the spectrum.

There is nothing exceptionally new about the pricing system described above – high polluting management strategies have to pay a higher price than those strategies which exert lower pressures on the environment. However, the unique characteristic of the pricing system lies in its efficiency improvement properties. By imposing a price differentiated permit system based on environmental pressures, it forces, or more appropriately "motivates", the sector to adopt management strategies that increase net profits. The profits under IEE are observed to increase by more than a factor of two to those in BASE. This at first glance may seem contradictory, as one would expect that with external costs included, net profits go down. However, on the contrary, with external costs internalized, a search for techniques to reduce mortality rates is initiated. This in turn produces a combination of techniques and farm density, which increases the overall profits of the sector.

From a policy perspective, the results above suggests that policymakers can, by introducing a price differentiated permit system, motivate the sector to move to a higher production frontier which implies higher profits and lower environmental costs.

We next ran a couple of sensitivity tests on two crucial parameters used in the model; price of shrimps and the opportunity costs of abandoned land to investigate if significant changes in management strategies occur.

4.3 Sensitivity Analysis

We began by reducing the price of shrimp by 20%. The most obvious change observed was the switch from close to open systems and stocking rates of 75PL/m^2 across all three regions – a similar strategy to the BASE run. The primary reason for the switch to open systems was as before dictated by the economics of the sector. With a 20% reduction in prices, net profit accruing from actual yields is lower in the case of techniques using closed water systems and stocking rates of 100PL/m^2 versus those using an open-water system and stocking rates of 75PL/m^2; this is even when environmental costs are internalized and with permit prices going up from 3,000 Baht to 6,000 Baht per pond.[3]

This policy option may seem counter-intuitive at first glance: reducing the number of farm permits and increasing their prices when the price of shrimps decreases. In fact, the standard response would have been to reduce the permit prices in order to reduce the financial burden on farmers. However, if this had been the case or even if the authorities did not respond at all, the price decrease would have caused shrimp farmers to adopt even higher intensive farming strategies which would have inevitably caused higher environmental damages and caused a production crash within a shorter time span. In this particular case, the imposition of fewer permits coupled with higher permit prices motivates farmers to use techniques that actually increase overall profits by 57% for the sector.

However, the higher permit prices are not sufficient to prevent a high level of abandoned farms as shown in Figure 8 below. The levels experienced are comparable to those observed in the BASE scenario. This observation has some important repercussions. The high rate of abandonment though considered optimal is unsustainable. The results would seem to suggest that some form of

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[3] A pond is assumed to be approximately 4 rai.

regulatory intervention is necessary if the myopic and exploitative behavior of the sector is to be averted. One form of intervention would be to impose some form of sustainability criteria on the model. On form, which we adopted, is the imposition of an upper bound on the total amount of abandoned land acceptable. The results in Figure 8 below show that permit prices need to be increased from 6,000 Baht to prices ranging from 12,000 to 25,000[4] Baht if the level of abandoned land is to be restricted to 15% of total land within each site.

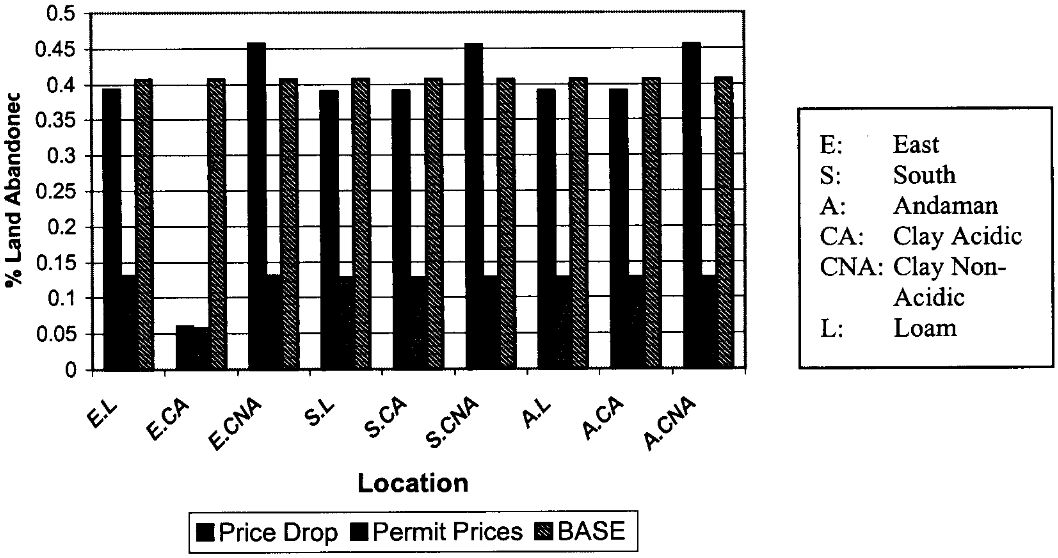

Figure 8. Rate of Land Abandonment with a Price Drop

The next sensitivity test involved increasing the opportunity cost of land. In the IEE strategy, the opportunity cost of land was set at 2,000 Bath per rai; this was computed based on net profits earned if the land was used for rice farming. It was observed that as this cost item was increased, the main behavioral change observed was the switch from close to open water exchange systems. As the opportunity cost of land goes up, there is a trade off between using all land for grow out ponds and the higher mortality rate experienced from using the open-watesystem to less land allocated for grow out ponds (close-water system) but with a higher survival rate. The economics of the shrimp sector dictate that farmers opt for the larger volume-low survival rate than the low volume-high survival rate strategy. Policymakers can only make sure that the environmental costs are captured through the permit pricing system. The range over which permit prices vary goes from approximately 6,000 to 10,000 Baht per grow out pond, depending on the technique used. The opportunity cost at which there is no incentive to convert land to shrimp farming is about 18,000 Baht per rai.

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[4] One management strategy requires a permit price of 25,000 Baht. However, the strategies adopted in all other regions and soil types were similar and the permit price was approximately 12,000 Baht.

The high profitable profile of the shrimp sector makes it very difficult for policymakers to discourage shrimp farming. The only option would be to make sure that the sector is monitored and motivated to pursue sustainable farming strategies. One policy tool which we have shown above could be used to achieve this goal is through a price differentiated farm permit system.

5. CONCLUSION

The model developed in this study highlighted a number of crucial factors.

- The present management strategies of the shrimp sector are unsustainable.
- The sector is also economically inefficient
- The sector can increase its economic and environmental through the use of a farm permit system.
- The farm permit system determines the total number of permits which should be allowed. This number is dependent on the total area under consideration, the soil types in the area, and the farm management techniques.
- The permits are price differentiated. The prices are determined accordingly to soil type, stocking density and the water exchange system used.
- The farm permit system must be designed in a manner such that the rate of farm abandonment is within acceptable levels.
- The permit system must be continually monitored and adjusted according to prevalent economic conditions in the country.
- An institutional structure needs to be established in order to implement and enforce the permit system. Although the system is self-regulatory to a large extent, some system of checks need to be put in place in order to ensure farmers are adopting the farm management strategies specified in their permits.

The farm permit system we have suggested in this paper is one of many alternatives possible. But whatever the system that is adopted, the critical issue on farm density must be addressed. The present policy of limiting total area available for shrimp is not sufficient. More important to the equation of sustainability is the number of farms possible within specified geographical boundaries and the management strategies these farms adopt.

The results and policy recommendations put forward in this paper are undoubtedly dependent on the accuracy of the model. We should like to emphasize here that this model is still in its infancy and there is still a significant amount of work yet to be done before actual figures and numbers can be adopted with confidence. Nevertheless, the model has demonstrated its strengths and usefulness as a guiding tool for policymakers.

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APPENDIX 1
MATHEMATICAL MODEL

Sets

R	Regions
D	Land Type
P	Farm Techniques
W	Water Management Options
C	Commodities
T	Time Periods

Parameters

A	Technology Input-Output Matrix
L	Land Availability
P	Prices
IC	Initial Conditions
TC	Terminal Conditions

Variables

z	Activity Levels
x	Final Shipment
u	Raw Material Purchases
la	Abandoned farms
n	number of farms

Model Equations

Raw Material Purchases by respective farms

1. $a_{cpdw} z_{rpdwt} + u_{c,r,p,d,w,t} \geq 0 \qquad c \in CFV, p \in P, d \in D, w \in W, t \in T$

Let us begin by identifying the amount of raw materials used by the sector. The CFV set is the commodity sub-set which consists of only raw materials. These are: (1) energy; (2) feed; (3) seed; and (4) chemicals. The z variable tells us the activity level of all in region r, using process p located in land type d and using water management option w in time t. The actual number of farms is given by equation 10 below.

Total Land Use

2. $a_{"tarea"pdw} z_{rpdwt} = l^{u}_{rpdwt} \quad r \in R, p \in P, w \in W, d \in D, t \in T$

Land use by shrimp farms is equal to the demand, which is denoted by the purchase level that in turn is determined by the activity or production levels. This area covers ponds plus land used for infrastructure.

Total Grow Out Area

3. $l^{ug}_{rpdwt} = a_{"garea"pdw} z_{rpdwt}$

In this equation we compute the total area covered by ponds used for actual shrimp farming.

Land Type Covered by Shrimp Farms in Each Region

4. $l^{ur}_{rdt} = \sum_{p \in P} \sum_{w \in W} l^{u}_{rpdwt} \qquad r \in R, d \in D, t \in T$

Equation four computes the total land of type d in each of the regions which is covered by shrimp farms.

Land Use Constraint

5. $l^{ur}_{rdt} \leq l^{a}_{rdt} \qquad r \in R, d \in D, t \in T$

The amount of land used by shrimp farms has to be less than the area under shrimp farming.

Land Accumulation

6. $l^a_{rdt+1} = l^a_{rdt} - l^b_{rdt+1} + l^c_{rdt+1} \qquad r \in R, d \in D, t \in T$

The land under shrimp farming is accumulative and depends on the level in the previous period minus land abandoned plus land converted.

Land Use Balance Equation

7. $la\bar{t}_{rdt} = l^a_{rdt} + l^{au}_{rdt} + l^{tb}_{rdt} \qquad r \in R, d \in D, t \in T$

The total amount of land under shrimps, alternative land uses and abandoned land must be equal to total amount of land available. This equation can be interpreted as an identity or balance equation.

Land Abandoned by Shrimp Farms

8. $l^b_{rdt} = \sum_{p \in P} \sum_{w \in W} l^u_{rpdwt} l^p_{rpdwt}$

The amount of land abandoned depends on the productivity drop witnessed on the farms.

Productivity Drop

9. $l^p_{rpdwt} = e^{-\frac{s_{rpdwt}}{pconst}} pgrad \qquad r \in R, p \in P, d \in D, w \in W, t \in T$

The degree of productivity drop is determined primarily by the survival rate. The lower the survival rate, the higher the productivity drops. The pconst and pgrad reflect the rate and magnitude of the impact the survival rate has on the productivity drop experienced by the farms. In many ways, we can use varying figures for pconst and pgrad to capture risk taking behavior on the part of the various shrimp farms. The figures we used were o.12 and 2.3007 respectively and this gives a productivity drop schedule shown in Figure one below.

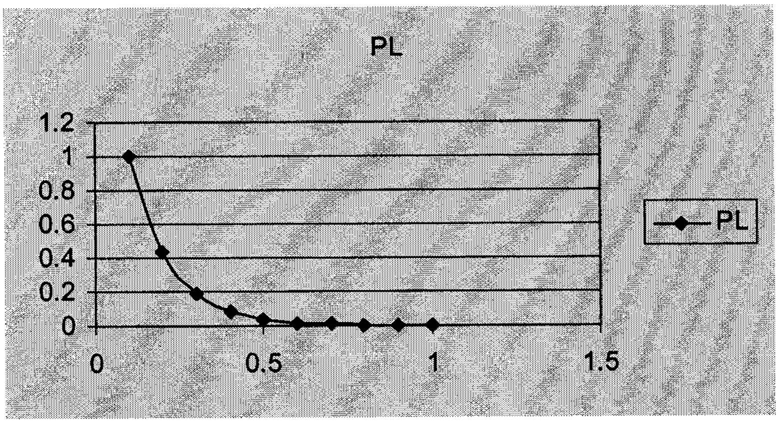

Figure One.

Natural Shrimp Production Level

$$10.\quad x^{p}_{rpdwt} = a_{\text{"}shrimp\text{"}pdw} z_{ripdwt} \qquad r \in R, i \in I, p \in P, d \in D, w \in W, t \in T$$

The natural shrimp production level denotes the harvest level, which can be experienced if no diseases occur. This level takes into account of natural mortality rates.

Actual Shrimp Production Levels

$$11.\quad x^{o}_{rpdwt} = x^{p}_{rpdwt} s_{rpdwt} \qquad r \in R, p \in P, d \in D, w \in W, t \in T$$

The actual shrimp harvested is net of mortality rates caused by controllable factors that are described in detail in the survival equation below.

Shrimp Survival Rate

$$12.\quad s_{rpdwt} = e^{\substack{a_1 \ln f^{i}_{rpdwt} + a_2 \ln s^{i}_{rpdwt} + a_3 \ln f^{md}_{rt} + a_4 \frac{\ln f^{i}_{rpdwt}}{\ln s^{i}_{rpdwt}} + \\ a_5 z_{rpd\text{"}close\text{"}t} + a_6 \left(\ln f^{md}_{rt}\right)^2 + a_7 \left(\ln f^{i}_{rpdwt}\right)^2 + a_8 \left(\ln s^{i}_{rpdwt}\right)^2}} \qquad r \in R, p \in P, d \in D, w \in W, t \in T$$

The shrimp survival rate is a translog function which was econometrically estimated using survey data from a sample size of 350 farms.

Feed Intensity

13. $f^{i}_{rpdwt} = \dfrac{u_{\text{"}feed\text{"}rpdwt}}{l^{ug}_{rpdwt}} \qquad r \in R, p \in P, d \in D, w \in W, t \in T$

Feed Intensity is primarily computed as the total amount of feed purchased by the farms divided by the grow out area used by the respective farms.

Seed Intensity

14. $s^{i}_{rpdwt} = \dfrac{u_{\text{"}seed\text{"}rpdwt}}{l^{ug}_{rpdwt}} \qquad r \in R, p \in P, d \in D, w \in W, t \in T$

Seed intensity is computed in a similar manner as the feed intensity.

Number of Farms

15. $n_{rpdwt} = \dfrac{l^{u}_{rpdwt}}{a_{\text{"}tarea\text{"}pdw}} \qquad r \in R, p \in P, d \in D, w \in W, t \in T$

The number of farms is equal to the total land under use by the various farm categories divided by the unit area required by a hypothetical farm. We assume that each category as described by the technology matrix is representative of a farm.

Farm Density

16. $f^{md}_{rt} = \dfrac{\sum\limits_{p \in P}\sum\limits_{d \in D}\sum\limits_{w \in W} l^{ug}_{rpdwt}}{\sum\limits_{d \in D} \bar{lat}_{rd}} \qquad r \in R, t \in T$

Sludge Production

17. $x^{s}_{rpdwt} = a_{\text{"}sludge\text{"}pdw} z_{rpdwt} \quad r \in R, p \in P, d \in D, w \in W, t \in T$

Sludge production is dependent on the farm category adopted. The total amount is in turn determined by the actual production levels on each respective farm.

The Profit Function

$$18.\ \pi = \sum_{t \in T} \frac{\left(\pi_t^r - \pi_t^{dc} - \pi_t^{idc}\right)}{(1+i)^t}$$

The profit function for each farmer is equal to revenues minus costs. The revenues are from the sale of the shrimps while the costs are comprised of the following components: direct and indirect costs. Within the first component, we further clarify between fixed and variable costs. Fixed costs will be land costs and capital costs. Variable cost components will be feed, chemicals, fry, energy. The indirect costs will be off-site environmental costs such as sludge disposal and the opportunity costs incurred from land conversion as well as land abandonment.

Revenues

$$19.\ \pi_t^r = \sum_{p \in P} \sum_{d \in D} \sum_{w \in W} \sum_{r \in R} x_{rpdwt}^{o} p_{"shrimp"}$$

Revenue is equal to actual harvest of shrimps multiplied by the price. Price is a parameter.

Direct Costs

$$20.\ \pi_t^{dc} = \sum_{p \in P} \sum_{d \in D} \sum_{w \in W} \sum_{c \in CF \cup CV} \sum_{r \in R} u_{ripdwct} p_c$$

Direct Cost is equal to fixed costs plus variable costs. CC is a sub-set of commodities which are fixed cost items. These would be capital in this version of the model. The CFV is a sub-set of commodities which depend on the production levels. These would be feed, fry, energy, chemicals, etc.

Indirect Costs

$$21.\ \begin{aligned} \pi^{idc} &= \left(\sum_{p \in P} \sum_{d \in D} \sum_{w \in W} \sum_{r \in R} a_{"sludge" pdw} z_{rpdwt} \right) p_{"sludge"} \\ &\quad + \sum_{d \in D} \sum_{r \in R} l_{rdt}^{c} p_{"opport"} + \sum_{d \in D} \sum_{r \in R} l_{rdt}^{b} p_{"opport"} \end{aligned}$$

Indirect Costs primarily relate to the environmental costs, which are caused by the shrimp sector. We begin by computing the costs of sludge disposal. The next two components are the opportunity costs foregone when land is converted to shrimp farming and when shrimp farms are abandoned.