Optimal Coastal Land Use and Management in Krabi, Thailand: Compromise Programming Approach

Tipparat Pongthanapanich

February 2006

Editor: Eva Roth

Department of Environmental and Business Economics
IME WORKING PAPER 67/06

ISSN 1399-3224

Tipparat Pongthanapanich
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Tel.: +45 6550 4151
Fax: +45 6550 1091
E-mail: tpo@sam.sdu.dk

Abstract

This paper identifies the optimal options of Krabi's coastal land use to facilitate the final planning decision. Through compromise programming approach, the optimization models with respect to the weights assigned to two objectives of maximizing the net private and environmental benefits are formulated to derive the options. Various externality management scenarios based on different applications of policy tools are assessed. All scenarios suggest the optimal options in favour of mangrove conservation when both objectives are considered equally important. This is not the case when the private benefit objective is assigned a higher weight at a certain level for each scenario, which results in the pro development of shrimp farming. The policy framework based on a combination of carrying capacity and green taxation regime would ensure that even if the pro development option were chosen, the positive net environmental gain and the integrity of coastal receiving waters would be obtained.

Keywords: coastal land management, weighted compromise programming, decision making, Krabi province

JEL classification: C61, D62, D74, Q22, Q24

Acknowledgements
The author appreciates the comments from Urs Steiner Brandt.

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1. Introduction

The coast provides immense benefits to people's livelihoods and society as a whole in goods and ecological services. Lacking in proper management, the utilization of coastal land degrades the capacity of the coast to continuously provide such benefits. As experienced in many tropical countries including Thailand, rapid expansion of coastal shrimp farming contributed to vast conversion of mangrove forests. In addition, shrimp farming that follow common practices could generate adverse impacts on coastal waters and soil such as pollution of coastal waters from pond effluents and salination of agricultural land. These generate social conflicts between shrimp farmers and other coastal resource users. See Pongthanapanich (2005a) for the review.

Seeking a balance between coastal development and conservation is a dilemma that societies have been facing. Bell and Cruz-Trinidad (1996), Cruz-Trinidad et al. (1996) and Kantangkul (2000) have provided the empirical evidences for mangrove utilization in Ecuador, Philippines and Thailand, respectively. These studies offer the optimal use option that was derived from a single-criterion (objective) approach via linear programming. On the other hand, Pongthanapanich (2005b) demonstrated that coastal land use (CLU) is an inherent multicriteria problem. That is rather than a single optimal option, it involves a set of traded-off CLU options, which constitutes Pareto-efficiency frontier.

This paper further explores the competing CLU issue expressed by Pongthanapanich (2005b). From the previous study, the case of Krabi's Coastal Land Development Zone (CLDZ) in Thailand where mangrove, shrimp farming and agriculture (i.e. para rubber and oil palm) significantly compete for land use was examined. The main empirical model of maximizing the net private benefit objective (later referred to as "max-NPB") and maximizing the net environmental benefit objective (as "max-NEB") subject to technical constraints such as land availability, limits of effluent discharge from shrimp farming and rice consumption was optimized. Various model scenarios differed by the management schemes were assumed. Using the solving technique under multiobjective programming (MOP) approach, the optimal CLU options as well as their tradeoff information along the efficiency frontier were obtained. However, MOP *per se* does not provide a decision rule regarding the preferences and weights on different objectives (or criteria) for seeking the sensible optimum choices to facilitate the final decision. Through the compromise programming (CP) approach together with its weighting technique, so-called weighted CP, such choice can be assessed. Besides, the overwhelming choices located along the efficiency frontier can make the decision making difficult. CP approach also has an important property to reduce the number of the optimal choices into a managerial size.

CP was proposed by Yu (1973) and Zeleny (1973). The underlying concept of CP is to generate the efficient (non-dominated) solution closest to the ideal (utopia) point. In the CLU problem at hand, the ideal point can simply be obtained from optimizing each of the objectives, namely max-NPB and max-NEB, separately. The ideal thus represents the highest optimal values of both objectives. Nontrivially, the ideal is unachievable (or infeasible). In practical decision making, the option closet to the idea could then be presumed as the most preferable choice for the society. This compromise option ensures the decision maker's confidence based on this norm. Unlike in the classical decision making postulated in multiattribute utility theory (Keeney and Raiffa, 1976), revealing the decision maker's preferences on various criteria in advance is not required in the CP approach. The assessment of utility function for each criterion and individual decision maker is known to be a formidable task (Ballestero and Romero, 1998; Yu, 1973).

While CP approach is widely recognized especially in the fields of operations research and engineering, the application in economics particularly in environmental-related issues are still limited. The examples include the management of a reservoir watershed in Taiwan where water qualities, income and employment objectives were considered simultaneously (Chang et al., 1995), planning of regional aquaculture development in Egypt where the availability of protein, employment and foreign exchange earning objectives were considered simultaneously (El-Gayar and Leung, 2001), and solving the optimal production planning of a textile-dyeing firm in Taiwan where the costs of air pollution were imposed (Wu and Chang, 2004). Meanwhile, this paper identifies the optimal CLU planning in Thailand by highlighting the case of Krabi province. The analysis is with respect to the weights assigned to the objectives, and based on various externality management scenarios, of which the different environmental regulations and tools are presumed. This provides the results of a few sensible options within particular policy frameworks to base the final decision in coastal planning and zoning.

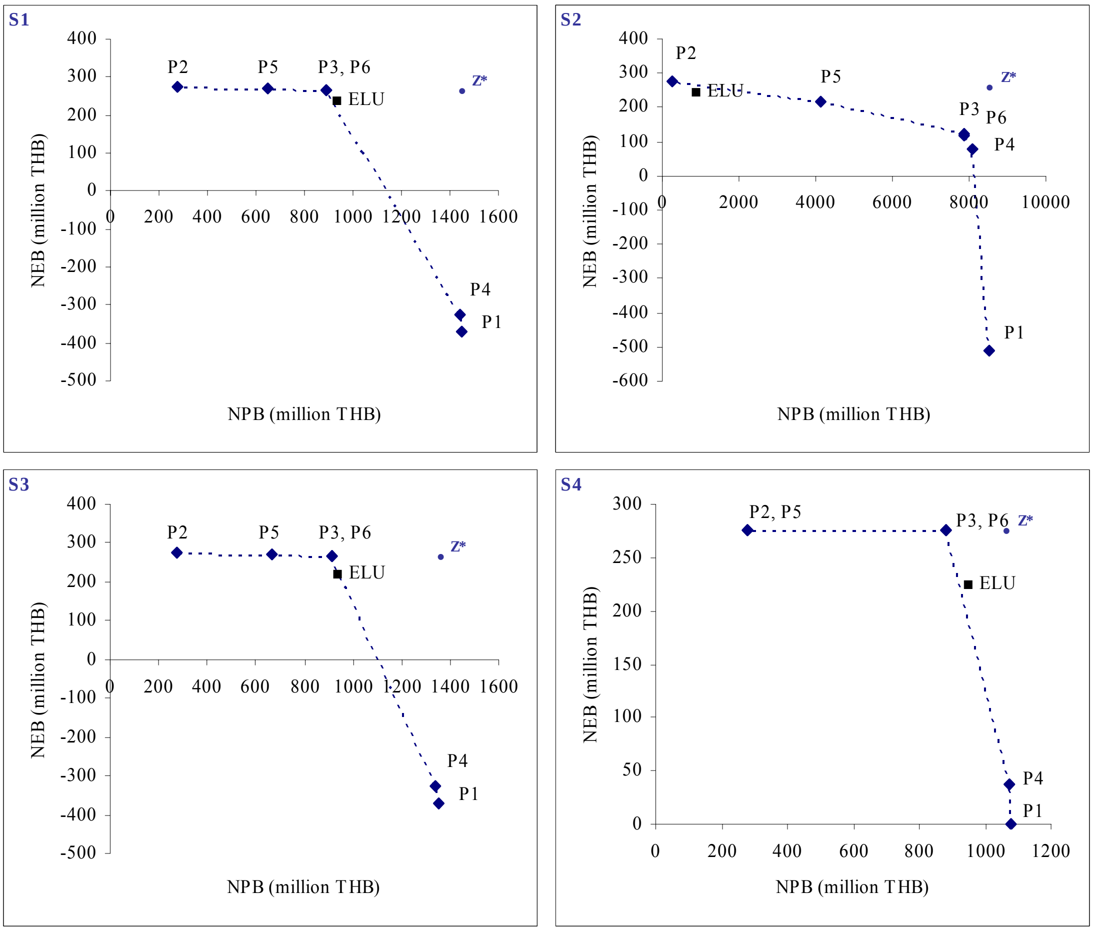
The next section briefly presents the settings of model and scenarios in previous study (Pongthanapanich, 2005b). These base the empirical analysis of this paper. Then, the main concept of CP approach and its link to the decision theory are described. Subsequently, the model that bases the numerical analysis of this paper is presented. The numerical results are presented and discussed, and followed by a conclusion in the final section.

2. The Background Study

The decision problem from Pongthanapanich (2005b) is summarized as follows. The objective functions of max-NPB and max-NEB comprise 65 decision variables, which were defined by potential competing activities in each existing land use, ELU (x) and each zone in CLDZ (X). The activities in each ELU and CLDX considered are mangrove reforestation (mgrXx), mangrove conservation (mgvXx), oil palm plantation (oilXx), para rubber plantation (rubXx), shrimp farming (srpXx) and transplanted paddy field (tpdXx). These activities exist on the study site, except mangrove reforestation, which was an introduced activity. Abandoned paddy fields (apd) also exist. The zones in CLDZ explored are aquaculture zone (AQZ or shorten as “A”), mangrove economic zone B (MBZ or “M”), paddy zone (PDZ or “P”) and rubber and oil palm zone (ROZ or “R”).

Four scenarios were set in corresponding to the management schemes proposed to tackle with shrimp farm externalities: scenario 1 (S1) - considering the carrying capacity or limit of receiving waters for the effluent discharge, S2 - compliance with the effluent standard, S3- combined S1 and S2, and S4 - adopting a green (corrective) tax regime together with carrying capacity. Among these scenarios, S1, S2 and S3 do not internalize the external costs of shrimp farming in max-NPB, while S4 does; and S1, S3 and S4 incorporate the effluent discharge constraints to capture the carrying capacity consideration, while S2 does not as the individual shrimp farmers comply with the effluent standard. The results of optimal CLU options (P1, P2, P3,…,P6) along the frontiers of all scenarios are presented in Figure 1.

Figure 1. Approximated Pareto frontier of Krabi's optimal coastal land use in various scenarios



Note: 1) NPB and NEB are denoted as net private benefit and net environmental benefit, respectively.
2) ELU represents the benefits obtained from existing land use.
3) Z^* is the ideal point of each scenario.

Source: Pongthanapanich (2005b).

3. The Methodological Concept

CP performs under the axiom of choice (Zeleny, 1982: 156), by which the decision maker attempts to maintain his/her confidence by considering the feasible option closet to the perceived ideal. In the above, Figure 1 shows the extreme values obtained from a single-objective optimization, i.e. P1 (for max-NPB) and P2 (for max-NEB) that constitute the ideal point Z^* of each scenario. Obviously, the ideal is unattainable. Because the maximum values of both objectives cannot be achieved at once. However, the ideal conveys the problem of choice.[1] That is it plays an important role as the reference point for the comparison of distances between the feasible options (such as those optimal options along the efficiency frontier) and the ideal. Consequently, the option closest to the ideal can be considered as the "best" compromise option. Thereby, this maxim helps to resolve the conflict between the feasible options and the ideal. The standard distance measure (Yu, 1985; Zeleny, 1982) can be expressed as follow:

$$\text{Min}\, L_p = \left[\sum_{k=1}^{n} \left| Z_k^* - Z_k \right|^p \right]^{\frac{1}{p}} \quad (1)$$

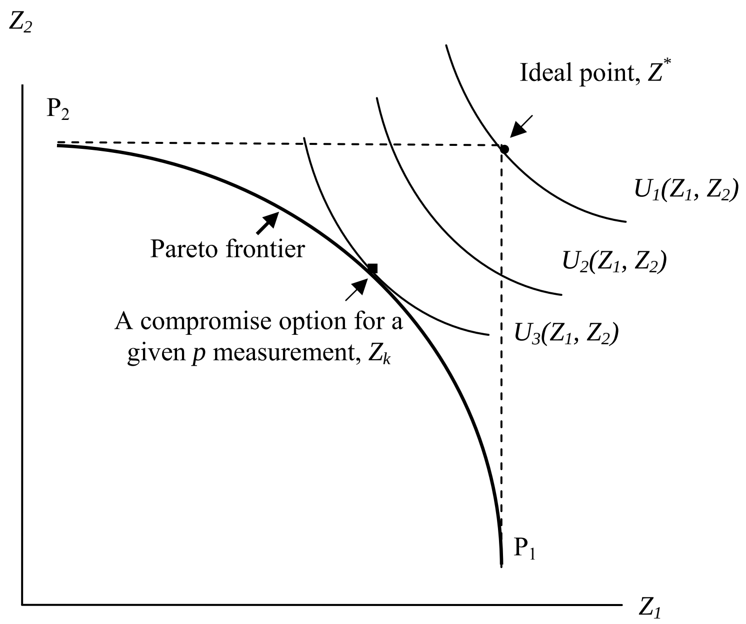
where $1 \le p \le \infty$. Z_k^* is the ideal value of objective k and k=1,2,3,…,n. Z_k is the value of objective k derived from the feasible choice being evaluated.

The underpinning concept of CP has some linkage with the decision theory, of which the details were thoroughly described in Ballestero and Romero (1998). Here, it is summarized and presented in Figure 2 as followed. The ideal can be presumed as the landing point for the highest utility curve, U_1, if it is achievable. Unfortunately, the ideal is usually unachievable (as described above) so that the utility needs to be reduced in order to meet the achievable level. The "best" compromise choice is thus represented as Z_k in the figure

1 Feasible or attainable ideal may exist in other decision problems. If it is the case, it would turn out to be a trivial case. See Ballestero and Romero (1998).

where the possible maximum utility meets the feasible choice closet to the ideal for a given L_p norm.

Figure 2. Solution concept of compromise programming in two objectives space



In principle, the metric in equation 1 generates a compromise set that is bound by minimizing the distance L_1 (Manhattan distance) and L_∞ (Tchebycheff distance). These are as follows:

$$\text{Min}\, L_1 = \sum_{k=1}^{n} \left| Z_k^* - Z_k \right| \tag{2}$$

$$\text{Min}\, L_\infty = \underset{k=1}{\overset{n}{Max}} \left| Z_k^* - Z_k \right| \tag{3}$$

The metric L_1 represents the minimizing of total deviation. Total deviation is calculated from total distance between the ideal and the feasible option being evaluated with respect to all objectives (or criteria). Among many feasible options, their total deviations are compared. The option that gives the lowest total deviation is defined as the best compromise choice based on this norm. In opposite, the metric L_∞ represents the minimizing of maximum deviation (instead of total deviation). In the same sense as the above, the deviation is the measure of the distance with respect to each objective. For example, each feasible option in two objectives decision problem would have 2 deviations. The feasible option with the lowest maximum deviation is defined as the best compromise choice based on this norm. That is as p increases (from 1 to infinity) more and more weight is given to the largest deviation. The numerical example of these distance measures can be seen in Zeleny (1982: 316-317).

The L_1 bound is compatible with the measure of the maximum additive utility (see Romero, 1996). or the summation of individual regrets in group decision problem (see Yu, 1973). Meanwhile, the L_∞ bound is compatible with the measure of the maximum Rawlsian utility or maximum individual regret. The compromise set of feasible options is bounded from L_1 to L_∞. The compromise solutions are also independence of irrelevant options, namely, other options outside the compromise set can be discarded without changing the solution as long as the ideal is not changed. For more details of the properties of compromise solutions, see Yu (1985).

4. The Model

Empirically, this paper follows the simple majority rule (Yu, 1985: 78) by measuring the Manhattan distance, i.e. L_1 norm. More specifically, the sum of deviations from both objectives (i.e. max-NPB and max-NEB), not the maximum deviation, is considered. The multiobjective linear programming model in Pongthanapanich (2005b) is then transformed to the CP model (see below). The weighting technique is used to observe the effects of decision preferences on the compromise solutions, namely, the optimal CLU options of each management scenario with respect to the weights assigned to the two objectives. That is the relative importance of each objective is presented through the weight, $w_k^p \geq 0$ (p=1 in this case). In fact, when and equal weighting, w_1:w_2=1:1, is given to both objectives, the model will become a standard CP. Through interactive method based on computerized dialogues between the decision maker and the analyst, this preference information can be obtained (Ballestero and Romero, 1998). Rather this paper performs a switching-weight analysis. It begins with equal weighting 1:1 and then increases the weight of each objective systematically until the based-case solution (of the weighting 1:1) begins to change. Thereby, the compromise solutions obtained can inform the decision maker on how critical is the increased weight of max-NPB or max-NEB affecting the optimal planning outcomes. The tradeoff information and efficiency frontiers obtained from previous study are used for comparison and justify the results of this switching analysis.

Furthermore, since the compromise solution is not independent of scaling of the objective (Yu, 1985: 71), the scaling technique is also applied here to assure that the chosen weights are not nullified by other considerations (Gershon, 1982). Hence, the weighted distance obtained represents the percent shortfall, not the absolute term. The model as followed is used to base the estimation as its numerical results are presented in the next section.

$$MinL_1 = w_1 \left| \frac{Z_1^* - Z_1(\underline{x})}{Z_1^* - Z_{*1}} \right| + w_2 \left| \frac{Z_2^* - Z_2(\underline{x})}{Z_2^* - Z_{*2}} \right|$$

s.t.

$\underline{x} \in \underline{F}$

where Z_1^* and Z_2^* is the ideal point of max-NPB and max-NEP, while Z_{*1} and Z_{*2} is the anti-ideal (nadir) point, respectively. $Z_1(\underline{x})$ and $Z_2(\underline{x})$ is the NPB and NEB objective function for the set of decision variables, $\underline{x}$. The feasible set, $\underline{F}$, is generated by a given constraint set for each model scenario. The decision variables, constraint set and model scenarios were described in details in the previous study, or see the above for the summary. GAMS, the General Algebraic Modeling System (Brooke et al., 2003), is used to solve the models.

It should be noted that the solutions from CP optimization model presented here has some other important properties other than those discussed in previous section. This includes feasibility and Pareto optimality. This means that the non-dominated or efficient solutions are obtainable with respect to Pareto preference, of which the concept of "more is better" holds.[2] See Yu (1985) in Chapter 4 for the details. This property of compromise solutions, thus, guarantees the decision maker's confidence.

5. Numerical Results

Table 1 summarizes the optimal values of the objectives obtained from various model scenarios and weightings. The details of optimal CLU patterns are presented in the Appendix. Each of the scenarios with the weighting of 1:1 (w_1:w_2) represents the case when both objectives are presumed to be given equal importance in decision making process. It turns out that this case gives the same optimal solutions as P3 of each scenario in Pongthanapanich (2005b), i.e. S1P3, S2P3, S3P3 and S4P3 (see Figure 1 above). Meanwhile, the same optimal solutions as P4, i.e. S1P4, S2P4, S3P4 and S4P4, are obtained when a higher weight is given to w_1 (but the results are also subject to the degrees of weight sensitivity among the scenarios as discussed later). Chiefly, the compromise solutions from the equal weighting are conservation favour in the sense that they suggest stand mangrove be kept. This generally implies that obtaining the optimal conservation planning of CLU in question requires the environmental benefit objective (i.e. max-NEB) is at least given an equal importance (or weight) to the private benefit objective (i.e. max-NPB). In contrast, the latter case (i.e. when increases w_1) leans on the pro development prospect as the options suggest all stand mangrove can be converted for further development for shrimp farming. It should be noted that the mangrove zone in

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2 The Pareto preference is defined by $Z^1 \succ Z^2$ *iff* $Z^1 \geq Z^2$, i.e. Z_k^1 >= Z_k^2 and $Z^1 \neq Z^2$. That is the feasible option, Z^1, is better than or preferred to the other, Z^2, if and only if there is at least Z_k^1 of an objective k (k=1 and 2 for the problem at hand) is greater than Z_k^2.

consideration was classified as an economic zone (i.e. zone B) under the Cabinet Resolution (CR) on 15 December 1987. It used to be allowed for economic uses, including for shrimp farming. Subsequently, the proclamation of the CR on 22 August 2000 prohibits any uses of this zone. Hence, the optimal CLU options that favour conservation prospect as presented above would be in line with the current policy action under the CR on 22 August 2000. However, in the case when the pro development prospect is applied, the CR on 15 December 1987 is suggested for reconsideration as to achieve the optimal planning outcome.

The compromise solutions obtained are then arranged by the optimal objective values. It is found that the first group of five options (when sorted by ascending NPB) or the last group of five options (when sorted by ascending NEB), i.e. S1 with the weighting of 1:30, S3 with 1:30, S1 S3 and S4 with 1:1, gives higher NEB than the rest of the options. This group of options suggests the remaining mangroves be conserved. Noticeably, the benefits are close to that from existing land use (see Figure 3). Nevertheless, the reallocation of land use is suggested in order to reach the optimum (see the Appendix).

The results also show the degrees of weight sensitivity among the scenarios. That is scenario 1, S1, is rather sensitive to the change of weight w_1 (i.e. 2:1) but not to w_2 (i.e. 1:30). S2 is the most sensitive one to the change of both w_1 and w_2. An increase of w_1 from 1:1 to 2:1 or w_2 from 1:1 to 1:2 would change the compromise solution. Unlike S2, S3 and S4 are much less sensitive, that is, the solution begins to change at the weight of 3:1 and 1:30 for S3, and 4:1 for S4. In S4, an increase of w_2 does not change the results from the case of 1:1. This is mainly because all coefficients of max-NEB are assigned non-negative value due to the internalization of externalities. In other words, the environmental costs of pollutive CLU (i.e. shrimp farming) are taken into account in the NPB objective. These results suggest that a tougher policy framework would be needed in order to enhance the development of optimal planning aiming to support the current policy action that favours conservation outcome. This is as the results from weight sensitivity imply that the optimal planning decision based on a single management regulation or tool such as designation of carrying capacity (S1) or implementation of shrimp effluent standard (S2), would be more inclined to the pro development outcome than that based on a combination of tools such as carrying capacity and effluent standard (S3) or carrying capacity and a green tax (S4).

Moreover, one may argue that S2 could be an attractive management scheme since it would generate much higher NPB than the other scenarios and has a positive NEB. Nevertheless, as concluded in previous study this scenario potentially leads to the detrimental optimum since the carrying capacity of receiving waters is not taken into consideration. While the scenario suggests all mangrove be kept (which results in the net environmental gain), it suggests shrimp farms be optimally increased up to level that would be over the carrying capacity (compare its results with S1, S3 and S4). S3 gives nearly the same benefits as S1 at all levels of weighting, but it requires an extra control on shrimp farm effluent. S1 would thus be preferred to S3. Meanwhile, S4 does not give different results from S1. However, the positive upshot of S4 over S1 is that it ensures non-negative NEB, and it is not as highly sensitive to the increase of w_1 as S1. As seen above S1 with the weights 2:1 compared to S4 with at least 4:1 would become a pro development optimum.

Table 1. Compromise solutions of Krabi's optimal coastal land use in various scenarios and weightings

Sorted by Scenarios

Scenarios	S1	S1	S1	S2	S2	S2	S3	S3	S3	S4	S4
Weights [1/]	1:1	2:1	1:30	1:1	2:1	1:2	1:1	3:1	1:30	1:1	4:1
Comparison [2/]	=S1P3	=S1P4		=S2P3	=S2P4		=S3P3	=S3P4		=S4P3	=S4P4
NPB	890	1438	752	7860	8099	7798	912	1342	775	881	1075
NEB	267	-326	270	122	80	127	265	-328	269	276	37
NPB+NEB	1157	1112	1022	7982	8178	7926	1178	1014	1044	1157	1112

Sorted by NPB and then by NEB

Scenarios	S1	S3	S4	S1	S3	S4	S3	S1	S2	S2	S2
Weights [1/]	1:30	1:30	1:1	1:1	1:1	4:1	3:1	2:1	1:2	1:1	2:1
Comparison [2/]			=S4P3	=S1P3	=S3P3	=S4P4	=S3P4	=S1P4		=S2P3	=S2P4
NPB [3/]	752	775	881	890	912	1075	1342	1438	7798	7860	8099
NEB [3/]	270	269	276	267	265	37	-328	-326	127	122	80
NPB+NEB	1022	1044	1157	1157	1178	1112	1014	1112	7926	7982	8178

Sorted by NEB and then by NPB

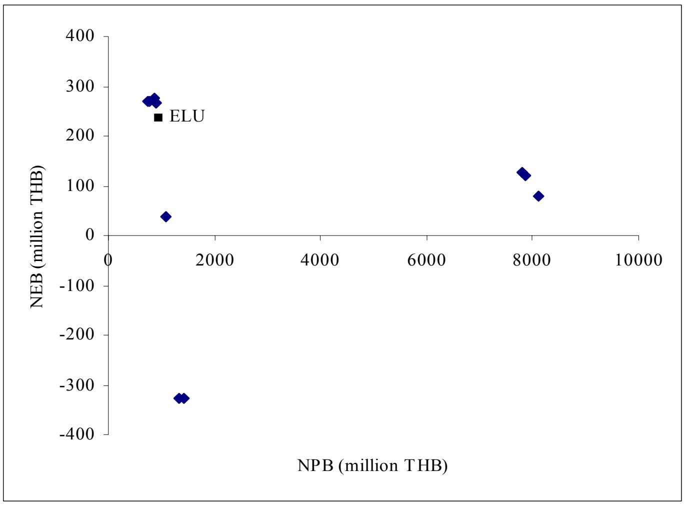
Scenarios	S3	S1	S4	S2	S2	S2	S3	S1	S3	S1	S4
Weights [1/]	3:1	2:1	4:1	2:1	1:1	1:2	1:1	1:1	1:30	1:30	1:1
Comparison [2/]	=S3P4	=S1P4	=S4P4	=S2P4	=S2P3		=S3P3	=S1P3			=S4P3
NPB [3/]	1342	1438	1075	8099	7860	7798	912	890	775	752	881
NEB [3/]	-328	-326	37	80	122	127	265	267	269	270	276
NPB+NEB	1014	1112	1112	8178	7982	7926	1178	1157	1044	1022	1157

Note: [1/] w_1:w_2

[2/] Compare the results with Pongthanapanich (2005b), see Figure 1.

[3/] The scenarios are grouped in borders by the similar magnitude of optimal objective values, see also Figure 3.

Figure 3. Compromise solutions in two objectives space



Note: 1) NPB and NEB are denoted as net private benefit and net environmental benefit, respectively.

2) ELU represents the benefits obtained from existing land use. See also Figure 1.

3) Refer to Table 1 for data labels.

6. Conclusion

Generating the decision choice on the basis of utility theory requires high interaction between analyst and decision maker to elicit the preference information. "I am not sure" or "It is hard to tell" answers can be expected. Deriving the precise mathematical representation of true utility function is another challenge. This study offers the CP as an alternative approach to get around these difficulties since the approach does not require the revealing of decision maker's preferences in advance. The feasible option closet to the ideal point is deemed to be the "best" compromise choice, and thus be the sensible optimum choice to base the planning decision. This merit of CP stems from the way it links to the utility theory and the Pareto preference as stated above. The effects of decision maker's preferences, through the weights given to different objectives, on the optimal CLU planning outcomes, can be observed. Furthermore, the ideal point generated on the basis of maximizing net benefits, when both private and environmental benefits are considered simultaneously, could be an acceptable reference point for the society viewpoint. This, however, presumes that there is a society's concern of private actions that affect the coastal environment. The compromise solutions obtained ensure the decision maker's confidence and a collective consent based on this norm.

The main empirical results from this paper give the same optimal CLU patterns and consistent policy implications as those presented by Pongthanapanich (2005b). Except that this study provides additional information on the influence of the weights on particular optimal options with regards to each environmental management scheme (scenario). It is found that if the decision maker realizes that environmental benefit objective is at least, if not more, as important as private benefit objective, the optimal planning options that favour mangrove conservation prospect would be obtained. This finding is implied for all management schemes. If the decision maker tends to give a higher weight to the private benefit, which is usually the case in real decision making, a more stringent policy framework would then be required in order to promote the optimal conservation planning. In this case, the implementation of combined carrying capacity and a green tax regime (i.e. scenario 4) is deemed to be the most sensible scheme in achieving of such planning target. This scheme ensures a positive net environmental gain for the society and maintains the integrity of coastal receiving waters at the same time. These advantages of the scheme would be obtained even if the pro development option (i.e. conversion of mangrove economic zone B to shrimp farms) were chosen for Krabi's CLU planning.

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Appendix. The details of numerical results in various scenarios and weightings

Scenarios		S1	S1	S1	S2	S2	S2	S3	S3	S3	S4	S4
Weights [1/]		1:1	2:1	1:30	1:1	2:1	1:2	1:1	3:1	1:30	1:1	4:1
Comparison [2/]		=S1P3	=S1P4		=S2P3	=S2P4		=S3P3	=S3P4		=S4P3	=S4P4
L_1 distance		0.490	0.952	0.873	0.276	0.353	0.465	0.425	0.963	0.861	0.248	0.891
Objectives (million THB)												
	NPB	890	1438	752	7860	8099	7798	912	1342	775	881	1075
	NEB	267	-326	270	122	80	127	265	-328	269	276	37
	NPB+NEB	**1157**	**1112**	**1022**	**7982**	**8178**	**7926**	**1178**	**1014**	**1044**	**1157**	**1112**
Decision Variables [3/] (Rai)												
1	oilAa	1874	1874	1874	0	0	0	1868	1868	1868	1874	1874
2	rubAa	0	0	0	0	0	0	0	0	0	0	0
3	srpAa	33	33	33	1907	1907	1907	39	39	39	33	33
4	mgvAm	6439	0	6439	6439	6439	6439	6439	0	6439	6439	0
5	srpAm	0	6439	0	0	0	0	0	6439	0	0	6439
6	oilAo	4357	4357	4357	0	0	0	3918	3918	3918	4357	4357
7	srpAo	2634	2634	2634	6991	6991	6991	3073	3073	3073	2634	2634
8	rubAr	16319	16319	18140	0	0	0	16016	16016	18140	16319	16319
9	srpAr	1821	1821	0	18140	18140	18140	2124	2124	0	1821	1821
10	srpAs	1068	1068	1068	5080	5080	5080	1246	1246	1246	1068	1068
11	srpAt	0	0	0	2691	2691	2691	0	0	0	0	0
12	tpdAt	5704	5704	5704	3013	3013	3013	5704	5704	5704	5704	5704
13	mgrMa	268	268	268	268	0	268	268	268	268	268	268
14	oilMa	0	0	0	0	0	0	0	0	0	0	0
15	rubMa	0	0	0	0	0	0	0	0	0	0	0
16	srpMa	0	0	0	0	268	0	0	0	0	0	0
17	mgvMm	4650	0	4650	4650	4650	4650	4650	0	4650	4650	0
18	oilMm	0	0	0	0	0	0	0	0	0	0	0
19	rubMm	0	0	0	0	0	0	0	0	0	0	0

Scenarios		S1	S1	S1	S2	S2	S2	S3	S3	S3	S4	S4
20	srpMm	0	4650	0	0	0	0	0	4650	0	0	4650
21	mgrMo	476	476	476	0	0	476	476	476	476	476	476
22	oilMo	0	0	0	0	0	0	0	0	0	0	0
23	srpMo	0	0	0	476	476	0	0	0	0	0	0
24	mgrMr	1860	1860	1860	1860	0	1860	1860	1860	1860	1860	1860
25	rubMr	0	0	0	0	0	0	0	0	0	0	0
26	srpMr	0	0	0	0	1860	0	0	0	0	0	0
27	mgrMs	1008	1008	1008	1008	0	1008	1008	1008	1008	1008	1008
28	srpMs	0	0	0	0	1008	0	0	0	0	0	0
29	mgrMt	32	32	32	32	0	32	32	32	32	32	32
30	oilMt	0	0	0	0	0	0	0	0	0	0	0
31	rubMt	0	0	0	0	0	0	0	0	0	0	0
32	srpMt	0	0	0	0	32	0	0	0	0	0	0
33	tpdMt	28	28	28	28	28	28	28	28	28	28	28
34	oilPa	2254	2254	2254	0	0	0	2254	2254	2254	2254	2254
35	rubPa	0	0	0	0	0	0	0	0	0	0	0
36	srpPa	0	0	0	2254	2254	2254	0	0	0	0	0
37	mgvPm	268	0	268	268	268	268	268	0	268	268	0
38	oilPm	0	0	0	0	0	0	0	0	0	0	0
39	rubPm	0	0	0	0	0	0	0	0	0	0	0
40	srpPm	0	268	0	0	0	0	0	268	0	0	268
41	oilPo	8064	8064	8064	8064	8064	8064	8064	8064	8064	8064	8064
42	rubPr	50420	50420	50420	50420	50420	50420	50420	50420	50420	50420	50420
43	srpPs	0	0	0	314	314	314	0	0	0	0	0
44	oilPt	2671	2671	2671	0	0	0	2671	2671	2671	2671	2671
45	rubPt	0	0	0	0	0	0	0	0	0	0	0
46	srpPt	0	0	0	2671	2671	2671	0	0	0	0	0
47	tpdPt	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994
48	oilRa	175	175	175	0	0	0	175	175	175	175	175
49	rubRa	0	0	0	0	0	0	0	0	0	0	0

Scenarios		S1	S1	S1	S2	S2	S2	S3	S3	S3	S4	S4
50	srpRa	0	0	0	175	175	175	0	0	0	0	0
51	mgvRm	487	0	487	487	487	487	487	0	487	487	0
52	oilRm	0	0	0	0	0	0	0	0	0	0	0
53	rubRm	0	0	0	0	0	0	0	0	0	0	0
54	srpRm	0	487	0	0	0	0	0	487	0	0	487
55	oilRo	12633	12633	12633	0	0	0	12633	12633	12633	12633	12633
56	srpRo	0	0	0	12633	12633	12633	0	0	0	0	0
57	rubRr	38685	38685	38685	0	0	0	38685	38685	38685	38685	38685
58	srpRr	0	0	0	38685	38685	38685	0	0	0	0	0
59	oilRs	782	782	782	0	0	0	782	782	782	782	782
60	rubRs	0	0	0	0	0	0	0	0	0	0	0
61	srpRs	0	0	0	782	782	782	0	0	0	0	0
62	oilRt	241	241	241	0	0	0	241	241	241	241	241
63	rubRt	0	0	0	0	0	0	0	0	0	0	0
64	srpRt	0	0	0	241	241	241	0	0	0	0	0
65	tpdRt	280	280	280	280	280	280	280	280	280	280	280
	Sum 1-65	**168525**	**168525**	**168525**	**172851**	**172851**	**172851**	**168703**	**168703**	**168703**	**168525**	**168525**
1. OCLU in all zones classified by activities (rai)	mgrXx	3644	3644	3644	3168	0	3644	3644	3644	3644	3644	3644
	mgvXx	11844	0	11844	11844	11844	11844	11844	0	11844	11844	0
	oilXx	33051	33051	33051	8064	8064	8064	32606	32606	32606	33051	33051
	rubXx	105424	105424	107245	50420	50420	50420	105121	105121	107245	105424	105424
	srpXx	5556	17400	3735	93040	96208	92564	6482	18326	4358	5556	17400
	tdpXx	9006	9006	9006	6315	6315	6315	9006	9006	9006	9006	9006
	sum	**168525**	**168525**	**168525**	**172851**	**172851**	**172851**	**168703**	**168703**	**168703**	**168525**	**168525**
2. Land use change: Item 1 minus ELU (rai)	mgrXx	3644	3644	3644	3168	0	3644	3644	3644	3644	3644	3644
	mgvXx	0	-11844	0	0	0	0	0	-11844	0	0	-11844
	oilXx	4887	4887	4887	-20100	-20100	-20100	4442	4442	4442	4887	4887
	rubXx	-3681	-3681	-1860	-58685	-58685	-58685	-3984	-3984	-1860	-3681	-3681
	srpXx	-1628	10216	-3449	85856	89024	85380	-702	11142	-2826	-1628	10216
	tdpXx	-2944	-2944	-2944	-5635	-5635	-5635	-2944	-2944	-2944	-2944	-2944

3. Item 2 in % of ELU	mgrXx	0%						0%			0%	
	mgvXx	0%	-100%	0%	0%	0%	0%	0%	-100%	0%	0%	-100%
	oilXx	17%	17%	17%	-71%	-71%	-71%	16%	16%	16%	17%	17%
	rubXx	-3%	-3%	-2%	-54%	-54%	-54%	-4%	-4%	-2%	-3%	-3%
	srpXx	-23%	142%	-48%	1195%	1239%	1188%	-10%	155%	-39%	-23%	142%
	tdpXx	-25%	-25%	-25%	-47%	-47%	-47%	-25%	-25%	-25%	-25%	-25%
4. OCLU of shrimp farming: Reallocation of ELU for shrimp farms (rai)	srpXa	33	33	33	4336	4604	4336	39	39	39	33	33
	srpXm	0	11844	0	0	0	0	0	11844	0	0	11844
	srpXo	2634	2634	2634	20100	20100	19624	3073	3073	3073	2634	2634
	srpXr	1821	1821	0	56825	58685	56825	2124	2124	0	1821	1821
	srpXs	1068	1068	1068	6176	7184	6176	1246	1246	1246	1068	1068
	srpXt	0	0	0	5603	5635	5603	0	0	0	0	0
	sum	**5556**	**17400**	**3735**	**93040**	**96208**	**92564**	**6482**	**18326**	**4358**	**5556**	**17400**
5. OCLU of shrimp farming in AQZ (rai)	srpAx	5556	11995	3735	34809	34809	34809	6482	12921	4358	5556	11995
	srpAs	1068	1068	1068	5080	5080	5080	1246	1246	1246	1068	1068
	srpAx-srpAs	**4488**	**10927**	**2667**	**29729**	**29729**	**29729**	**5236**	**11675**	**3112**	**4488**	**10927**
6. OCLU correspond with CLDZ [5/] (rai)	srpAx	5556	11995	3735	34809	34809	34809	6482	12921	4358	5556	11995
	mgrMx	3644	3644	3644	3168	0	3644	3644	3644	3644	3644	3644
	mgvMm	4650	0	4650	4650	4650	4650	4650	0	4650	4650	0
	tdpPt	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994
	oilRx	13831	13831	13831	0	0	0	13831	13831	13831	13831	13831
	rubRx=rubRr	38685	38685	38685	0	0	0	38685	38685	38685	38685	38685

Note: [1/] w_1:w_2.

[2/] Compare the results with Pongthanapanich (2005b).

[3/] The decision values in borders indicate the changes from the case of equal weighting (1:1).

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