Cost-benefit Analysis of Climate Adaptation: A Case Study of Mangrove Conservation and Reforestation in Ca Mau Province, Vietnam

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Abstract

Mangroves are widely acknowledged for their great biodiversity values and their protective values against climate change impacts, particularly high waves from extreme events. This paper was aimed at partially filling the information gap relating to the economic valuation and cost-benefit analysis (CBA) of mangroves in Ca Mau province, Vietnam. Accordingly, two project options were examined, mangrove conservation and mangrove reforestation. The study found that the total net benefit of mangroves in Ca Mau is US$ 1,692.50 per hectare per year and that both mangrove conservation and reforestation would likely be beneficial to the province. Nevertheless, individuals from other perspectives might have different opinions. Local people may favor other sources of income, such as shrimp farming, rather than public mangroves. Results of the CBAs can be useful bases for decision makers in the province.

Keywords: mangroves, valuation, cost-benefit analysis, conservation, reforestation, climate change adaptation

บทคัดย่อ

ป่าชายเลนเป็นที่รู้จักกันอย่างแพร่หลายถึงคุณค่าที่ยิ่งใหญ่ในความหลากหลายทาง ชีวภาพ และคุณค่าที่มีต่อการป้องกันผลกระทบจากการเปลี่ยนแปลงสภาพภูมิอากาศ โดยเฉพาะอย่างยิ่งคลื่นสูงที่เกิดจากเหตุการณ์สุดขั้วต่างๆ บทความนี้เป็นส่วนหนึ่งของ การเติมเต็มข้อมูลที่เป็นช่องว่างของการประเมินค่าทางเศรษฐกิจกับการวิเคราะห์ ความคุ้มค่า (cost-benefit analysis: CBA) ของป่าชายเลนในจังหวัดกาเมา ประเทศ

เวียดนาม จากการศึกษาทางเลือกในการทำโครงการ 2 ทางเลือก คือ การอนุรักษ์ ป่าชายเลนเอาไว้และการปลูกสร้างป่าชายเลนขึ้นใหม่ พบว่าผลประโยชน์สุทธิที่ ได้รับจากป่าชายเลนรวมเป็นเงินทั้งสิ้น 1,692.50 ดอลลาร์สหรัฐต่อเฮกตาร์ต่อปี ทั้งการอนุรักษ์ป่าชายเลนเอาไว้และการปลูกสร้างป่าชายเลนขึ้นใหม่น่าจะเป็นผล ประโยชน์ต่อจังหวัด แต่อย่างไรก็ตามด้วยมุมมองที่แตกต่างกันของปัจเจกจึงอาจ มีความคิดเห็นที่แตกต่างออกไป คนท้องถิ่นอาจจะชื่นชอบป่าชายเลนในฐานะที่เป็นแหล่ง รายได้จากทางอื่น เช่น การทำฟาร์มกุ้ง มากกว่าที่จะมองว่าป่าชายเลนเป็นสาธารณะ สมบัติ เป็นต้น ผลการวิเคราะห์ความคุ้มค่าจะสามารถนำไปใช้เป็นฐานในการตัดสินใจ ของผู้มีอำนาจในจังหวัดได้

คำสำคัญ: ป่าชายเลน การประเมินค่า การวิเคราะห์ความคุ้มค่า การอนุรักษ์ การปลูก สร้างป่าขึ้นใหม่ การปรับตัวต่อสภาพภูมิอากาศ

Introduction

Ca Mau province is located in the southernmost part of the Mekong River Delta of Vietnam (MRD), one of the world's three deltas most vulnerable to climate change, along with the Nile Delta in Egypt and the Ganges Delta in Bangladesh and India (IPCC, 2007: 327). Because of its coastal position and low topography of 0.6-1.6 meters above sea level, Ca Mau is subject to various climate change impacts such as sea-level rise, storm surges, saline intrusion and typhoons (Southern Institute for Water Resources Planning [SIWRP], 2008: 25).
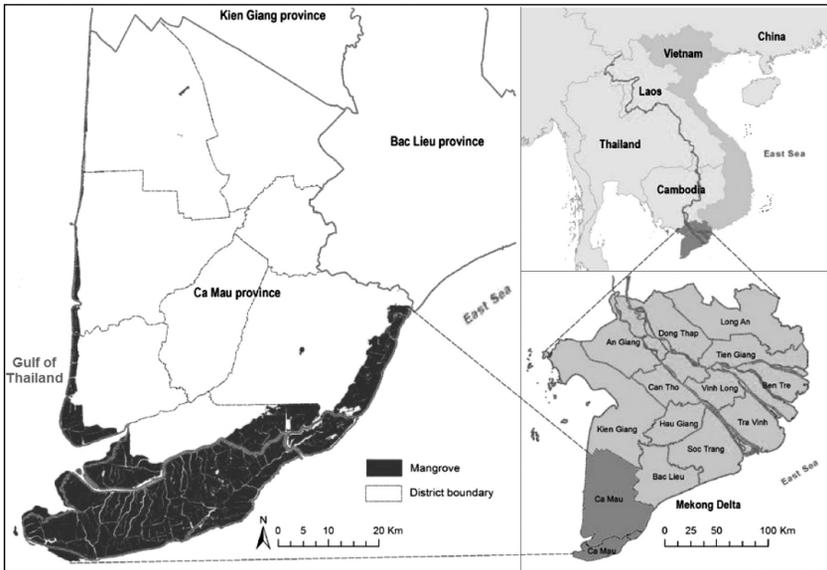
Figure 1: Ca Mau province of the Mekong Delta of Vietnam
Source: adapted from Vo et al., 2013.

Meanwhile, mangrove forest is located along the coastal line of the province. It shelters and protects the coast from a range of possible hazards, including shoreline erosion, saline intrusion, tidal waves and even the impact of extreme events such as cyclones, storm surges and tsunamis (Giesen et al., 2007: 34). In addition, McIvor et al. (2013) recently found that mangrove forests can protect inlands against sea level rise by raising the soil surface elevations by 1-10 millimeteres per year. Thus, mangrove forests are important as a way for Ca Mau province to deal with climate change. Indeed, ideas regarding protecting and rehabilitating mangrove forest were addressed as two focuses of Ca Mau's Action Plan in responding to climate change (Government of Vietnam, 2012).

This article examines the question of whether the two actions are economically worthwhile. Accordingly, two assumed projects - mangrove conservation and mangrove reforestation - are presented for

testing. The mangrove-conservation project includes activities that maintain the existing mangrove ecosystem in Ca Mau province. The mangrove-reforestation project expands the mangrove area by planning new mangroves as the mangroves have decreased significantly in recent years (Vo et al., 2013).

Methodology

Market based-valuation methods

In order to examine the two projects, this article provides a basic valuation of mangrove forests in Ca Mau. Valuation methods are classified in various ways. A common classification considers them as market-based methods, surrogate market methods or non-market based methods (simulated value survey-based methods) (UNEP, 2007: 14). In terms of market-based methods, a standard approach is to measure the net benefits of a goods or service through examining the consumer surplus and producer surplus in the market. The total economic value (TEV) of the goods or service is then derived as the sum of the two surpluses. However, as this study focuses on the benefits that mangroves can gain for local people, only the producer surplus is estimated. That is the surplus that local people get from the mangrove ecosystem and provide to the market. There can also be some consumers of mangrove benefits who live in Ca Mau. They are likely to gain consumer surplus and thus might be willing to pay more than the price charged in the market. However, such consumer surplus is hard to measure due to lack of data. For simplicity, we assumed that all benefits of mangroves are sold in the market to generate producer surplus. This approach is applied for fuelwood and carbon-sequestration values of mangroves in Ca Mau province. For other values, data on the price and amount of products, such as the increased amount of aquaculture due to mangroves or the increased price of fish captured in mangrove forests, are not available. Therefore, the values are estimated, based on the net incomes generated for local people by mangrove forests. For example, the aquaculture-support value of mangroves is measured by the increased

incomes of local people (since they have mangroves) minus the cost of aquaculture production.

Benefit-transfer method

Due to lack of data, some values of Ca Mau's mangrove forest are estimated using the benefit-transfer method (BTM). This method is commonly used in ecological and economic research when the valuation process can be costly and impractical in policy settings (Smith et al., 2002). This research used BTM to transfer the net benefits of timber and medicinal plants in Can Gio mangrove forest to Ca Mau province. Can Gio was chosen for a number of reasons. First, Can Gio's and Ca Mau's mangroves share some common characteristics since both are coastal mangroves in the Mekong River Delta of Vietnam (Hang & An, 1999: 210). The distance between the two is only 150 kilometers (Ca Mau Statistics Office, 2011) and thus their hydrological and climatic conditions are fairly identical. Second, the mangrove management model in Can Gio in the early 2000s, which is the time of the data used for BTM, is considered successful (Hong, 2005: 58). At that time, the timber exploitation rate in Can Gio was reasonable; consequently, it can be a good example for Ca Mau province to follow. This is the key reason for choosing Can Gio as a study site for Ca Mau. BTM is also used in this paper for the case of erosion control and capture fisheries.

Cost-benefit analysis

From an environmental policy perspective, Hanley et al. (2009) define the cost-benefit analysis (CBA) framework/method as "a technique for measuring whether the benefits of a particular action are bigger than the costs, judged from the viewpoint of the society as a whole" (Hanley et al., 2009: 1). Accordingly, the CBA framework is fairly simple: compare the costs and benefits of a project; and approve the project if the benefits are higher than the costs. However, the challenges lie in defining the viewpoints, examining all possible benefits and costs as well as assigning them to the right property. For example, a forest warden considers his salary as a benefit, but to the government it is one of the

costs of forest preservation. From a social viewpoint, costs and benefits can be numerous and CBA often faces difficulties in accounting for them. In addition, when the benefits and costs occur at different times or can change with time, the CBA needs to present an estimate of net present value (NPV). In this study, two projects for examination are mangrove conservation and mangrove reforestation, which have different time horizons.

Results

Economic valuation of mangroves in Ca Mau
Mangroves provide numerous values, as listed by Barbier et al. (1997: 83). However, the present research estimates only some direct-use and indirect-use values of the forest (see Table 1).

Table 1: Total economic value of mangrove forest

Use values			Non-use values
Direct-use values	**Indirect-use values**	**Option values and quasi-option value**	
• *Aquaculture support* • *Capture fisheries* • *Timber* • *Fuelwood* • *Medicinal plants* • Recreation (e.g., tourism) • Transport • Wildlife harvesting	• Nutrient retention • Saline intrusion control • *Erosion control (for shoreline or sea dikes)* • Flood control • Storm protection • Groundwater recharge • External ecosystem support • *Carbon sequestration*	• Potential future uses (as per direct and indirect uses) • Future value of information	• Biodiversity • Culture, heritage • Bequest value

Note: Goods and services in *italics* are quantified in this study

Source: adapted from Barbier et al., 1997: 83, modified.

Erosion control
Mangroves can prevent shoreline and sea dikes from being eroded by sea waves. In Ca Mau province, as a sea dike already exists in the west

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of the province and a sea dike system is under construction on the east coast (Government of Vietnam, 2009), this indirect-use value of mangroves primarily consists of erosion control for the sea dikes.

Vo (2013) estimated this value using the replacement cost method (RCM). The replacement for mangroves here was a concrete embankment along the sea dike in non-mangrove or thin-mangrove areas. The construction of the embankment cost approximately US$ 470,000 per kilometer in 2010 (Government of Vietnam, 2011). Using surveys to define the weighting factor of the erosion control value, Vo (2013) found that the erosion control value of mangroves could vary according to the distance to the coastline; it was estimated at US$ 136.5 million for 187,533 hectares of mangroves. It was equivalent to US$ 728.20 per hectare per year. We used Vo's result in this study.

The erosion control value of mangroves can also be estimated using the damage-cost avoided method (DCAM). Tri et al. (1996) used DCAM to estimate the value in Nam Dinh Province. The idea was that since mangrove forests could reduce the costs of dike maintenance, the reduction of maintenance costs could represent the erosion control value of mangroves. However, due to lack of precise data on the annual dike maintenance costs in Ca Mau province, DCAM was not used in this study.

Capture fisheries

As previously discussed, the mangrove ecosystem provides habitat for many aquatic species. Thus the existence of mangroves helps increase the capture fisheries[1] production (Rönnbäck, 1999) (Kapetsky, 1987). Several authors have studied the correlation between mangrove and capture fisheries in various areas, e.g., Barbier (2000) in Indonesia, Bann (1997) and Sathirathai (1998) in Thailand. However, the linkage has not been measured in Ca Mau province. In this research, we use the estimated linkage provided from a large-scale study by the World Bank, which found that a loss of 100 ha of mangroves would cause the yield

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[1] Capture fisheries are sometimes called "wild" fisheries, in distinguishing from the "farmed" fisheries and aquaculture.

of capture fisheries to fall by 70 tons (World Bank, 1996: 57). Thus, the correlation of mangroves/capture fisheries was assumed at 0.7, meaning that one hectare of mangroves could increase the inland fish stocks/resources of Ca Mau by 0.7 tons.

Using the same assumption, Do and Bennett (2006) estimated that the net benefits from capture fisheries of Ca Mau's wetlands (including mangrove forest and *Melaleuca* forest) were VND 1,253,575 per hectare per year in 2001. The net benefits were determined by subtracting costs of fishing (e.g., labor, equipment) from benefits (measured by the market price of fish). Noticeably, mangrove forest and *Melaleuca* forest were assumed to be identical in this estimate (Do & Bennett, 2006: 17). Thus, net benefits per hectare of the wetlands were identical to the net benefits per hectare of mangroves and equal to VND 1,253,575 per hectare per year in 2001. GDP deflator in 2001 and 2010 were 164.5 and 359.1 respectively (World Bank, 2013). Using GDP deflator, the capture fisheries' value of mangroves in Ca Mau province in 2010 is estimated at VND 2,736,527 per hectare per year, equivalent to US$ 147 per hectare per year.

Aquaculture support
Aquaculture (including shrimp farming and fish farming) is one of the main income sources in Ca Mau (Ca Mau Statistics Office, 2011: 155). Noticeably, mangroves and aquaculture are often intertwined in the province (Vo, 2013: 77). As mangroves are capable of creating spawning and nursery grounds for aquatic species (Marchand, 2008: 12), since they sequester nutrients and act as air and waste-water filters (Nuttle & Fletcher, 2013: 94), they can increase the productivity of aquaculture. In some provinces, aquaculture products such as shells and oysters have increased by 209 to 780 percent since mangroves were rehabilitated (International Federation of Red Cross and Red Crescent Societies [IFRC], 2010: 7). However, this linkage in Ca Mau province has not been examined in the literature. Pauly & Ingles (1986) analyzed a large set of data compiled from various areas around the world and found that the correlation between mangrove and shrimp yield was

significantly positive and could be as high as 0.734. Nevertheless, they noted that this result should not be used directly for predictive purposes, such as predicting the change of shrimp yield with the reduction of mangroves, because the linkage could vary according to the latitude (position of the area on earth) (Pauly & Ingles, 1986: 314). Haris et al. (2013) estimated the correlation between mangroves and aquaculture production of 0.485 (with R^2 =0.99) in South Sulawesi, Indonesia. This province is located in the same latitude as Ca Mau and it is only 2,166 kilometers away from the Vietnamese province (Google Maps, 2013). Thus, the mangrove-aquaculture correlation in South Sulawesi might be similar to that in Ca Mau. Consequently, we confirm that it is sufficient to assume the mangrove-aquaculture correlation in Ca Mau at 0.5, as has been done by Do and Bennett (2006). Although they did not provide any explanation for the assumption, several subsequent studies, e.g., Brander et al. (2012) and Tuan et al. (2009), have acknowledged it.

In order to estimate the net benefits of aquaculture in Ca Mau, Vo (2013) conducted a survey for various mangrove-covered areas. The famers were asked about their total incomes (benefits) and costs (e.g., labor, land preparation, seeds). Accordingly, the average net benefits from aquaculture in Ca Mau's mangrove ecosystem were estimated at US$ 17,720,222 in 11,458 hectares (Vo, 2013: 87), equivalent to US$ 1546.67 per hectare in 2010. Applying the assumed mangrove-aquaculture correlation of 0.5, the aquaculture-support value of mangroves in Ca Mau was estimated at US$ 773.35 per hectare in 2010.

Timber
Our research used BTM to estimate the timber value of mangroves for the year 2010. There are some data in Can Gio available for applying the method. An important reason for using the data of Can Gio mangrove forest is that the mangrove management model in Can Gio in the early 2000s has been considered successful (Hong, 2005: 58). At that time, the mangrove trimming rate of the forest was reasonable, which can be an example for Ca Mau province to follow. Most recently, Vo and

Kuenzer (2012) estimated the total value of mangrove timber and fuelwood in Can Gio at US\$ 12.72 million. This result was based on an assumption that 50 percent of households were dependent on mangrove forest for construction wood and fuelwood (Vo & Kuenzer, 2012: 73). The basis of this assumption, however, was not explained. In addition, we find that this assumption might not be valid for Ca Mau, since the average income there is lower than that of Ho Chi Minh City and thus people in Ca Mau might rely more on mangroves. Therefore, this data is not suitable for transfer to Ca Mau province.

Tri (2000) calculated the value of mangrove timber in Can Gio based on the net benefits of mangrove trimming provided by the Management Board of the Protected Areas (MBPA). The result was VND 670 per hectare per year in 1999 (Tri, 2000: 14). However, Tri's estimate did not provide a detailed itemization. For example, it was unclear whether or not labor costs were included. For that reason, Tri's result was not used for BTM in this study. A more useful study is that of Hang and An (1999), which calculated the net benefits of mangrove trimming in Can Gio using surveys and technical measures in 1996. Labor costs, including hired and household labor, were clearly itemized. In addition, as the trimming times could be different according to the age of mangroves, Hang and An examined a five-year period (a cycle of trimming) to derive the average annual benefits of trimming. Consequently, the net benefits of mangrove trimming were estimated at VND 1,209,923 per household for 1,200 hectares. With 134 households in the study site involved in mangrove trimming, the value of timber of Can Gio mangrove forest in 1996 was VND 135,072. GDP deflators in 1996 and 2010 were 127.2 and 359.1 respectively (World Bank, 2013). Using the deflator adjustment, the value of timber of Ca Mau's mangrove forest is estimated at VND 381, 323.5 or US\$ 20.50 per hectare per year in 2010.

Fuelwood

The output of fuelwood collection in Ca Mau in 2010 was 189,800 cubic meters (Ca Mau Statistics Office, 2011: 152). The price of

fuelwood was VND 142,857 per cubic meter in 2010 (Government of Vietnam, 2010a). Thus, the gross revenue from fuelwood is estimated at VND 27,114 million per year. This is the revenue collected from 100,791 hectares of all kinds of forest in Ca Mau in 2010 (Ca Mau Statistics Office, 2011: 151). The revenue per hectare of fuelwood is therefore estimated at VND 269,014 per hectare per year. As there is no data on the difference of fuelwood collected in mangrove forests and in other types of forest, it is assumed that there is no difference. Thus, the benefits from fuelwood were VND 269,014 per hectare per year, or US$ 14.45 per hectare per year in 2010.

Data on the costs of fuelwood collection, such as the number of households involved and time spent on this activity, are not available. However, for the local people who live close to the mangrove forest, these costs are often small. Therefore, this study assumes that the cost of fuelwood collection in Ca Mau province is negligible (zero). Thus, the net benefits from fuelwood are estimated at US$14.45 per hectare per year in 2010.

Medicinal plants

A number of unique fauna and flora species in mangrove forests are used as medicine in Vietnam (Ministry of Natural Resources and Environment (MONRE), 2002: 35). Do and Bennett (2006) estimated the net benefits (including the medicinal benefits and the labor costs) using the benefit-transfer method. Their results indicate that a hectare of mangroves in Ca Mau provides net benefits of VND 77, 201.6 in terms of medicinal plants. GDP deflators in 2001 and 2010 were 164.5 and 359.1 respectively (World Bank, 2013). Accordingly, the value of medicinal plants from mangrove forest in 2010 is estimated at VND 168,529 per hectare per year, or US$ 9 per hectare per year.

Carbon sequestration

Mangrove forests have exceptionally high capacity of storing carbon dioxide compared to most forest types (Donato et al., 2010; McNally et al., 2011: 11). Examining the mangroves in Ca Mau province, Tan

(2002) pointed out that the carbon-sequestration rate varies greatly according to the age of the tree. Consequently, McNally et al. (2011) suggested that an average rate of 32 ton CO_2 equivalent per hectare per year (tCO_2e/ha/year) could be used for analyzing reforestation projects in Ca Mau province.

The global carbon price fluctuates every year. It was approximately US$ 35 per tCO_2e in 2008 but dropped to below US$ 10 per tCO_2e by the end of 2011 (World Bank, 2012: 18). Based on analyses by Tol (2008) and Stern (2007), the World Bank suggested that the carbon value of US$ 29/CO_2e could be used for assessing some projects in 2010, including reforestation projects (World Bank, 2010: 79). Accordingly, the value of carbon sequestration of Ca Mau's mangrove forest was estimated at US$ 928 per hectare per year in 2010.

However, since Vietnam is not among the countries with binding targets of emission reduction in the Annex I&II parties of the Kyoto Protocol and it has not launched its Emissions Trading Scheme (ETS), the estimated value does not reflect the "real" benefits of mangroves in Ca Mau province. At the present, the carbon sequestration value of mangroves can economically benefit Ca Mau only via the Clean Development Mechanism (CDM). However, two points should be considered. First, the CDM does not include mangrove conservation (Laurance, 2007; Moutinho et al., 2005). Thus, the carbon sequestration value of existing mangrove cannot improve local people's incomes. Second, mangrove afforestation and reforestation are included in the CDM, although the revenues from these activities are non-permanent. Indeed, afforestation and reforestation CDM projects (A/R CDM) can only earn temporary certified emission reduction (tCERs) or long-term certified emission reduction (lCERs) (Angelsen et al., 2009: 312) rather than the regular CERs. The tCERs can expire after a subsequent commitment period (often five years) while the lCERs expire at the end of a project crediting period (verifying that the carbon stocks are still in place) (Baker & McKenzie, 2013; World Bank, 2007: 32). This is because carbon stocks can be released back into the atmosphere if mangroves are eventually cut down. For that reason, the prices of tCERs

and lCERs are often lower than the price of regular CERs (e.g., one-third the price of CERs) (McNally et al., 2011: 14). The price of tCERs and lCERs can vary according to CERs and the projects' characteristics (Streck et al., 2009: 126). Due to the great variation of price and the lack of data, this research uses the average historical price of afforestation/reforestation credits of US$4.27/tCO2e (World Bank, 2007: 38). Thus, the "real" value of carbon sequestration of Ca Mau's mangrove forest is estimated at US$ 136.64 per hectare per year in 2010.

Total net benefits of mangroves

Total net benefits of Ca Mau's mangrove forest are the sum of all net benefits of direct-use values (e.g., capture fisheries, aquaculture supports, timber, fuelwood, and medicinal plants) and in-directed use values (e.g., erosion control and carbon sequestration) estimated in the previous section. Table 2 summarizes the results.

Table 2: Total net benefits per hectare of mangrove forest in Ca Mau for the year 2010

Category	Estimated values	Net benefits with labor costs (US$/ha/year)
Direct-use values	Capture fisheries	147
	Aquaculture supports	773.35
	Timber	20.5
	Fuelwood	14.45
	Medicinal plants	9
Indirect-use values	Erosion control	728.2
	Carbon sequestration	0 * 136.64 ** 928 ***
	TOTAL	**1,692.5**

Note: *   Carbon-sequestration value of mangrove conservation

   **   Carbon-sequestration value of mangrove reforestation

   ***   "Nominal" carbon-sequestration value of mangroves (indicates the equivalent value of carbon reduction in carbon markets)

The total net benefits per unit of mangroves are US$ 1692.50 per hectare per year. This implies that by conserving one hectare of mangroves, Ca Mau can earn US$ 1692.50 per year. Total value can be even higher if the CDM includes conservation projects or Vietnam has its emissions trading scheme (ETS) in place. These results confirm the importance of mangrove forest to Ca Mau province, from an economic perspective.

CBAs of mangrove conservation and reforestation

CBA of mangrove conservation
This section presents a cost-benefit analysis of the mangrove conservation project from two perspectives. The first is the social viewpoint (of the government) and the second is the private viewpoint (of the local people) in Ca Mau province.

The benefits of mangrove conservation are the benefits gained from having mangroves, which are the total net benefits estimated in the previous section. For local people, the most-recognized benefits of mangroves are the direct-use values. Their appreciation for the value of erosion-control varies according to their distance to the coast (Vo, 2013: 85) and the carbon sequestration value is often not recognized. Therefore, private benefits might only include direct-use values but not indirect-use values.

In terms of the costs, mangrove conservation involves all the activities that maintain the existing qualities of the mangrove ecosystem in Ca Mau province. These activities include protection against deforestation by lumberjacks and routine work such as tree care and trimming. However, detailed data on the costs of mangrove conservation in Ca Mau are unavailable. Therefore, it is assumed that the conservation costs in Ca Mau are equal to the fixed rate for forest protection of VND 200,000 per hectare per year (equivalent to US$ 15 per hectare per year), which was set in the investment norms approved by Decision No. 60/2010/QD-TTg (Government of Vietnam, 2010b). They are also consistent with the estimated costs for mangrove

maintenance in Ca Mau by McNally et al. (2011).

In Ca Mau, these costs are often paid by the local government (Ca Mau People's Committee) with support from the central government and some foreign organizations (e.g., the IFRC, AusAID, SNV and GIZ). These payments benefit the local people who conserve mangroves in return for their labor and equipment costs of conservation. For simplicity, it is assumed that the payments are just sufficient to cover such private costs. Thus, the costs of mangrove conservation in Ca Mau are social costs rather than private costs (see Table 3).

Table 3: Private net benefits and social net benefits of mangrove conservation

	Benefits (US$/ha/year)	Costs (US$/ha/year)	Net benefits (US$/ha/year)
Private	964.3	0	964.3
Social	1692.5	15	1677.5

Note: Private benefits include the direct-use value of mangroves.

Social benefits include all TEV of mangroves.

As can be seen, the private net benefits and the social net benefits of mangrove conservation are both positive. This result demonstrates the economic efficiency of the project in the province. In addition, the result shows that even though the local people do not have to pay for the conservation, their net benefit is still smaller than the social benefits. This may explain different incentives in some cases. For example, shrimp farming might generate higher private benefits (excluding environmental costs) than mangrove conservation. In such cases, local people will favor shrimp farming over mangroves. From a social perspective, however, the government, in making its decision, has to consider the environmental costs of shrimp farming.

CBA of mangrove reforestation

Unlike the mangrove-conservation project, some benefits and costs of the mangrove-reforestation project can change or occur in different years. Thus, the CBA of this project needs to account for time. Figure 2 illustrates the benefits and costs of the projects in a 10-year-time horizon. The 10-year time horizon is chosen for this analysis because decision makers in Vietnam often design and revise policies according to five-year plans or ten-year plans.
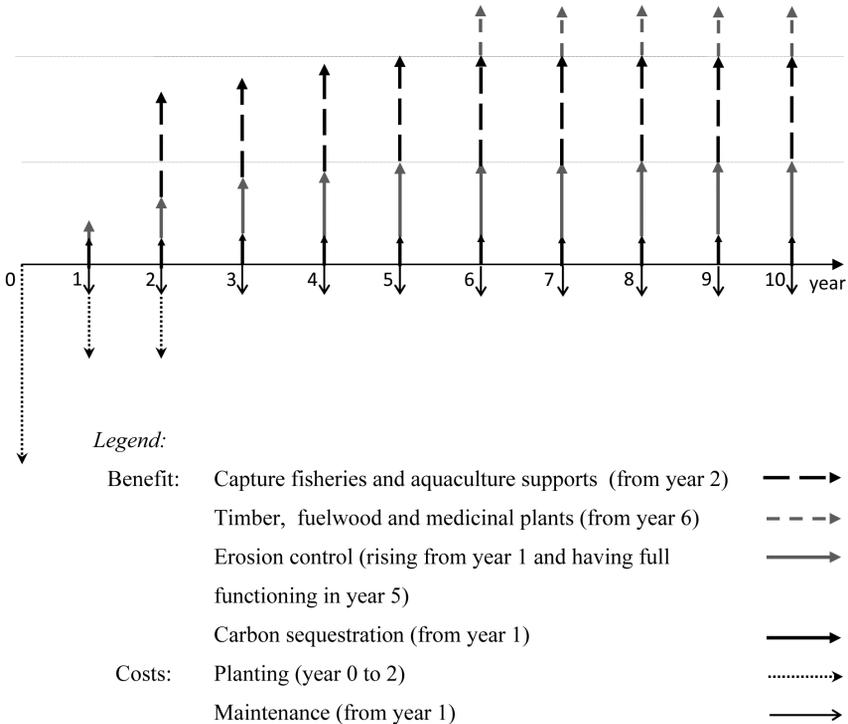

Legend:

Benefit:	Capture fisheries and aquaculture supports (from year 2)	– – ▶
	Timber, fuelwood and medicinal plants (from year 6)	– – – ▶
	Erosion control (rising from year 1 and having full functioning in year 5)	⟶
	Carbon sequestration (from year 1)	⟶
Costs:	Planting (year 0 to 2)	⋯⋯▶
	Maintenance (from year 1)	⟶

Figure 2: Timing of costs and benefits of mangrove reforestation

In terms of benefits, as reforestation is included in CDM, the carbon-sequestration value can benefit mangrove-reforestation projects

via tCERs. This carbon-sequestration value is estimated at US$ 136.64 per hectare per year (see Table 2). This is the average carbon-sequestration value of mangroves at different ages, which remains stable throughout the project life and starts from year 1 (see Figure 2).

The erosion-control value of mangroves also increases with age. According to Mazda et al. (1997), a half-year-old mangrove belt has a rate of wave reduction r of 0.01-0.03; this rate increases as mangroves grow and mature (five to six years old), r is as large as 0.20. Thus, the erosion control value of mangroves rises from year 1 to year 5 and reaches the full value in year 5. Based on the full value of erosion control of US$ 728.20 per hectare per year estimated in Section 3.1.1, the values of erosion control according to mangrove ages are estimated accordingly. In detail, the erosion-control value of mangroves increases from US$ 36.41 per hectare in year 1 to US$ 728.20 in year 5 and remains stable afterward. Accordingly, the erosion-control values of mangroves in different years of the project are illustrated in Table 4 below.

Table 4: Relation between age of mangroves and erosion control value

Age of mangroves	0	1	2	3	4	5
Percentage of full function (erosion control)	0 percent	5 percent	28.75 percent	52.5 percent	76.25 percent	100 percent
Value of erosion control (US$/ha/year)	0	36.41	209.36	382.30	555.25	728.2

The values of capture-fishery and aquaculture-supports start from year 2 after planning (Hoang Tri et al., 1998: 52). Forest thinning and exploitation of timber, fuelwood and medicinal plants are allowed from year 6.

The costs of mangrove reforestation include the planting costs (e.g., seedlings, labor and land costs) for the first three years and maintenance costs for all years of the project. According to McNally et al. (2011), the planting costs were US$ 900 in the first year and US$

300 per year in each of the following two years, and the maintenance costs were US$ 15 per year (data for the year 2010). In addition, there are up-front costs of setting up and planning the project as well as administration costs which occur every year. These costs can vary greatly according to the project characteristics and scale. However, there is lack of information on those costs in Ca Mau province. Therefore, this study only focuses on the implementation costs.

The planting costs at the start of the project (year 0) are US $900; in the following two years they are US$ 300 per year. Maintenance costs are $15 per year and incur from year 1. The results of cost-benefit analysis of mangrove reforestation in Ca Mau province are presented in Table 5.

Table 5: Cost-benefit analysis of mangrove reforestation in Ca Mau province (base year: 2010)

Discount rate (percent)	Direct-use benefits (PV USD/ha)	Erosion-control (PV USD/ha)	Carbon sequestration (PV USD/ha)	Implement costs (PV USD/ha)	NPV (PV USD/ha)	B/C ratio
3	7,130.80	4,580.80	1,165.50	1,601.90	**12,877.20**	8.0
6	6,043.90	3,817.80	1,005.70	1,560.40	**10,867.40**	6.9
10	4,921.90	3,038.80	839.60	1,512.80	**8,800.30**	5.8

The positive NPVs indicate that it is worthwhile to undertake mangrove-reforestation projects, although the costs for one hectare of mangrove can be as much as US$ 1601.90 (at a discount rate of three percent). This result implies that if national projects, such as the Restoration and Development of Mangrove Forest in Coastal Areas Program, proposed by the Ministry of Agriculture and Rural Development (MARD), (2008), with estimated costs of VND 25 million per hectare (or US$ 850 per hectare), are undertaken in Ca Mau province, they are likely to be economically efficient. With a discount rate in 2010 of six percent (SBV, 2012), one hectare of reforested mangroves can generate a net present value of US$ 10,867.40 in 10 years. Given that Ca Mau's income per capita was US$ 1,064 in 2010 (Ca Mau Statistics Office,

2011), the reforestation project can significantly improve the province's economy.

As can be seen in Table 5, erosion control plays an important part in the total benefits of mangroves in Ca Mau province. With increasing impacts of climate change, this value can be even more significant. However, it should be noted that mangroves are sensitive to some changes in natural conditions, especially sea-level rise (Blasco et al., 1996; Furakawa & Baba, 2001). They can survive only with proper care, which will need improvement since the effects of climate change are becoming more complex (Marchand, 2008; McIvor et al., 2013). Thus, the enhancement of investments in mangrove conservation and reforestation is necessary to maintain the values of mangroves.

However, from the perspective of CDM managers, the examined mangrove reforestation project in Ca Mau does not appear worthwhile. In Table 5, the present values of carbon sequestration (which are the benefits of CDM projects) are less than the implementation costs at all discount rates. Moreover, CDM projects might have to bear some additional costs, such as those of registration and verification every five years (McNally et al., 2011: 23). Thus, CDM projects are likely to experience net costs in Ca Mau. Nevertheless, from a social perspective, such projects will be beneficial for the province. In order to balance the difference, it might be sensible for the government to provide some financial support for CDM projects. Since the direct and indirect values of mangroves are sizeable, it is feasible for the government to do so. For example, a budget which could have been spent on dike reinforcement made necessary by the reduction of mangroves can be transferred to some CDM projects. When the projects are implemented, dike erosion will be reduced and thus the dike reinforcement would be unnecessary. In addition, direct-use values of mangroves are gained and they benefit local people. That is perhaps a Pareto efficient decision. On a larger scale, the central government might launch an emission-trading scheme and promote forest conservation in the CDM. These activities may help to diversify the benefits of CDM projects and reduce the costs (since conservation is often less costly than reforestation). The ultimate

aim of decision makers is to increase natural resources, like mangrove forests.

Conclusion

Apart from great biodiversity value, mangroves can be considered a measure to deal with certain impacts of climate change. This paper presents an economic valuation of mangroves and an application of cost-benefit analysis (CBA) to test the economic effectiveness of two assumed projects: mangrove conservation and mangrove reforestation in Ca Mau province, Vietnam.

This is not the first valuation study in the province; nevertheless, it is the most updated one and it focuses only on mangroves, not including *Melaleuca* forest, which also exists in the province. The values estimated are direct-use values (e.g., capture fisheries, aquaculture support, timber, fuelwood and medicinal plants) as well as indirect-use values (e.g., erosion control and carbon sequestration). The results show that one hectare of mangroves can generate a total social net benefit of US\$ 1,692.50 per year to Ca Mau province, with labor costs included.

Consequently, this study found that mangrove conservation is worthwhile in Ca Mau province, given that the total benefits gained from having mangroves far exceed the costs of conservation. In terms of mangrove-reforestation projects, as some costs and benefits can occur differently in time, a simulated ten-year project was created. The result indicates that mangrove reforestation is likely to be beneficial in Ca Mau. Sensitivity tests show that the net present value and benefit-cost ratio of the project remain high with the change in discount rate. However, individuals from other perspectives might have different viewpoints. Local people may favor other sources of income, such as shrimp farming, rather than public mangroves. From the perspective of a CDM manager, mangrove restoration projects in Ca Mau are likely to suffer a net cost. Therefore, it might be sensible for the government to provide support to individuals in order to maintain and develop these native treasures.

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