Appendix A. Integrated modelling of Bandon Bay: socio-economic aspects

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1. Introduction

This report is part of the Integrated Biogeochemical and Socioeconomic Modelling Project supported by the SARCS/WOTRO/LOICZ Project which was undertaken in four countries, namely Philippines, Malaysia, Vietnam and Thailand. The overall objective of the project was to explore the approaches toward integrated modelling of the biogeophysical and socio-economic processes through an intensive case study. For Thailand, the Bandon Bay area in Suratthani Province, Southern Thailand was selected as the site for the case study.

For the socio-economic study, the objectives of the study are:

- To present a description of the social and economic setting of Bandon Bay
- To examine the human uses of the ecosystems present in the study area
- To estimate the amount of the anthropogenic contribution of the Carbon, nitrogen and phosphorus fluxes in Bandon Bay
- To estimate the values of the ecosystem in economic terms

1.1 Methodology

A number of methodological approaches are used to achieve the objectives of the study. These are:

- A review of secondary data sources relating to the socioeconomic condition of the province
- An economic analysis of specific activities present in Bandon Bay
- Construction of an input-output table of Suratthani province for the estimation of the anthropogenic CNP fluxes
- An economic valuation of ecological variables relating to ecosystem-based production activities

1.2 Data Sources

The data sources for the study are:

- Publications for the Suratthani province
- The Thailand National Input-Output Table for 1990
- The WHO Data book for emission
- Field trips were made with the science team in 1998-99
- Comments from the SWOL Meetings were taken into consideration in the completion of the Final Report.

1.3 Organization of the Report

The report is divided into six parts. Part 2 gives the overview of the socio-economic setting of the study area. It looks at the growth of economic activities in particular, and identifies important production activities, which are dependent on the resource endowment based on the ecosystem attributes of the study area.

Part 3 describes the methods and results of the estimation of anthropogenic CNP fluxes using the input-output table constructed for the provincial economy.

Part 4 assesses the economic returns from resource use in the Bandon Bay area. In particular, the economic returns to shrimp farming and mariculture of oysters and clams in the Bay area are estimated.

Part 5 provides an estimate of the values of ecosystem inputs into economic activities. The analysis in this chapter looks at the trade-off between shrimp farming in mangrove areas and the culture of oyster which utilizes the natural flows of nutrients into the Bay area to support the growth of the oysters. The focus of the analysis is the value of the carbon flows relating to these two activities.

Part 6 summarizes the results and outlines a number of issues for further study.

2. Description of the study area

Suratthani province is located in the upper southern region of Thailand. It has an area of 12,890 km^2 and a population of approximately 861,200 in 1997. The province is well endowed with natural resources, with forest covering about 25% of the area, while the coastal zone has mangrove forest. The sea provides a livelihood for fishermen and aquaculturists, while the offshore islands have become well known internationally as tourist destinations. The rich natural resources of the province provide the raw materials for industries which have developed in the area.

2.1 Population

The 1997 population of the province is distributed into 19 districts, and three urban centres as shown in Table A2.1.

2.2 Land Use

Land use in Suratthani province in 1994 was largely agricultural and forest. Agricultural land is mainly land for rubber and oil palm plantations. Most of the land area is rolling foothills suitable for upland crops and tree cultivation. The lowland areas suitable for rice cultivation is limited. However, a large area is still under forest, and it is now protected by law as national parks, wildlife sanctuaries and non-hunting areas. One part of the protected forest was used for the construction of a hydroelectric dam and the reservoir A small amount of land is used for urban centres and industry. See Table A2.2.

In the last ten years, a lot of the mangrove forest in the coastal zone has been converted to shrimp farms. The loss of the mangrove has raised concerns about the ecological and economic damage, and the remaining mangrove areas is now closely guarded by the local communities and the provincial administration.

2.3 Mangrove forests and changes through time

The depletion of mangrove forests in Bandon Bay during 1961-1979 was due to coastal development with the highest rate of depletion of about 77%. Conversion to aquaculture in particular shrimp ponds was not likely the major pressure. The area for shrimp farms was 241.60 ha in 1979 (Haemaprasit and Paw, 1988). However the shrimp farming steadily increased in the area to 1592.32 ha in 1983 (Boonpakob, 1983) and to 3,262.0 ha in 1985 (Haemaprasit and Paw, 1988). The rates of increase in shrimp farm areas were 6.59 and 13.50 folds respectively as compared to the original area in 1979. Boonpakob (1983) had predicted the expansion of shrimp farms in Suratthani to its fullest capacity of 3,200 ha. Within two years, the shrimp farms in Ban Don Bay had already expanded to its full prediction. However, the expansion of shrimp farm area continued to 6,115.20 ha in 1993 and to 13,780.52 ha in 1996. Of this, shrimp farms on the previous mangrove area comprised about 54% of the total shrimp area in this province.

Coastal development is the other major force for the loss of mangrove area. The total population has grown steadily over the years from 588,400 in 1980 to 816,400 in 1990, with the projected population of 926,000 by the year 2000. The coastal resources of Ban Don Bay are heavily utilized for economic development, particularly tourism and aquaculture. Table A2.3 shows the comparison for the land use zonation in the mangrove area between the year 1993 and 1996 in Suratthani Province.

2.4 Production

The main products of the province are: rubber, oil palm, fruit, fishery products, canned seafood, and tourism. The gross provincial product for 1994 is shown in Table A2.4.

2.5 Future trends

Given its rich natural resource base, Suratthani has a high potential to continue to develop its economy. The main concerns are to make that development will be sustainable with proper balance between using resources for the present and the future. In this regard, the main issues may be briefly described:

- Forest and Agriculture: the preservation of forest area to maintain the ecological balance and the functions is crucial. Conversion of forest to other tree crops such as fruit tree and rubber plantations will be damaging to the ecological balance of the area.

- Mangrove and Shrimp farm: the need to maintain the mangrove forest as nursery ground for marine life has to be balanced against the use of the area for shrimp farming. Shrimp farms can be sustainable, but need to be highly managed. The mangrove areas need to be preserved to support its various ecological functions.

- Urbanization and Industrialization : with the increasing development of urban activities, based on tourism, and industrialization, based on processing of agricultural raw materials, there is a need to ensure that the wastes from urban centres and industries do not pollute the natural water sources. In particular, the aquaculture in the Ban Don Bay area is highly sensitive to variation in the water quality, and wastewater from urban and industrial sources can be highly damaging. However, plans are now in place to install wastewater treatment plants for the urban centres, while industrial wastewater is under close monitoring. The plan for the industrial estate is also closely scrutinized for its potential impact on the water resources, and such impact is likely to be minimal.

Table A2.1: Population Distribution in Suratthani Province, by district, 1997

District	Area (Sq.km.)	Municipal Area	Population	Urban Population	Number of Households
Muang Suratthani	231.31	68.97	40,169	107,888	54,050
Kanchanadit	873.53		91,011		22,663
Koh Samui	227.25		34,792		12,397
Kiriratnikom	1,347.37		37,578		8,186
Chaiya	1,004.63		42,905		10,314
Don Sak	458		33,473		9,081
Tha Chang	1,160.42		28,819		6,577
Tha Chana	683.08		43,125		10,825
Ban Nasan	835.06	67.13	47,827	19,390	15,337
Panom	703.22		28,515		6,576
Phra Saeng	1,328.06		52,148		11,815
Phunphin	1,201.16	14.1	67,724	22,520	22,444
Wiangsa	420.39		56,678		13,235
Koh Pangan	193		9,029		3,218
Kiansa	580		35,503		8,191
Ban Ta Khun	1,300		13,211		3,572
Ban Nadoem	206		20,974		5,013
Chaiburi	112		18,552		4,381
Vipavadee	529.25		9,402		2,403
Total	13,393.73		711,435	149,798	230,278

Source: National Statistical Office

Table A2.2: Land Use

A2.2.1 Land Use : Forest and farm land

Year	Total area	Forest	Mangrove
	12891.47	5830	
1975			37.00
1979			58.08
1982		4138	
1985		3787	
1986			42.84
1988		3397	
1989		3388	37.67
1991		3283	22.04
1993		3166	31.64

A2.2.2 Farm Holdings by Type 1993

Land Use	Area (Sq.km.)
Total farm holding	
Housing area	137.59
Paddy land	501.19
Field Crops	33.16
Tree Crops	2772.62
Vegetable and flowers	16.18
Livestock	3.93
Idle land	79.17
other land	79.15
Unclassified*	6102.58

*includes encroached and degrade reserved forests

Table A2.3: Land use zonation in the mangrove area in Suratthani Province between the year 1993 and 1996 (Charuppat and Ongsomwong, 1995; Charuppat and Charuppat, 1997).

Land use	Area in ha	
	1993	1996
Mangrove (conservation area)	3,164.00	3,133.80
Shrimp farms	6,115.20	6,337.60
Urban development	3.44	35.44
Other coastal development	2,520.36	2,296.16

Table 2.4: Gross Provincial Products in 1994

Sector	Current Prices (1,000 Baht)	% Share	Constant Prices (1,000 Baht)		% Growth
	1994		1989	1994	
Agriculture	13,389,171	37.64%	8,665,187	12,010,134	6.53%
Crops	9,138,789	25.69%	6,501,716	8,753,855	5.95%
Livestock	584,431	1.64%	420,307	589,878	6.78%
Fishery	2,285,042	6.42%	778,488	1,541,236	13.66%
Forestry	0	0.00%	57,418	0	-100.00%
Agri.Services	44,097	0.12%	44,784	34,302	-5.33%
Agri.processing	1,336,812	3.76%	862,474	1,090,863	4.70%
Mining and Quarrying	666,666	1.87%	392,801	384,885	-0.41%
manufacturing	2,728,564	7.67%	1,901,190	2,228,548	3.18%
Construction	2,270,185	6.38%	715,854	1,476,789	14.48%
Electricity and Water Supply	830,443	2.33%	364,530	643,102	11.35%
Transportation and Communication	1,829,373	5.14%	794,954	1,539,903	13.22%
Wholesale and retail trade	4,472,944	12.57%	2,495,807	3,318,153	5.70%
Banking and Insurance	2,268,615	6.38%	551,373	1,701,362	22.54%
Ownership of dwelling	1,224,930	3.44%	656,647	828,333	4.65%
Public administration	1,747,087	4.91%	718,024	955,115	5.71%
Other services	4,143,827	11.65%	1,778,276	2,409,640	6.08%
Total	**35,571,805**	**100.00%**	**19,034,643**	**27,495,964**	**7.36%**

3. Estimation of emission

3.1 The methodological approach

The approach that is used to estimate the anthropogenic emission of CNP fluxes is based on the input-output table and the production -emission relationship. Input-output table is a representation of interrelationship between various sectors of an economy. The economy is classified into sectors of productions. Each sector is assumed to require input from other sectors, and at the same time it produces outputs, some of which are used as inputs by other sectors, and some output is consumed. The output consumed by other sectors is referred to as intermediate demand, while the output that is consumed is referred as final demand. Total output is the sum of intermediate and final demand. Assuming a linear relationship between input and output, the flows between sectors can be represented by a matrix equation as follows:

$$X = AX + F$$

Where X = vector of gross output
A = matrix of input coefficients
F = vector of final demand

Using matrix algebra, the equation can be solved for gross output vector, X , as follows:

$$X = (I - A)^{-1} F$$

To estimate the emission from production activities, the relationship between output and emission is assumed to be linear, and can be written in matrix form as follows:

$$E = eX$$

Where E = vector of emission of type 1 to k,
e = matrix of unit emission from activities
X = gross output vector

E as estimated from the above model will be the amount of emission generated by production activity X. In addition, emission will be generated from household consumption activities, which has to be estimated separately. This is done by estimating the amount of emission from households directly.

3.2 Construction of the Input-output table for Suratthani

In order to apply the above approach to the study area, it is necessary to construct an input-output table, which is appropriate for the area. In principle, this can be done by conducting a field survey of activities presented in the area. However, due to budget and time constraints, this approach is not possible to be done. Instead, an input-output table for Suratthani was constructed from the national input-output table for the year 1990. The methodology for this is described below.

- Step 1: The activities considered to be present in Suratthani is selected from the total classification of 180 sectors in the national IO table.
- Step 2: Selected sectors are aggregated into 10 sectors to be used in the analysis. This step requires the reclassification of sectors into a more aggregated classification.
- Step 3: The aggregated sectors are transformed into a matrix of input coefficients, arranged by columns.
- Step 4: For each column, the ratio of value-added to total output is computed.
- Step 5: The gross output for each is obtained by applying the computed ratio of gross output to value added for the sector.
- Step 6: The flows in the transaction table are computed using the input coefficients for each sector (column).
- Step 7: The gross output by row is assumed to equal the computed gross output by column, so that the IO table is balanced. The ratio between intermediate and final demand is checked for consistency and found to be plausible.
- Step 8: The table is used to project the gross output for the year 1997-1998.

The constructed 10x10 sector A matrix is presented in Table A3.1.

Table A3.1 Inter-industry Coefficient matrix for the Suratthani economy.

Description	Agriculture	Fishery	Manuf1	Manuf2	Utilities	Construction	Trade	Rest. & hotel	transcom	Othserv
Agriculture	0.0591	0.0010	0.1230	0.2639	0.0000	0.0036	0.0000	0.0480	0.0001	0.0024
Fishery	0.0059	0.0182	0.0726	0.0000	0.0000	0.0000	0.0000	0.0239	0.0000	0.0011
Manufacturing I	0.0017	0.0020	0.1255	0.0072	0.0000	0.0031	0.0009	0.0571	0.0018	0.0009
Manufacturing II	0.0138	0.0532	0.0070	0.0330	0.0015	0.1308	0.0034	0.0342	0.1144	0.0062
Utilities	0.0019	0.0020	0.0094	0.0099	0.0869	0.0028	0.0106	0.0261	0.0046	0.0143
Construction	0.0012	0.0003	0.0011	0.0030	0.0006	0.0017	0.0016	0.0032	0.0009	0.0057
Trade	0.0328	0.0310	0.0735	0.0306	0.0063	0.0625	0.0051	0.0787	0.0232	0.0212
Rest&Hotel	0.0005	0.0000	0.0021	0.0025	0.0031	0.0040	0.0227	0.0046	0.0060	0.0042
TransCom	0.0081	0.0088	0.0203	0.0236	0.0133	0.0546	0.0129	0.0165	0.0412	0.0063
Other services	0.0152	0.0155	0.0138	0.0133	0.0159	0.0143	0.0839	0.0147	0.0223	0.0287
Total Inter-Surat	0.1402	0.1321	0.4483	0.3870	0.1275	0.2773	0.1412	0.3071	0.2145	0.0910
Total Imported	0.1539	0.2348	0.1996	0.2934	0.3322	0.3412	0.0751	0.2551	0.3518	0.0903
Total value added	0.7059	0.6331	0.3521	0.3196	0.5402	0.3815	0.7837	0.4378	0.4337	0.8187
Total Output	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

3.3 Estimation of emission coefficients

To obtain estimates for the emission coefficients, a number of data sources were consulted. Where specific data relating to Suratthani are not available, Thailand country data is used. Where the national data are not available, the WHO values for the comparable activities are used as default values. However, due to data limitations, only BOD is used as the measure of emission from anthropogenic activities. This limitation is justified with reference to the study area on the reasoning that most of the activities are generating only wastewater from production processes.

The resulting coefficient matrix and total BOD emission from economic activities are presented in Table A3.2. The major sources of human-based BOD generation are agriculture and manufacturing, which together account for around 50% of the total BOD generation. The household sector also generated a high proportion of around 15% of total BOD.

3.4 Results

Using the calculated values of gross output and the estimated emission coefficients, the total amount of BOD emission is calculated as shown in Table A3.3. The CNP fluxes are estimated from the BOD flux using standard ratios.

Table A3.2 BOD emission coefficient vector and estimates of total emission from economic activities in Suratthani.

Sector	**Output (VA based)**	**Coefficient**	**Total BOD discharge**	
	mB	ton/mB	ton/year	%share (total human=100)
Agriculture	12,182	0.1075	1,309.70	20.92%
Fishery	2,246	0.0537	120.75	1.93%
Manufacturing I	8,101	0.2150	1,741.88	27.82%
Manufacturing II	2,231	0.1075	239.88	3.83%
Utilities	1,035	0.2150	222.59	3.56%
Construction	3,774	0.1075	405.76	6.48%
Trade	4,620	0.0709	327.51	5.23%
RestHotel	3,582	0.0709	253.92	4.06%
TransCom	2,672	0.1075	287.24	4.59%
otherservices	5,746	0.0709	407.31	6.51%
Total from production			5,316.56	84.92%
Domestic household	679,672	0.0014	943.89	15.08%
Total from Human activity			**6,260.44**	**100.00%**

Table A3.3 Estimated Emission of CNP from BOD from Economic Activities in Suratthani

Estimated from IO table for 1997	ton/year	C ton/year (C:BOD=1.7)	N ton/year (N:BOD=0.5:1)	P ton/year (P:BOD=0.042:1)
Total BOD	6,260.45	10,642.76	3,131.7	262.8
Assimilation rate 80%	0.2	2,128.55	626.34	52.56

4. Economic uses of Bandon Bay ecosystems

The economic activities that are closely related to the ecosystems of Bandon Bay are:

- shrimp farming, which takes place on the shore area, initially using mangrove, which was cleared to make way for the shrimp farms. Later, with improved farming techniques for water and feed management, the mangrove area was used less. Nevertheless, the damage to the mangrove ecosystem has been done. Mangroves do not grow back on disused shrimp farms naturally.

- Oyster farming in the bay area is done by placing poles into the bay to provide anchor for the oysters to attach to. The oysters are left to feed naturally in the bay until it is big enough for harvest, usually taking about 18 months to 2 years. In addition, fishery in the Bandon Bay provides employment and income for a significant number of small-scale fishermen. The main catch consists of shrimps, which have a good price in the market. Finally, the mangrove forest provides a range of use values for the local population. Villagers collect wood and marine animals such as shrimps and crabs for both own consumption and for sale.

For the analysis of the economic returns from each activity, see section 4.1 in the main report, and Tables 4.1 to 4.3 (main report).

5. Valuation of carbon in the ecosystem of Bandon Bay

5.1 A conceptual model to estimate the economic value of carbon in Bandon Bay

The economic value of carbon in the Bandon Bay can be estimated in terms of the highest value use of carbon in the area. Based on existing activities, it is oyster farming that is generating the highest income among all activities.

5.1.1 Approach to modelling economy and ecology interaction

The approach for modelling the linkage between economy and ecology of Bandon Bay is based on de Kok (1998). This approach views the link in the form of flows of materials between the two systems. The economy takes nutrients from the ecosystem for producing goods, and in exchange the economy discharges wastes into the ecosystem.

The main links in Bandon Bay area are:

- **Uptake of nutrients:**
  - Oyster and clam production takes up the nutrients from the bay
  - Fishery also removes nutrients from the bay.
  - Conversion of mangrove to shrimp farms removes nutrient supply from the bay.

- **Input of nutrients**
  - Mangrove forest provides nutrients to the bay.
  - Economic activities, including shrimp farms, discharge waste into the bay.

The value of nutrients in the bay can be estimated from the value of goods produced. In this analysis, we use the value of oyster as a proxy for the value of a ton of carbon.

The analysis proceeds in step as follows:

- First, the amount of carbon input into the Bandon Bay is estimated. Carbon input to the bay is derived from 3 sources: anthropogenic emission (1.1), mangrove under natural conditions (1.2) and shrimp farm waste (1.3).

- The uptake of carbon is then estimated. Under the natural conditions, the process would be through the food chain from primary production to fishery. However, due to the favourable conditions of the bay for oyster and clam growth, part of the primary production goes to support oyster and culture. The use of carbon in the food chain for oyster production can be considered to provide a measure of the opportunity cost of carbon in the bay area. This is calculated in (2).

- The total flows of carbon from different uses in and around the Bandon Bay are estimated in (3).

- When the carbon balance for the bay is calculated, it can be seen that carbon in the form of primary production is converted into fishery biomass. The lower the carbon input, the lower will be the fishery biomass that can be produced in the Bandon Bay ecosystem. Thus, a trade-off can be identified between activities that reduces the carbon input and the use of the carbon in the bay. This can be considered as the resource cost of the carbon in the bay. Among the alternative uses of carbon in the bay, the highest value use is oyster culture. Thus, it may be reasonable to assume that the loss of oyster value is an appropriate measure of the value of carbon in the bay area.

  The rationale for this assumption is that because oyster is the highest valued product that can be obtained from the bay, a trade-off exists between it and other uses of carbon. This trade-off would apply to all other users of carbon in the bay, so that more oyster would mean fewer shrimps in the sea to be caught, for instance. But the most obvious use of the carbon input, and one that is irreversible, is the conversion of the mangrove into shrimp farms on land. Thus, the potential loss of oyster due to the loss of mangrove carbon input provides a direct measure of the external cost of the shrimp farm conversion of mangrove.

- When this reasoning is applied to the case of mangrove removal for shrimp farming, the cost of mangrove removal can be estimated (4).

  The calculation indicates that shrimp farms in mangrove areas cause a loss of carbon by the amount of 87 thousand tons carbon per annum. This is equivalent to the same amount of carbon in primary production, which in turn can be converted into oyster. Using the unit value of carbon estimated from oyster production, the total value of the loss of carbon input to the bay can be estimated. Finally, the cost of carbon loss per unit area can be estimated from the total area of shrimp farm established in mangrove. The result is that 1 rai of shrimp farm causes a loss of value of approximately 11,000 Baht.

See Table 4.6 (main report) for the value flows of carbon in Bandon Bay.

5.2 A model for calculating the economic value of carbon in Bandon Bay

The above process of reasoning points to an approach to estimate the economic value of the carbon flows in the Ban Don Bay. In order to formalize the analysis, a model is proposed to generalize the analysis.

Let Q = production of oyster

$Q = f(CPP)$

Where CPP = carbon in primary production

Let P = net price of oyster, in Baht kg^{-1}
Then value of oyster production is

$V = PQ = P\ f(CPP)$

The marginal product of CPP can be expressed as
$dV/dCPP = P\ f'(CPP)$

where $f' = df/dCPP$

Let $f(CPP) = a_1a_2CPP$, assuming a simple linear production function for oyster and primary production,

Where a_1 = ratio of kg_{oyster} to $kg_{carbon\ in\ oyster}$ = 1:0.05
a_2 = ratio of $kg_{carbon\ in\ oyster}$ to $kg_{carbon\ in\ primary\ production}$ = .0084:1

Then dV/dCPP = P* (1/0.05)*(0.0084/1)

From the analysis of oyster profit margin, value added of oyster is 38.xx Baht/kg. Thus, the marginal product of CPP = 6.53 Baht/kgCPP, or 6,530 Baht/tCPP

If the process of primary production can be described in terms of nutrients and other factors, we then have a way of relating the feedback of CNP fluxes to one of the economic activities. In this case, the value is applied to the loss of carbon from mangrove clearing for shrimp farming, which leads to the same result as described in 5.1. However, the relationship between production of economic value, such as oyster, and primary production needs to be further elaborated. It is likely that natural processes will not be linear as presented here, and therefore there is a need to specify the relationships more fully.

An extended model, which is specified for the Bandon Bay case is proposed below:

For primary production:

PP = f(C,N,P, other environmental conditions)

For oyster, production will also depend on investment, including growing materials, as well as operations. In addition, there is competition for primary production from other living organisms. Thus, the production function for oysters may be written as:

Qoyster = f(PP, INVESToyster, other fishery production)

Other fishery production may be dependent also on effort, such as the number of fishing boats with pushnets, or the number of artisanal fishermen. Thus, we can write the production function for other fishery as

Qotherfishery= f(PP, fishing effort)
Investment in oyster production and in fishing effort can in tern be thought of as responsive to price changes.. Thus, for each type investment,

INVESToyster = f(price oyster, price of fish)
INVESTfisheryeffort = f(price of fish)

The above equations can be estimated and then solved simultaneously, so that they jointly determine the optimal levels of production of oysters, fishery and other variables.

By substituting the variables in the equation system, it is possible to reduce the number of equations to two, which are:

Qoyster = f(CNP, price oyster, price other fishery)
and
Qother fishery. = f(CNP, price other fishery product)

This model may be refined and empirically estimated at a later stage.

6. Summary of Results

In this study, we have attempted to integrate the biogeophysical and the socioeconomic modelling by setting three objectives as follows:

(1) To estimate the amount of anthropogenic inputs of CNP fluxes into the environment
(2) To valuate the human use of the nutrients in the natural ecosystem and
(3) To estimate the economic value of these elements in the ecosystem.

The approaches for estimation and valuation are based on well-known models being widely used in economic analysis, namely the input-output model and analysis of farm budgets.

For the estimation of anthropogenic emissions, the input-output table for the study area was constructed, based on the national input-output table but modified to fit the conditions of the study area in terms of activities and scale of output. This was then used to estimate the value of production of output generated by the economy. The amount of emission of BOD was then estimated using emission coefficients estimated from a variety of data sources, which were then applied to the estimated output figures. It was found that anthropogenic emission of BOD was a significant share of total CNP fluxes in the Bandon Bay ecosystem.

Human activities impact on Bandon Bay in terms of emissions and uptake of nutrients

The study calculates the estimated input of BOD is 6,240 ton/year, or 10,642 ton carbon/year. Shrimp culture adds approximately 3,000 ton carbon/year from shrimp farm waste discharge. However, the main impact is due to the removal of mangrove forest fringing the bay area, which results in the loss of approximately 87,000 ton carbon/year.

The analysis of the utilization of ecosystem elements was focused on the use of carbon flows into and uptake from the bay area ecosystem. A range of economic activities was identified to be associated with varying magnitudes of carbon flows. For each economic activity identified, an economic value of the activity was estimated, which was then related to the value of carbon flows associated with the activity. In the specific case of Bandon Bay, the value of carbon was estimated with reference to the value of oysters being cultured in the bay area. Bandon Bay provides a rich breeding ground for marine aquatic life, and is being used for culture of oysters and clams which have a high market value, estimated at around 1,200 million Baht per year in terms of value added.

The value of the carbon was then applied to the loss of carbon flux as a result of mangrove clearing for shrimp farming. An estimate of the external cost of the shrimp farming activity was made with the values obtained from the analysis.

The resources of Bandon Bay have competing uses. The study focused on the trade-off between land-based shrimp farming in mangrove areas and the aquaculture in the bay area. The removal of mangrove for shrimp farms results in the loss of supply of nutrients to the bay and thus affects the growth of aquatic life in the bay ecology. This loss is calculated in terms of the market value of oysters to be around 12,000 Baht per rai of shrimp farm. It is proposed that this external cost of shrimp farming be internalised by imposition of a tax of the same amount on shrimp farmers.

Limitations of the study

However, the analysis depended on an assumption about the conversion of carbon flows into primary production and oyster biomass which need to be further refined and calibrated for the specific condition of the study area.

Nevertheless, the approach is considered to combine the findings from the biogeophysical and the socioeconomic analysis in an integrated framework for the analysis of the options in managing an ecosystem.

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