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'The economics of land degradation and technological change: a case study in Vietnam'

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Key words: land degradation, technological change, Vietnam

ABSTRACT
This paper explores the economics of land degradation in the rice-shrimp system in the Mekong Delta of Vietnam. A bioeconomic NPV model was developed to evaluate and compare the long-term benefits of alternative production choices and farm technologies. There is an alternative rice-shrimp technology emerging in Vietnam that does not have the same land degrading impacts as the 'traditional' system, however the high capital outlay and risk associated with such technology presents its own problems. In the paper the economic incentives for adoption of the non-land degrading rice-shrimp technology are explored. Conclusions are drawn with regard to the opportunity cost of land degradation and technological change. Some conclusions are also provided on the policy implications arising from the results presented.

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1. Introduction

Land degradation arising from a build up of sediment in the rice-shrimp system in the Mekong Delta of Vietnam is the subject of this paper. A farm-level economic analysis of land degradation in the rice-shrimp system is presented. A simple bioeconomic net present value (NPV) model is developed and applied in an evaluation of the long-term economic benefits of alternative production choices, which have different implications for land degradation.

The practice of rice-shrimp farming has developed in a diversity of ways through local farmer innovation, which is a reflection of the diversity of the physical, social and economic environment in the Delta. The method of shrimp recruitment is one of the most important distinguishing features among rice-shrimp farming practices. Recruitment of shrimp is done either through tidal recruitment of natural shrimp or more recently stocking of *P.monodon* (Tiger prawns) postlarvae purchased from a hatchery has become an option for farmers in the delta. The land degradation problem addressed in this paper arises in the rice-shrimp systems reliant on tidal recruitment of natural shrimp rather than the systems based on stocking of hatchery-purchased postlarvae.

The differing water exchange practices makes the choice between tidal recruitment and "artificial" stocking of hatchery-purchased shrimp critical to the problem of land degradation. In the hatchery-based system, water exchange tends to be infrequent whereas with tidal recruitment high water exchange rates are required for the recruitment of shrimp. The frequency of water exchange is a significant factor in the land degradation as it is through the exchange and inundation of turbid water throughout the shrimp season that suspended sediment settles to the floor of the rice-shrimp polder. It is this build-up of sediment that is the cause of the land degradation problem addressed in this paper. The bioeconomic aspects of the land loss is described in the following section.

The tidal-recruitment system has the advantage of requiring very little cash outlay, which makes is a low-risk and accessible technology for poorer farmers. However, the land loss observed in these systems raises questions about the sustainability of the system.

The aims of the paper are to: 1. explore the economic nature of the land degradation problem arising in the rice-shrimp system; 2. evaluate the benefits from and incentives for prevention of land degradation; and 3. evaluate options for technological change in response to the land degradation problem. The analysis of technological change is confined to an investigation of the *P.monodon* rice-shrimp technology as an alternative to the tidal system.

The data supporting the research presented in this paper is drawn from several sources including: a cross-sectional economic survey of 424 farms conducted in 1997 under the rice-shrimp ACIAR project; scientific studies and expert opinion; and where specified, data is drawn from a survey of 17 farmers that was conducted to specifically address economic issues concerning land degradation.

The outline of the paper is as follows. In the first section the case study is introduced. This includes a brief introduction to the study area, the rice-shrimp system, and the bioeconomic aspects to land degradation in the tidal recruitment system. In the section following a brief discussion is provided of market failure in the context of land degradation. This is followed by a discussion of some of the farm-level responses to land degradation. The farm model is then presented and the results of the economic evaluation of alternative farm technology is provided. Finally some concluding comments are provided.

2. The case study

2.1 The study area

The study region comprised two districts in the Mekong Delta; My Xuyen district in Soc Trang province and Gia Rai District in Bac Lieu province. Farmers in Gia Rai have been practicing integrated rice-shrimp farming since the 1960s, and in My Xuyen adoption of the system did not occur until the 1980s.

2.2 The rice-shrimp system

Rice-shrimp systems have been practiced since the mid 1960s by farmers in the coastal provinces of the Mekong Delta where cropping is significantly constrained by the intrusion of saline water from the sea in the dry season. The system involves alternative cropping of wet season rice and dry season shrimp on the same field. The integration of a saline cropping option (shrimp) into the traditional fresh water paddy rice system has provided rice farmers in the saline affected areas with an important source of income in the dry season.

In the rice-shrimp system, the traditional paddy rice field is modified in order to create a pond environment which can also support the raising of shrimp. Dikes (mounds) are built around the periphery of the field, and trenches are dug out along the inside perimeter of the rice field. This redesigned field/pond is referred to as the rice-shrimp polder.

Two distinct rice-shrimp technologies have developed in the delta - tidal recruitment and hatchery-based stocking. One of the basic economic differences between these two technologies is that seed purchased from hatcheries requires cash input and has a high but risky payoff compared to tidal recruitment which is a very low cash input system. Other distinguishing production choices among farmers include decisions about feeding, the time of shrimp and rice cropping, rice variety, and the intensity of production.

The practice of tidal recruitment of natural shrimp as a targeted activity is most prevalent in Gia Rai district. Farmers may choose to recruit natural shrimp in either the dry or wet season, or to recruit in both seasons. Recruitment of shrimp in the wet season means that shrimp are raised in amongst the rice and in the trenches around the rice field. Throughout this paper, the tidal recruitment system is referred to as the 'traditional' system.

The *P.monodon* hatchery-based rice-shrimp systems are a more recent development in the delta and are more prevalent in My Xuyen district than Gia Rai. Throughout this

paper this system will be referred to as the alternative technology (with reference to the 'traditional' system).

The price attracted for *P.monodon* is significantly higher (3-4 times) than natural shrimp. This high price has meant that farmers have, on average, been able to capitalize on the high cash investment required for *P.monodon* production. In My Xuyen, the *P.monodon* rice-shrimp systems on average significantly outperformed the 'traditional' systems in terms of income per hectare. In Gia Rai farmers have experienced a somewhat reduced level of success with *P.monodon* production, although on average the income earned, while not significantly higher, was found to be slightly higher than income per hectare in the 'traditional' system. The generally poorer performance in Gia Rai is a result of lower shrimp survival observed in Gia Rai (Brennan *et al.* 2000).

The shrimp survival rate continues to be one of the most contentious and difficult factors in the sustainability of *P.monodon* based technology. Survival rates experienced by farmers in the 1997 ACIAR survey were extremely low. Many farmers (14%) in the survey reported complete crop loss (Brennan *et al.* 1999). The average survival rate of *P.monodon* on the survey farms in My Xuyen was thirty per cent. The survival rates in Gia Rai district were significantly lower and averaged around ten per cent.

The average shrimp stocking rate of *P.monodon* in the 1997 ACIAR survey was very low at around two postlarvae per square metre in My Xuyen and one per square metre in Gia Rai. The intensity of *P.monodon* shrimp systems in Vietnam, especially in the rice-shrimp system, is at a level well below other areas of Asia. However, despite the low input nature of the systems, the cash outlay required to purchase postlarvae and other inputs (such as feed and chemicals) is very high in proportion to the low-income levels of farmers. For example, on average the total cash outlay for *P.monodon* is of the same order of magnitude as total income earned from other farm and household activities (Brennan *et al.* 2000). Because of the risky nature of shrimp survival, this has meant that low income households are exposed to very high levels of income risk with the production of *P.monodon*. The issue of shrimp survival and economic viability of the *P.monodon* rice-shrimp system relative to the 'traditional' system is explored in detail in this paper.

2.3 Land degradation in the 'traditional' system

2.3.1 Bioeconomic dimensions

As illustrated in Figure 1, water exchange decisions are linked to household income in two main ways. First, shrimp postlarvae are recruited into the pond via the exchange of water and are later harvested for sale at local markets or kept for home consumption. Second, water brought into the pond also brings in sediment, which builds up on the polder floor and, as it is explained below, overtime the sediment build up leads to a loss of productive land. The essence of the sustainability problem in the 'traditional' rice-shrimp system is that household income is affected positively by the level of water exchange (and the density of shrimp per unit of water) in the short-term via shrimp recruitment and negatively in the long-term via land loss arising from sedimentation.

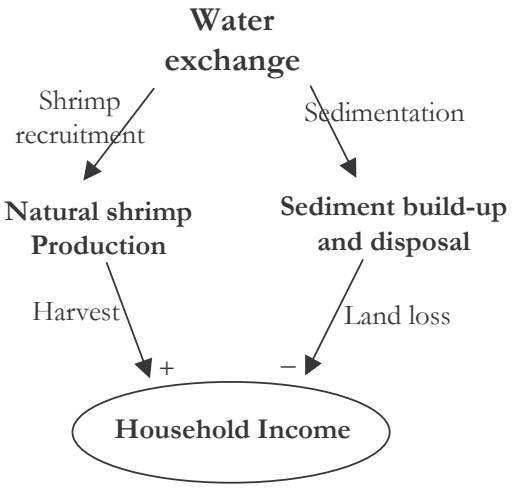

Figure 1. Components of the natural shrimp production system under land degradation.

The build-up of sediment throughout the shrimp production cycle in the already shallow rice-shrimp polder needs to be removed at least once per year to maintain a pond depth necessary for a healthy pond environment for shrimp. Sediment removal is a labour intensive process and imposes a large cash cost on the farm due to the need to employ casual labour for the task (Tran *et al.* 1999). Opportunities for flushing the sediment back to the river or canal are very limited due to prohibitive legislation as well as constraining physical factors such as shallow, narrow canals. Without any alternatives, farmers commonly dispose of sediment within the farm boundary, either around the house, on vegetable plots or on top of the dikes bordering the rice-shrimp field. However, once these areas reach their full capacity, new dikes (mounds) are created within the rice field for the sole purpose of sediment disposal. Over many years the sediment mounds take up space on land that could otherwise be used for production.

2.3.2 Extent of land loss

Cross-sectional data on temporal changes in dike area are very difficult to obtain because the demand on farmer's recall memory is high due to the complexity of the rice–shrimp polder design. For example, the design of the polder in some cases incorporates a sedimentation pond, several different polders and several polder design changes over time. Despite the difficulties experienced in primary farm data collection, the ACIAR farm surveys and related fieldwork indicate that sedimentation and the associated land loss varies substantially across the ACIAR study region but is a significant problem for many farmers. Evidence indicates that farmers in Gia Rai district are more severely affected by the loss of productive land compared to those in My Xuyen. This is attributed to the dominance of tidal recruitment practices in Gia Rai which is consistent with the higher sedimentation rates observed there (Tran *et al.* 1999).

In an original rice-shrimp polder design a dike area of around 10 to 20% would be expected. A dike area over 20% is attributed to either the long-term disposal of sediment that builds up over the shrimp production cycle, or the disposal of earth

from an increase in the depth or width of the trench (Brennan *et al*. 1999). In some cases, the expansion in trench size is a direct response to sediment build up over the production cycle. This was the case for several of the farmers interviewed in this research. This is because the filling of trenches with sediment can be very rapid and can need to be removed up to 2 or 3 times over the shrimp production cycle.

The data on dike area for farms in the 1997 ACIAR survey who produced at least one crop of shrimp (355 of the 424 farms surveyed) are shown in Figure 2 below. Around 24% of the farms reported dike areas of 30% or more and of these Gia Rai farms made up the largest proportion (64%).

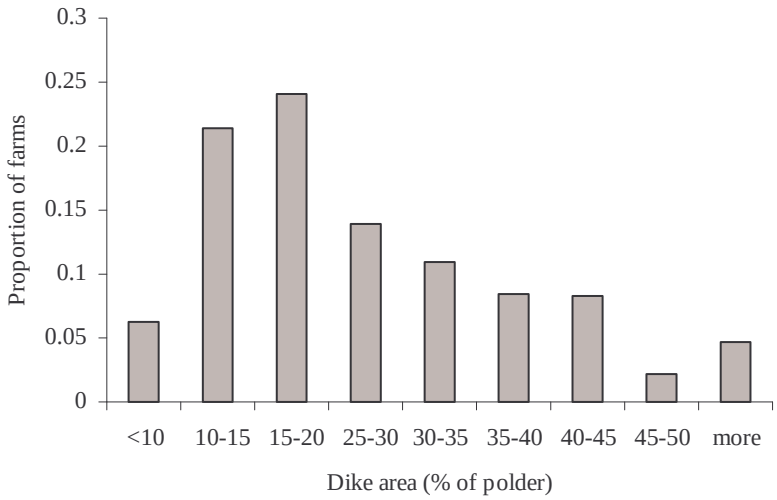

Figure 2: Sample distribution of dike area percentage for farmers practicing shrimp farming

3. Market failure and land degradation

The costs associated with land degradation arising from on-farm deposition of sedimentation are contained completely on the farm. In a scenario of perfect land markets when all costs are contained onsite, the full cost of private decisions can be incorporated in the market value of the land. In such cases there are no economic or policy issues as all costs are accounted for and therefore the level of production and associated degradation is socially optimal (Blyth and McCallum 1987, Ch 4). Economics is concerned with circumstances under which these and other theoretically ideal outcomes do not prevail, and hence the extent to which private decisions about the use of resources are reflective of society's values.

Certain conditions are required for the existence of perfect land markets. However, it is questionable whether these conditions prevail in the economic context of the rice-shrimp system in the Mekong Delta. Market failure is a concern with respect to divergent private and social time preferences, insecure land tenure, and imperfect information about the long-term implications of high water exchange.

The convergence of private and social discount rates is questionable in the development context in the Mekong Delta where the capital market operates on a very

short-term basis and long-term capital markets are either imperfect or non-existent. The upward pressure this places on the market interest rate is likely to discourage farmers' investment in long-term land quality because of the high returns necessary to outweigh the high interest rate costs (Quiggin 1987). Another indication of a divergence between private and social time preferences in the Mekong Delta is the poor financial capacity of households. Farmers in financial difficulty (or poverty as is the case in the delta) are likely to face high effective discount rates because of the high demand and need for current consumption relative to consumption in the future (Quiggin 2001).

The security of land tenure can also have a significant effect on farmer's discount rates and motivation in the adoption of sustainable land use practices. This arises because of the importance of property rights in the temporal distribution of benefits and costs from decisions (Quiggin 1997). In a situation of ill-defined land tenure it is argued that farmers act with finite planning horizons as they may not anticipate being able to pass the land on or the option to stay on the land beyond the foreseeable future (Beaumont and Walker 1996). This is a concern in the delta where formal land use rights for rice-shrimp farming are only specified for 15 years. While the limited empirical investigation in this study precludes a reliable conclusion to be made regarding land tenure and market failure, the short-term nature of the formal land use certificates suggest that insecure land tenure is a source of market failure.

A final point to be raised with regard to market failure and land degradation, relates to information. In the case of onsite costs associated with land degradation, Chisholm (1987b, Appendix A) suggests that it is most likely that farmers are operating on the basis of imperfect information as the complexity of environmental processes makes it difficult for farmers to have complete knowledge of the effects of farm management decisions on land quality. In the 'traditional' rice-shrimp system, the physical causes of land degradation are reasonably easy to observe, however forewarning of land degradation that has arisen in the system is likely to have been fairly limited at the initial stages in the development of the farming practice. In the small group of 17 farmers interviewed during the fieldwork in this research, all farmers experienced a build-up of sediment over the shrimp production cycle, yet all but one of the farmers perceived that they would never have to stop the farming of natural shrimp as a result of land loss. The evidence of the significant loss of land in the 'traditional' system does raise questions about the appropriateness of such perceptions, and suggests that poor information, or the nature of farmers perceptions about land loss, is a source of market failure.

4. Farm-level response to land degradation

There is some evidence of responses by farmers to ameliorate the effects of sedimentation. For example, some farmers have invested in pumps to flush sediment back to the river which has been permitted by some local authorities at designated times of the year. However, as mentioned previously, in the main, flushing of sediment back to the river is prohibited because of the potential environmental impacts and the difficulties associated with the capacity of canals to cope with additional sediment.

A reduction in water exchange is an obvious response to the sedimentation problem. On a minor scale some farmers have tried to limit their water exchange to known

times of lower sediment load in the water. It is also known that some 'traditional' rice-shrimp farmers try to reduced their water exchange for the purpose of reducing sedimentation. However, in an economic analysis of the long-term benefits of low water exchange in the 'traditional' system, despite the benefits of maintaining land productivity over the long-term, Clayton (2002) concluded that there was little incentive for farmers to reduce their water exchange below the high rates currently observed in the delta. This result was most pronounced under high discount rates and short planning horizons yet it was robust under parameter values which were less favourable to the high-exchange option and biased toward long-term social values (Brennan et al. 2000).

The difficulty with land degradation in the 'traditional' rice-shrimp system is that water exchange is, at the same time, a culprit behind the land degradation and the main source of income from the system. The economics is also driven by the high income from natural shrimp relative to rice farming (Brennan *et al.* 2002). Nevertheless, the results in Clayton (2002) suggest that the apparent problem of land degradation is not a social problem and hence there is not sufficient justification for policy or institutional intervention. The market failure problems that were discussed previous (poorly functioning capital markets and land tenure insecurity) do not enter into the “equation” because the land degrading option remains as the preferred option under social preferences.

The scenario of reduced water exchange in the 'traditional' system represents a reduction in the production intensity within the existing technology. In some cases an analysis of land degradation under a static representation of technology may be an appropriate and realistic representation of the land degradation problem. However, in other cases a static view of farm technology misrepresents the dynamic nature of rural development in which new technology can emerge as a result of farm-based trial and error, research and farm extension. In the second part of this paper technological change is introduced into the exploration of the economics of the land degradation problem. The economic benefits from low water exchange *P.monodon* rice-shrimp technology are compared to the high water exchange 'traditional' system. The results from this analysis suggest that there is a situation where it is socially and privately optimal not to degrade the land. The survival rates of *P.monodon*, however, are pivotal in this.

4. Introducing Technological Change

4.1 Introduction

In the study area some farmers have adopted rice-shrimp systems based on hatchery-stocking of *P.monodon* shrimp rather than tidal recruitment of natural shrimp. It has been through farmers’ trial-and-error, local extension activity and research activity of local universities and government departments in the Mekong Delta that *P.monodon* rice-shrimp technology has become a production option for farmers. This alternative technology has some advantages in the context of land loss because the system does not require high rates of water exchange, however the practise of *P.monodon* rice-shrimp systems in the Delta has not been without its own sustainability problems. In particular, the uncertain and low shrimp survival is a problem of crucial concern because of the effects that risky survival can have on economic viability and farm income risk (see Brennan 2002).

The model presented here is a simple net present value farm simulation model that describes the bioeconomic relationships inherent in the rice–shrimp system, both for 'traditional' technology under land degradation and for the *P.monodon* based technology. The model relationships and parameter values are based on ACIAR farm data, expert opinion and relevant scientific studies. The standard method of exponential discounting was applied to account for time preference in which specified rates of discount were used to calculate the 'present value' of a stream of net benefits accruing over time. The net present value was evaluated under a low (5%) discount rate argued to be reflective of social values, and a high (20%) discount rate to represent private time preferences. This high rate is based on the high market interest rates observed in the Mekong Delta.

The productivity level ('threshold') at which the alternative *P.monodon* rice-shrimp technology is socially (and privately) optimal to adopt was evaluated in comparison to the natural rice-shrimp system. The feasibility of this 'threshold' productivity level was investigated based on the ACIAR cross-sectional farm data on survival rates. As already discussed, farmers in My Xuyen have experienced a much better survival rates compared to farmers in Gia Rai. The ACIAR farm survey data have also revealed that the input costs and stocking rates in My Xuyen tend to be much higher on average compared to those in Gia Rai.

In the analysis presented below observed survival rates and production parameters in My Xuyen are used to represent "good" shrimp survival technology and the data in Gia Rai are used to represent "poor" survival technology. The purpose of evaluating the "good" and "poor" scenarios was to explore the sustainability concerns associated with risk and poor survival and also to evaluate the potential long-term benefits from technical change (improved survival) in an otherwise poor survival situation, as experienced in Gia Rai. The technical reasons for the lower survival rates in Gia Rai are not easily explained or understood however they have in part been attributed to farm management practices such as low or zero feeding, off-peak stocking which imposes risks of low salinity, purchasing of cheaper lower quality postlarvae, and adverse environmental conditions (ACIAR Final Workshop 2000 *Pers.Comm*[3]).

The *P.monodon* rice-shrimp farming practices in Gia Rai generally involve much lower inputs compared to My Xuyen. For example, the postlarvae costs in Gia Rai tend to be much lower because of off-peak stocking patterns and because postlarvae are more commonly purchased directly from trucks rather than from nurseries. The 'losses' from poor shrimp survival in Gia Rai are offset to some extent by these lower input costs. The parameter values for stocking density and input costs that are consistent with observed Gia Rai practices are shown in Table 7.4. These parameters are based on the 1997 ACIAR farm survey data.

In the following section the farm model relationships, scenarios and assumptions are outlined.

[3] Notes taken during group discussion at ACIAR final Workshop, December 2000, Can Tho University Vietnam

4.2 Model of the 'traditional' rice-shrimp farm

4.2.1 Net economic benefits in the 'traditional' system

The net economic benefits from rice-shrimp production in the 'traditional' rice-shrimp system was evaluated over time using the net present value (NPV) formula outlined below.

$$NPV_x = \sum_{t=0}^{T} \frac{y_{xt}}{(1+r)^t} \qquad \textbf{(1)}$$

Where:
The symbol *'x'* is applied as a label to distinguish the 'traditional' system
Y_{xt} is the net annual income from the 'traditional' rice-shrimp system in year *t*
r is the discount rate
T is final year of production.

4.2.2 'Traditional' rice-shrimp income

The annual net cash income per hectare for traditional rice-shrimp production is described in Equation (2a).

$$Y_{xt} = P_n.Q_{nt} - a.A_t - OV_t - FC + Y_{rt} \qquad \textbf{(2a)}$$

Where:

P_n is the harvest price for natural shrimp
Q_{nt} is the annual natural shrimp yield in year *t*
A_t is the hours hired for sediment removal in year *t*, *a* is the cost per unit
OV_t is the sum of other variable costs in year *t*, such as feed and chemical inputs
FC is fixed costs in year *t*, such as basic polder maintenance
Y_{rt} is the net income from rice production in year *t*

And, where the annual income under land loss is expressed as:

$$Y_{xt} = f(F, L_t) \qquad \textbf{(2b)}$$

Equation 2b is a simple representation of the temporal income tradeoff arising from land degradation. The income from the 'traditional' system is expressed as a function of water exchange frequency (F) and productive land area (L). Income is a positive function of land area, and water exchange, yet land area is negatively related to water exchange because of the land loss arising from a build-up of sediment over time.

4.2.3 Natural shrimp production

The natural shrimp yield is expressed in Equation 3.

$$Q_n = (c_1V_{in} - c_2V_{out}).\delta.w \qquad \textbf{(3)}$$

Where:

c_1 and c_2 are the density of shrimp juveniles per volume of intake and outtake water, respectively. c_2 are the "escapee" postlarvae.

V_{in} and V_{out} refer to the volume of intake and outtake water, respectively

δ is the survival rate of shrimp

w is average harvest weight of shrimp

4.2.4 Sediment build up in the 'traditional' system

The build up of sediment in the rice-shrimp polder depends on the annual load of sediment over the shrimp production phase. The total sediment load in the polder over an annual production cycle is expressed in Equation 4 below.

$$Z = \frac{\left(V_0 + \sum_{m}^{12} X_m\right).TSS}{1000} \qquad \textbf{(4)}$$

Where:

Z is the annual sediment load (kg)

V_0 is the pond volume at the start of the year (m^3)

X is the volume of water exchanged per month (m^3)

TSS is the net density of suspended solids per volume of water (g/m^3), which is the suspended solids in the intake water minus suspended solids in the outtake water.

m represents one month

And,

The total volume of the accumulated sediment in year t is expressed by Equation 5.

$$\eta = \sum_{t}^{Y} Z/d \qquad \textbf{(5)}$$

Where:

η is the volume of accumulated sediment in year t (m^3)

d is the density of dry sediment (kg/m^3)

d is calculated based on assumptions about the bulk density of the completely dry-sediment and the moisture content of the dike-dry sediment.

4.2.5 Land loss over time

The translation of the volume of accumulated sediment to loss of land area (area of inner dike) requires a number of assumptions about polder dimensions, outer dike capacity and inner dike dimensions. Based on the ACIAR survey data the original rice-shrimp polder dimensions (at t_0) are assumed to be: 0% inner dike, 8% outer dike area, 14% trench area and 78% field area.

As sediment accumulates over time it is assumed in the model that the outer dike capacity is exhausted first and once exhausted the construction of inner dikes is required. The outer dike dimensions at t_0 are assumed to be 0.5 metres high by 1 metre wide and it is assumed that the maximum height possible for the outer dike is 1

metre. Thus, initially the capacity (space available) of the outer dike (per hectare) for the deposition of accumulated sediment is: (1m - 0.5m).800m^2.

Based on farm observations, the inner dike dimensions on the field are assumed to be 1 metre in height by 1.5 metres wide. Hence, for each cubic metre of sediment accumulated (once the outer dike capacity has been exhausted), two thirds of a metre of the field length is lost. Therefore, the total area taken up per cubic metre of sediment is 1m^2 (1.5m wide by 0.66m field length).

The projected land loss over time (represented as increases in dike area over time) is shown in Figure 3 below. This simulation is based on the assumptions outlined in Table 1 below.

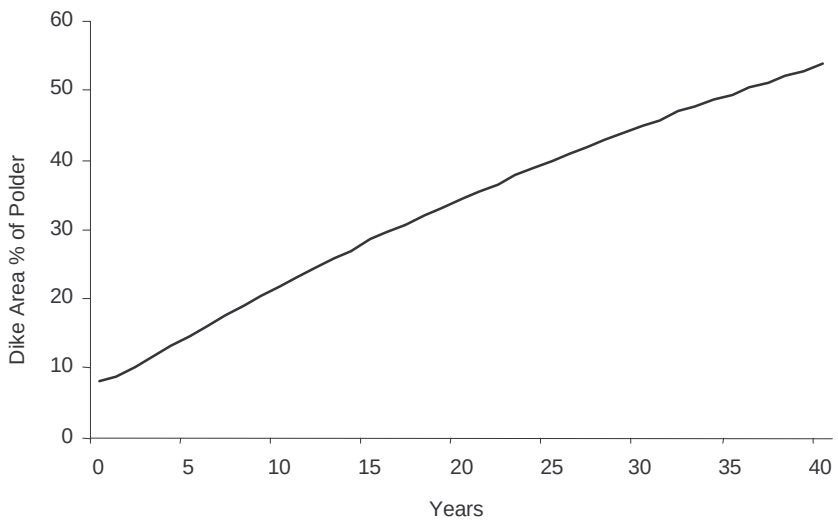

Figure 3: Projected increase in dike area over time

After the exhaustion of the outer dike capacity for the deposition of sediment, the model simulates construction of inner-dikes for deposition of continued sediment accumulation. As shown in the figure, the outer dike capacity is exhausted within the first few years, which means that the onset of land loss begins within the first two years of natural shrimp production. Over time, as more and more field area is taken up with inner sedimentation dikes, the pond capacity is reduced. The loss of land occurs at a decreasing rate because the rate of sediment accumulation slows with the declining pond water area. This is reflected in the 'curving-off' of the curve over time. The empirical evidence available on dike area increases supports the model-projected land loss in that the projections lie within the range of land loss experienced by many rice-shrimp farmers in the survey region over similar time frames. For a more detailed validation of the model see Clayton (2002).

4.2.6 Rice in the rice-shrimp system

$$Y_{rt} = P_r.(Q_{rt} - Q_{subt}) - VC_{rt} - FC_{rt} \qquad \textbf{(6)}$$

Where:

P_r is the harvest price for rice

Q_{rt} is the annual rice yield in year *t*
Q_{subt} is the quantity of rice yield kept for subsistence consumption

Rice is an important subsistence crop for farm households in the study region and therefore a subsistence level is assumed. In the model, costs equivalent to the subsistence rice needs is simulated if rice production falls below the assumed subsistence needs.

4.2.7 Assumptions

The assumed parameter values for the model are outline in the table and notes below (Table 1). These assumptions are based on data from the ACIAR farm survey. The opportunity cost of family labour is included in the relevant variable costs, valued at the market rate for labour (25,000 dong per day), which is reflective of foregone off-farm employment.

Table 1: Parameter assumptions for the 'traditional' farm model

	Value	Note
Sedimentation		
Net TSS g/m^3	250	*1*
Bulk density g/cm^3	1.5	*2*
Moisture content of dike	30%	*2*
Natural shrimp production		
Exchange months per year	10	*3*
Exchange days per month	20	*3*
Measure of water exchanged per time, m	0.27	*4*
Shrimp recruitment density PL/m^3	0.37	*5*
Shrimp survival %	0.3	*6*
PL Loss %	0.4	*7*
Harvest weight, grams	10	*8*
Sediment removal cost `000 VND/ha	1667	*9*
Feed costs `000 VND/ha	0	*10*
Fixed costs `000 VND/ha	717	*11*
Price '000 VND/kg	22.87	*12*
Rice assumptions		
Yield (year t_0) t/ha	3760	*13*
Subsistence consumption kg	1400	*13*
Variable costs `000 VND/ha	1925	*13*
Price `000 VND per kg	1.6	*13*

Notes
1. The density of TSS in intake water was measured using a data-logger positioned at the site of an experimental farm in My Xuyen in 1998 (ACIAR project data)
2. These assumptions are based on expert opinion (Riko Hashimoto, *Pers.Comm* 2000[4])

[4] Riko Hashimoto, PhD candidate in School of Geosciences, University of Sydney

3. The water exchange is assumed to be a scenario where farmers opt to exchange water as frequently as possible. The recruitment regime in this scenario is similar to those observed in the ACIAR survey for the sub-sample of farmers who raise only natural shrimp in both dry and wet seasons. In this scenario water is exchanged twice per month (at each spring tide) for ten days each time over ten months of the year. During the months of November and December farmers are assumed to carry out polder reconstruction and therefore do not recruit shrimp, which was a common practice for farmers interviewed in the ACIAR survey.
4. This is based on farmer's estimates of the height of water exchanged per exchange period. The 0.27 metres assumption is the average from the 1997 ACIAR farm survey data. The volumetric measure of water exchange is the height of water exchanged multiplied by the pond area. And the total volume of water exchanged per year is calculated as the number of metres exchanged per year multiplied by the polder area.
5. Recruitment data from Johnston *et al*. (2000) were used. The average density of postlarvae from January - October (0.369 PL/m^3) in the Johnston study was applied. The net recruitment density per unit of water exchange, after accounting for recruitment losses and shrimp mortalities, is calculated as 0.066 postlarvae per m^3 of water exchanged.
6. Data on natural shrimp survival is sparse because of the difficulties in data collection. Therefore the assumption of 30% was based on average survival rates in *P.monodon* systems in My Xuyen.
7. This assumption is based on sampling reported in Johnston *et al.* (2000) during harvests (ebb tides) in order to measure losses of shrimp juveniles in the harvesting process.
8. The weight assumption is based on expert opinion (Tran Than Be and Le Xuan Sinh, *Pers.Comm*, 2001[5]) and is consistent with the ACIAR data on shrimp prices against shrimp size.
9. Sediment removal cost based on average costs from ACIAR survey for the subset of farmers recruiting natural shrimp only in both the wet and dry seasons.
10. Zero feed cost assumption is supported by the ACIAR survey data that show limited or zero feeding for natural shrimp production.
11. Fixed costs are based on the polder preparation cost data from the 1997 survey (not including costs associated with sediment removal).
12. Average harvest price based on 3 year ACIAR survey data
13. Average, 1997 ACIAR data

4.3 Model of the *alternative (P.monodon)* rice-shrimp technology

4.3.1 Net economic benefits in the alternative system

In rice-shrimp systems based on stocking of hatchery-purchased *P.monodon*, any water exchange that takes place throughout the shrimp-growing season is generally low and therefore sediment build up is not significant enough to lead to land loss over time. Hence, the NPV of the *P.monodon* based technology is evaluated as the annuitized income stream from year zero. The NPV formula for the alternative production system is shown in Equation 7.

$$NPV_{alt} = \frac{y_{alt}}{r} \qquad \textbf{(7)}$$

Where:

Y_{alt} is the annual net income from the *P.monodon* based rice-shrimp system.

r is the discount rate

4.3.2 Rice-shrimp income in the alternative system

The annual net farm income per hectare for the alternative rice-shrimp system is expressed below (Equation 8).

[5] Informal discussion, University of Sydney

$$Y_{alt\,t} = P_m.Q_{mt} - (s.S_t + OV_{mt}) - FC_{mt} + Y_{rt} \quad \textbf{(8)}$$

Where:

P_m is the harvest price for *P.monodon*
Q_m is the annual *P.monodon* yield in year *t*
S is the stocking density of shrimp postlarvae, *s* is the cost per postlarvae
OV_m is the sum of other annual variable costs cost for the *P.monodon* crop
FC_m is the annual fixed costs

4.3.3 P.monodon production

The production of *P.monodon* depends on the number of shrimp stocked, the shrimp survival and growth rate. The growth rate is represented in the model as the final weight of harvested weight. In the empirical model the average weight of harvested shrimp is used as an estimate.

$$Q_m = Z.\alpha.w \quad \textbf{(9)}$$

Where:

Z is the total postlarvae stocked (number/ha)
α is the survival rate (number of shrimp harvested/number stocked)
w is the harvest weight of individual shrimp

4.3.4 The model scenarios

The two model scenarios evaluated - good and poor survival - are described below. The scenarios are based on the probability distributions of *P.monodon* shrimp survival in the two study districts which are shown in the figures 4a (My Xuyen) and b (Gia Rai) below.

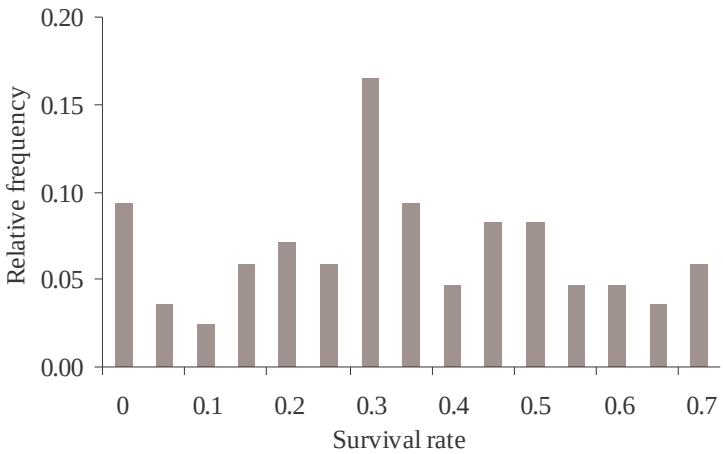

Figure 4a: Observed *P.monodon* survival rates in My Xuyen

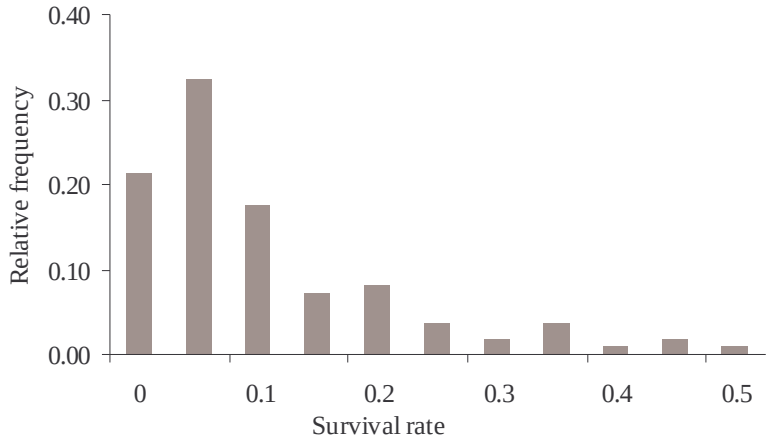

Figure 4b: Observed Gia Rai *P.monodon* survival rates

The high-input scenario - My Xuyen

The assumptions for the high-input scenario are outlined in Table 2 below. This scenario is representative of farmers in My Xuyen who invest in relatively high-input *P.monodon* shrimp production in the hope of bringing about good survival rates.

Table 2: Assumptions for a high-input *P.monodon* rice-shrimp system

Parameter	Symbol	Value	Unit
Stocking density	Z	2	PL/m^2
Harvest weight	w	30	G/shrimp
Shrimp harvest price	P_m	90	'000 VND/kg
PL cost	z	203	VND/PL
Feed cost	F	3560	'000 VND/ha
Chemical cost	C	400	'000 VND/ha
Sediment removal cost	S	685	'000 VND/ha

The projected *P.monodon* shrimp yield and income based on the assumptions in Table 2 are shown below in Table 3 for a range of survival rate intervals. This projected income range is then incorporated into an evaluation of the relative NPV of the alternative technology and the 'traditional' system. Results of this evaluation are shown in Section 4.4.

Table 3: Monodon shrimp survival and projected yield and income for the high-input alternative system

Survival Rate	Shrimp yield	Shrimp income	Rice-shrimp income
%	Kg/ha	VND/ha	VND/ha
0	0	-8.73	-7.28
10	55	-3.76	-2.31
20	110	1.21	2.65
30	166	6.18	7.62
40	221	11.15	12.59
50	276	16.11	17.56

The low-input scenario - Gia Rai

The assumptions for the low-input scenario are outlined below. This scenario is representative of farmers in Gia Rai who invest in low-input *P.monodon* shrimp production. The tradeoff of obtaining lower costs is experienced in lower survival rates. This tradeoff is evaluated in Section 4.4.

Table 4: Gia Rai parameter values

Parameter	Value GR	Value MX	Unit
Stocking density	1	2	PL/m^2
PL cost	94	203	VND/PL
Feed cost	0	3560	'000 VND/ha
Chemical cost	150	400	'000 VND/ha

The model-projected *P.monodon* yield and rice-shrimp income based on the Gia Rai parameter values are presented below for a range of survival rates (Table 5).

Table 5: *P.monodon* yield and rice-shrimp income results under Gia Rai assumptions

Survival Rate	Shrimp Yield	Shrimp income	Rice-shrimp Income
%	Kg/ha	VND/ha	Mill VND/ha
0	0	-2.49	-0.91
20	28	-0.01	1.58
20	55	2.48	4.06
30	83	4.96	6.55
40	110	7.4	9.03
50	138	9.93	11.51

4.4 Results: alternative versus 'traditional' technology

The economic benefit of the alternative technology relative to the 'traditional' system is illustrated here in terms of a ratio of the NPVs of the two systems. The NPV of the alternative system is chosen as the denominator so that for NPV ratios greater than one, the non-land-degrading option (the alternative system) is higher relative to the

land-degrading option (the 'traditional' system). The decision rule in this comparison is: from year zero, practice either the 'traditional' *or* the alternative system. Other decision rules are also feasible. The economics of delayed adoption of the alternative technology for *t* years is explored in Section 5 of this paper.

4.4.1 The "good" survival scenario

The NPV ratios (traditional/alternative) for a range of survival rates are presented below (Table 6). At the survival rate of thirty per cent, the alternative technology is socially and privately optimal compared to the 'traditional' system. The average of observed survival rates for the My Xuyen survey farms was thirty per cent, which is an indication that it is feasible for the NPV of the alternative option to, on average, outweigh the NPV of the 'traditional' system.

Table 6: NPV ratio under different survival rates

Survival Rate	NPV Ratio	
	Social	Private
0	-1.55	-1.17
10	-0.49	-0.37
20	0.57	0.43
30	**1.62**	**1.23**
40	2.68	2.03
50	3.74	2.83

In the figure below the ACIAR shrimp survival data for My Xuyen was used to represent the cumulative probability distribution for the projected NPV ratios shown in Table 6. Based on the "good" survival rates and the high-input scenario, it is predicted that twenty-five percent of the time under social discounts and around thirty per cent of the time under private discount rates, the NPV of the natural system outweighs that of the alternative (Figure 5). Based on "good" survival high-input technology (in My Xuyen), the results indicate that adoption of the *P.monodon* based rice-shrimp system is optimal over the long-term compared to the high-water exchange 'traditional' rice-shrimp system.

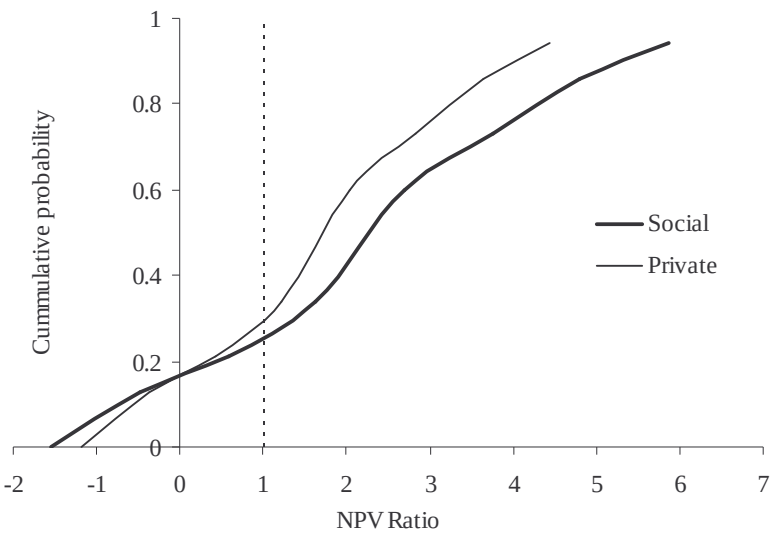

Figure 5: Cumulative probability distribution of the NPV ratio, 'good' survival rates

4.4.2 The "poor" survival scenario

In a similar way to the simulation of the income distribution for the "good" scenario, the income distribution is simulated under Gia Rai survival rates. As shown in Figure 6, it is predicted that the NPV ratios for the Gia Rai scenario would remain at less than one around 80% of the time under social discount rates and almost 90% under private discount rates. Therefore, despite the lower input costs in Gia Rai, the proportion of the income distribution for which the NPV of the alternative system is valued at less than that of the 'traditional' system is very high.

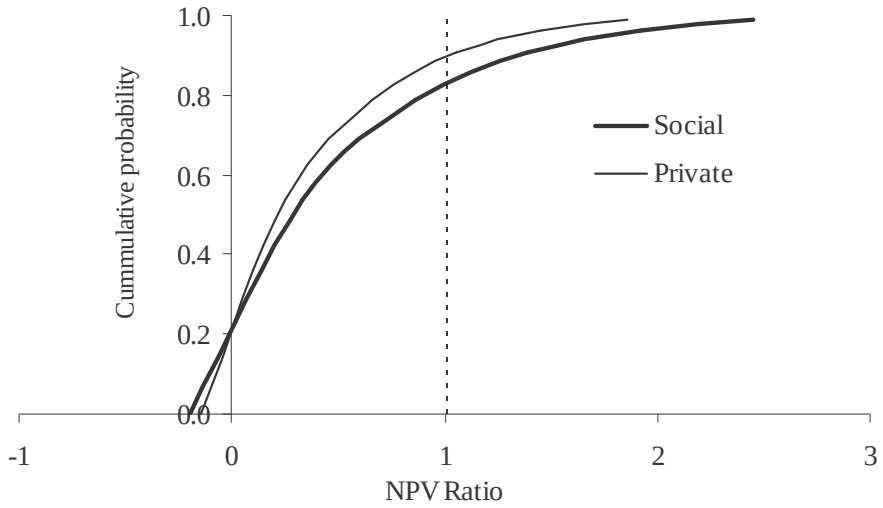

Figure 6: Cumulative frequency distribution of NPV ratios under Gia Rai survival rates and parameter assumptions

4.4.3 Summary comment

These results highlight the importance of good shrimp survival in providing an alternative non-land-degrading system which is a realistic and viable option for farmers who are currently practicing the high-water exchange 'traditional' rice-shrimp. The productivity of the alternative technology (of which shrimp survival is the dominant factor explored here) is crucial concern because of the implications it has for the opportunity costs of the land degradation in the 'traditional' system. As shown in the above results, the higher the *P.monodon* survival rate the less competitive is the 'traditional' rice-shrimp system, however the high water exchange natural system will dominate economically as long as its shadow price exceeds that of the alternative system.

Although the economics indicates that the *P.monodon* hatchery-based systems can provide an optimal solution away from the land degrading systems (as shown in the case of ‘good’ survival), the problem associated with low productivity due to poor shrimp survival can pose significant constraints in providing farmers with incentives to adopt the technology. The adoption of *P.monodon* in Gia Rai district under the current low levels of shrimp survival is unlikely.

The issue of the productivity of alternative technology is an important issue raised by others in the analysis of the economics of land degradation. Bathgate and Pannell

(2001) address the issue of financial incentives in the context of land degradation arising from dryland salinity. They argue that policy and research addressing salinity problems needs focus on developing profitable alternative technologies for farmers.

5. Conclusions and policy issues

One of the main advantages of the tidal-recruitment rice-shrimp system is that very little cash outlay is required and therefore it is a low risk and accessible technology for the poorer farmers in the saline affected agricultural areas in the Mekong Delta. However, the long term land loss in these systems raises concerns about the sustainability of the system, yet in a scenario of static technology, research reported on in this paper suggests that the wide-spread incidence of land degradation in the tidal-recruitment systems does not present an economic problem.

The social and private opportunity costs of the land loss in the 'traditional' system are highlighted in this paper in the context of technological change. It is argued that the economic problem of land loss is strongly connected to problems of accessibility to non-land degrading technology that is economic for poorer farmers who are dependent on the tidal recruitment of natural shrimp. The survival rates of *P.monodon* and associated risk are areas of particular concern in providing a viable alternative to the 'traditional' rice-shrimp farmers. In the case of low survival, as experienced in Gia Rai, the results indicate that there are no economic incentives for farmers to adopt alternative technology. Survival rates of at least 30% were found to be necessary for *P.monodon* to become an economically feasible option for farmers currently practicing the high water exchange rice-shrimp system. This result suggests that to the extent that the technological environment is dynamic and adoption of low-risk and good survival *P.monodon* technology is possible, the long-run opportunity costs of land loss are underestimated under a static representation of technological change.

These results show that there are potentially significant social benefits to be gained from research and extension that works toward achieving high and stable *P.monodon* survival. There is some evidence from the ACIAR data on *P.monodon* survival that farm management techniques as practiced in My Xuyen, such as feeding, postlarvae selection and water management can improve survival.

Apart from the problem of low and risky shrimp survival, credit policy is another area of concern in relation to the accessibility of alternative technology. Even if improved *P.monodon* technology (higher survival) was available, the poorly functioning formal credit market in the Delta presents constraints for 'traditional' rice-shrimp farmers in adopting the alternative technology. Improved access to formal credit for rice-shrimp farmers has been an important policy consideration of the provincial and district departments of Agriculture and Rural Development in the study area.

Credit policy, however is a complex policy area due to concerns about risk and farm indebtedness. In local credit policy in the study area there is an expectation that loans are provided to rice-shrimp farmers only as supplementary capital. The rationale for this is in part to limit the risk exposure to farmers raising *P.monodon*. Moreover, in some parts of the study area, mainly in My Xuyen, policy makers are currently grappling with growing concerns about the intensification of shrimp production in the

Delta either by farmers practicing higher stocking rates or abandoning rice-shrimp systems and instead practicing double shrimp cropping systems. Credit policy will have an important role to play in controlling intensification to manageable levels, socially and environmentally.

References

Bathgate, A. and Pannell, D.J., (2001), 'Economics of deep-rooted perennials in southern Australia', *Agroforestry Systems*

Beaumont, P. M. and Walker, R. T. (1996). 'Land Degradation and Property Regimes.' *Ecological Economics* 18(1): 55-66.

Blyth, M. and McCallum, A (1987) 'Onsite costs of land degradation in agriculture and forestry', Ch. 4 in *Land Degradation: Problems and Policies,* A.Chisholm and R.Dumsday (eds), Cambridge University Press and Australian National University CRES, Cambridge

Brennan, D (2002). 'Factors affecting farm financial risk: observations from a bioeconomic model' Ch.10 *in* Preston and Clayton (eds) *Sustainability of the rice-shrimp systems in the Mekong Delta, Vietnam*, ACIAR Technical Report 52(e).

Brennan, D., Clayton, H., Tran Thanh Be, and Tran The Nhu Hiep. (1999), *Economic and Social Characteristics and Farm Management Practices of Farms in the Brackish Water Region of Soc Trang and Bac Lieu Provinces, Mekong Delta, Vietnam: Results of a 1997 Survey*, ACIAR Rice-Shrimp Project Report.

Brennan, D., Clayton, H., Tran Thanh Be. (2000). 'Economic characteristics of extensive shrimp farms in the Mekong Delta'. *Journal of Aquaculture Economics and Management*, 4 (3/4): 127-137

Brennan, D., Preston, N., Clayton, H., and Tran, T B., (2002), *An evaluation of rice-shrimp farming systems in the Mekong Delta*. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium.

Chisholm, A (1987), 'Rational approaches to environmental issues, Appendix A' in *Land Degradation: Problems and Policies,* A.Chisholm and R.Dumsday (eds), Cambridge University Press and Australian National University CRES, Cambridge

Clayton, H., (2002). *The Economics of Land Degradation in the Rice-Shrimp System in the Mekong Delta, Vietnam*, Unpublished Masters of Agricultural Economics Thesis, Department of Agricultural and Resource Economics, University of Sydney.

Quiggin, J., (1987), 'Land degradation: behavioural causes', Ch.10 in *Land Degradation: Problems and Policies,* A.Chisholm and R.Dumsday (eds),

Cambridge University Press and Australian National University CRES, Cambridge

Quiggin, J. (1997). 'Discount Rates and Sustainability.' *International Journal of Social Economics* 24(1-2-3): 65-90.

Quiggin, J (2001), 'Environmental economics and the Murray-Darling river system'. *The Australian Journal of Agricultural and Resource Economics*, 45(1): 67-94

Tran Thanh Be, Le Canh Dung, and Brennan, D. (1999). Environmental costs of shrimp culture in the rice-growing regions of the Mekong Delta. *Aquaculture Economics and Management*. 3(1): 31-42.