
# Project Final Report

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Project Title: Assessment of the feasibility of applying payment for forest ecosystem services in Vietnam and Bangladesh mangrove forests

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## Executive summary

Mangrove restoration is an important approach to recover past losses and to contribute to climate change mitigation. There is strong international interest in this option, both as a result of countries making emission reduction pledges as part of the Paris Agreement to the UNFCCC, and from the corporate sector with ambitious targets to reduce emissions by 2050. The potential demand for mangrove carbon sequestration could be far in excess of the area of potential mangrove restoration.

Payment for mangrove carbon mitigation could also generate multiple co-benefits, such as coastal protection, improved aquatic habitat, and diversified sources of income for land-holders and associated communities. Such co-benefits will be of interest to investors who are seeking environmental and social outcomes in addition to carbon mitigation.

Project CRRP2018-05MY aimed to examine carbon mitigation and the valuation of co-benefits in mangrove restoration projects in Vietnam and Bangladesh. Several planned activities were significantly disrupted by Covid-19 restrictions; however, we suggest that the project has provided excellent insights for the management of carbon investments in mangrove restoration projects and identified future research needs.

Three main questions were addressed, with each of these being summarized in peer-reviewed publications.

1. How successful are mangrove restoration projects and programs in Vietnam and what are the main reasons for their success or failure (Hai et al. 2020)?
2. To achieve sustainable management of mangroves in the long-term, how can environmental, economic and social objectives be balanced for residents who participate in the protection of restored mangroves (Hai et al. 2022)?
3. Whether payment for mangrove carbon service schemes can be implemented as an incentive for local communities for mangrove protection (Hai et al. in review)?

In addition, global mangrove restoration projects and their carbon mitigation potential were examined, with particular emphasis on the veracity of the claims of rates of carbon sequestration. A desk-top review was undertaken of Bangladeshi mangrove restoration projects.

Some of the planned outreach and communication components of the project were undertaken including a workshop in Ca Mau province with different stakeholders including buyers and sellers of mangrove blue carbon services, an international workshop at Vietnam Forest University and an online briefing to 35 finance professionals interested in carbon mitigation investment.

Over the last three decades there has been considerable investment in mangrove restoration programs in Vietnam resulting in the restoration of *c*. 200,000 ha mangroves (Hai et al. 2020). The effectiveness of these mangrove restoration efforts was assessed. Failure in some projects can be attributed to poor site and species selection, lack of long-term monitoring and management, and lack of incentives to engage local residents in the long-term management of restored areas. To further improve mangrove restoration the following are proposed: improved site and species selection, establishment of a baseline for restoration planning, and adopting a robust monitoring and reporting process that informs the success or failure of restoration programs.

As one of important causes of failure of some mangrove restoration projects in Vietnam is the lack of long-term management of restored areas, engaging local residents in long-term management of restored mangroves is crucial. Hai et al (2022) explored the development of the mangrove-shrimp farming system as a method to protect mangroves by balancing economic, environmental and social objectives for local farmers who participate in mangrove protection. Using household survey data from Ca Mau Province, collected as part of this project, it is clear that integrating mangroves with shrimp farming can support multiple objectives. While mangrove-shrimp farming offers the highest rate of economic return (295%) as compared to intensive (145%) and extensive (183%) shrimp farming systems, it is also the least expensive and suitable for people with limited

financial capacity. The data showed that mangrove coverage may contribute to the economic efficiency, and the optimal mangrove coverage from the perspective of individual farmers (30% coverage) can be lower than what is demonstrated by empirical data (60% coverage). Though undertaken in a specific location, the study highlights the benefits of mangrove-shrimp farming as a possible triple-win approach towards sustainable development.

A further strategy for sustainable management of restored mangroves is to offer incentives for local communities (Hai et al. in review) such as a payment for carbon services (C-PFES). By collecting data from 73 stakeholders of potential sellers, potential buyers and intermediaries, this component investigated the feasibility of applying C-PFES for mangroves in Ca Mau province, Vietnam. Results showed that farmers are generally aware of climate change as an issue affecting their production. While they were aware of the environmental roles of mangroves, the carbon sequestration capacity of mangroves was rarely mentioned leading to challenges for implementing the C-PFES scheme. While potential sellers and intermediaries voiced strong support for C-PFES, only 29-56% of interviewed potential buyers are willing to join the scheme. This suggests the need for training around carbon and environmental markets, aimed at different sectors.

A review of mangrove C sequestration and storage indicated that although mangrove C storage is much higher than other terrestrial ecosystems, the rate of aboveground carbon sequestration is similar to that of tropical forests, and certainly not at the rates suggested in some promotional literature. While there are distinct advantages in retaining carbon in intact mangrove ecosystems, carbon sequestration alone may not be enough to drive restoration projects. Here, accounting for the co-benefits generated from mangrove

restoration projects may encourage restoration and importantly the maintenance of restored areas. Formal inventory and payment systems are required to allow this to occur.

## 1. Introduction

Mangroves are associations of trees and shrubs forming the dominant vegetation in tidal, saline wetlands, along tropical and subtropical coasts. Their latitudinal limits reflect major ocean currents and the 20°C seawater isotherm in winter (Alongi 2002). Mangrove forests are among the most productive ecosystems per unit area (Kodikara et al. 2017), providing important marine based ecosystem services such as raw materials and food, fish nursery maintenance, water purification, coastline protection, carbon storage, erosion control and tourism (Barbier et al. 2011).

However, more than half of the mangrove area worldwide has been lost during recent decades due to land conversion to aquaculture and agriculture, overharvesting and sea level rise (Duke et al. 2007; Giri et al. 2015; Richards and Friess 2016). Globally, the average rate of mangrove loss from 1996 to 2016 was 0.21% which exceeds the average loss of tropical and subtropical forests. Mangrove loss not only results in diminishing ecosystem services, but also increased emissions of $CO_2$ (Kauffman and Bhomia 2017) from millennium stored carbon (Wylie et al. 2016). The total mangrove area is estimated to be 14.7 million ha globally (Kauffman and Donato 2012) which is a substantial decline from 19.8 million ha in 1980 and 15.9 million ha in 1990 (Valiela et al. 2001). As an important carbon sink, mangrove loss can release a huge amount of emissions globally with estimates ranging from 0.09 to 0.45 Pg $CO_2$ per year. This is equivalent to 3-19% of total global GHG from deforestation resulting in economic damage of US$6-42 billion per year (Pendleton et al. 2012).

In Vietnam, mangroves are important ecosystems as the country has a long coastline and thus, it is vulnerable to climate change (World Bank 2010). Mangroves are distributed along coastlines from the north to the south (Hong and San 1993) with a total original area reported in 1943 of 408,500 ha (Westing 1983). However, due to the impacts of land conversion, conflict and economic development (Westing 1983; Hawkins et al. 2010; McNally et al. 2011; Richards and Friess 2016), large areas of mangroves were destroyed with 124,000 ha loss from 1965 to 1970 (Westing 1983), and about 0.25% loss annually from 2000 to 2012 (Richards and Friess 2016). Deforestation may also be exacerbated in the future due to the impact of climate change, further land conversion, and coastal erosion (Hai et al, 2020).

In order to recover mangrove loss and enhance ecosystem services, mangrove restoration projects and programs have been implemented by many countries. Mangrove restoration was first launched in the 1950s in China and India (Kodikara et al. 2017). Restoration gained increased momentum after the Indian Ocean tsunami in 2004 (Kodikara et al. 2017) and the Haiyan typhoon in the Philippines in 2013 (Wolanski and Elliott 2015; Barnuevo et al. 2017). In Vietnam, mangrove restoration activities commenced in 1975 after the end of the Second Indochina War (Hong 2008). Since then, with the emerging acknowledgement of the importance of mangroves to climate change adaptation and mitigation, many state and international projects have been implemented over the country. However, there has been limited assessment of the effectiveness of these programs. Additionally, protection of both remnant and restored areas is critical to sustainable management of mangroves in the long-term.

Payment for ecosystem services or a payment for environmental services (PES) scheme is emerging as a market-based approach for forest conservation with the expectation that it will

address underlying economic and political causes of forest loss by incentivizing land managers in better management of natural resources that maintain or enhance ecosystem service provision (Locatelli et al. 2014; Wunder 2015). As well as providing a wide range of ecosystem services, such as provisioning, regulating, supporting and cultural services, mangroves can create incentives for conservation and therefore the potential of mangrove PES has matured into a topic of current and critical debate (Thompson et al. 2014). Therefore, if designed correctly, a PES scheme applied to marine and coastal ecosystems should obtain as results as good as those achieved for land ecosystems (Lau 2013). Additionally, the international community has begun to evaluate how these ecosystems can be more effectively included within existing policy frameworks, including carbon financing mechanisms such as Reducing Emission from Deforestation and Forest Degradation, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries (REDD+) and other UNFCCC mechanisms. The majority of PES forestry projects, however, mostly concern terrestrial ecosystems (Warren-Rhodes et al. 2011) whereas little is known about the impacts of the PES scheme on mangrove dependent communities (Corbera et al. 2007). Only 87 $km^2$ of mangrove forests worldwide is currently included in operational PES schemes (Thompson et al. 2017). The PES schemes applied to mangrove forests are mostly focussed on payment for carbon services, for example, mangrove carbon projects in Kenya and Madagascar and voluntary carbon credits in the Sundarban mangrove forests, India (Wylie et al. 2016). Another mangrove PES is based on tourism services in Krabi, Thailand (Jarungrattanapong et al. 2016).

In Vietnam, in 2010, the Government of Vietnam passed Decree No. 99/2010/ND-CP on the Policy on payment for forest environmental services (PFES), which defined 5 types of forest environmental services entitled to payment as follows:

(i) Soil protection, restriction of erosion and sedimentation of reservoirs, rivers and streams;

(ii) Regulation and maintenance of water sources for production and social life;

(iii) Forest carbon sequestration and retention, reduction of greenhouse gas emissions by measures of preventing forest degeneration and forest area decrease and developing forests in a sustainable manner;

(iv) Protection of natural landscape and conservation of biodiversity of eco-systems for tourism services, and

(v) Provision of spawning grounds, sources of feed and natural seeds, use of water from forests for aquaculture.

To date, only services (i), (ii) and (iii) have been identified clearly in terms of subjects, levels of payment and methods of payments in some follow-up government documents. The other services have been assigned to the Ministry of Agriculture and Rural Development (MARD) to formulate guidance documents for the implementation. However, most of the studies on PFES in Vietnam focus on terrestrial forests rather than marine ecosystems. The only research on payment for environmental services for a marine ecosystem is the study on mangroves and markets in Mekong River Delta, Vietnam aiming at promoting shrimp certification (Wylie et al. 2016).

Results on the implementation of PFES in Vietnam shows that this is a successful mechanism with the total collected PFES money for the past 3 years from 2011 to 2014 being US$157 million, with 2.8-3.37 million ha of forests (accounted for 20-27% of the total forest area in the country) being protected and 355,047 households, mostly the poor and ethnic minorities, being involved in the payment mechanism (Ministry of Agriculture and Rural Development, 2014).

The objective of this project was to seek an approach to optimise carbon mitigation and community benefits from mangroves through payment of mangrove carbon for future sustainable management of this ecosystem. The project, as originally conceived and contracted, involved on-ground activities in Vietnam and Bangladesh, this including field inspections and workshops with landholders, government officials and potential investors. It was substantially disrupted by Covid-19 travel restrictions across the region; thus, the project as reported here had more constrained aims, with the work concentrating on Vietnam.

The following main questions were addressed, with each summarized in a formal, refereed publication.

1. How successful are mangrove restoration projects and programs in Vietnam and what are the main reasons for their success or failure? (Hai et al. 2020).[1]
2. To achieve sustainable management of mangroves in the long-term, how can environment, economic and social objectives be balanced for residents who participate in the protection of restored mangroves? (Hai et al. 2022).[2]
3. Whether payment for mangrove carbon service scheme can be implemented as an incentive for local communities for mangrove protection ? (Hai et al. in review).[3]

In addition, as a prelude to planned industry workshops (which didn't proceed because of the Covid disruption), we reviewed;

1. The evidence for claims around blue-carbon sequestration, compared to other forest systems and the putative co-benefits, and
2. The literature on mangrove restoration in Bangladesh. This will likely form the basis of a future PhD program for a researcher from the Bangladesh Forest Department.

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1 Hai, N.T., Harper, R.J., Dell, B. and Phuong, V.T. (2020). Towards a more robust approach for the restoration of mangroves in Vietnam. *Annals of Forest Science* **77** https://doi.org/10.1007/s13595-020-0921-0

2 Hai, N.T., Chu, L., Dell, B, Harper, R.J. and Hoang, H. (2022). Mangrove-shrimp farming: A triple-win approach for poor communities in the Mekong River Delta. *Ocean & Coastal Management* **221**, 106082. https://doi.org/10.1016/j.ocecoaman.2022.106082

3 Hai, N.T., Dell, B and Harper, R.J. (in review). Feasibility of implementing a payment for mangrove carbon service scheme: Case study in the Mekong River Delta, Vietnam. *Journal of Marine Policy*

## 2. Research location

Ca Mau province is located in the southern-most region of Vietnam. The province lies between 8° 33'–9° 35' N latitudes and 104° 42'–105° 24' E longitudes. The total land area is 5,211 $km^2$ (521,100 ha), making up 13.1% of the Mekong River Delta, of which 154,800 ha (29.7%) is in the coastal area. With a population of more than 1,226,000, the total provincial GDP growth rate is US$ 2,083,000/year (Ca Mau Statistic Office 2018). The majority of the population (948,000 people, 77.3% of the population) live in rural areas (Ca Mau Statistic Office 2018), and most engage in the aquaculture and fishing sectors.

Of the 29 Vietnamese provinces with mangroves, Ca Mau has the largest area which is *c*. 65,500 ha (MARD, 2014) accounting for about 72% of mangroves in the Mekong River Delta and 39% of the total mangrove area in Vietnam. Additionally, Ca Mau has favourable conditions, especially rainfall and alluvium, for the distribution and growth of mangrove trees. Thus, mangrove species composition is diverse in this area (Hong and San 1993). Mangroves in Ca Mau also represent an important carbon store. Above-ground carbon stocks, including biomass of trees and downed woody debris, ranged from 90-115 Mg C/ha, and below-ground carbon stock in the upper 250 cm of sediments was much higher at 629-687 Mg C/ha (Tue et al. 2014). According to Tue et al. (2014), it was estimated that the C stock in Ca Mau was high compared to other mangrove ecosystems with a total C storage in above- and below-ground components of 719-802 Mg C/ha. With around 13,400 ha of mangrove forests, Ca Mau Cape National Park stored $10.3 \times 10^6$ Mg C, equivalent to 38 Mt $CO_2$eq (Tue et al. 2014), accounting for significant past carbon sequestration from the atmosphere (Warner et al. 2016).

Ca Mau is the leading province for shrimp production, both in terms of production area and volume (Ha et al. 2012). In 2009, shrimp farmers produced 98,100 tonnes of shrimp,

21.5% of the national production, over an area of 265,730 ha (Ha and van Dijk 2013). By 2017 the area of shrimp farming in Ca Mau had increased to 280,849 ha and production was 157,660 tonnes, nearly 22% of the total country's shrimp production (GSO Vietnam 2017) (Fig. 1).

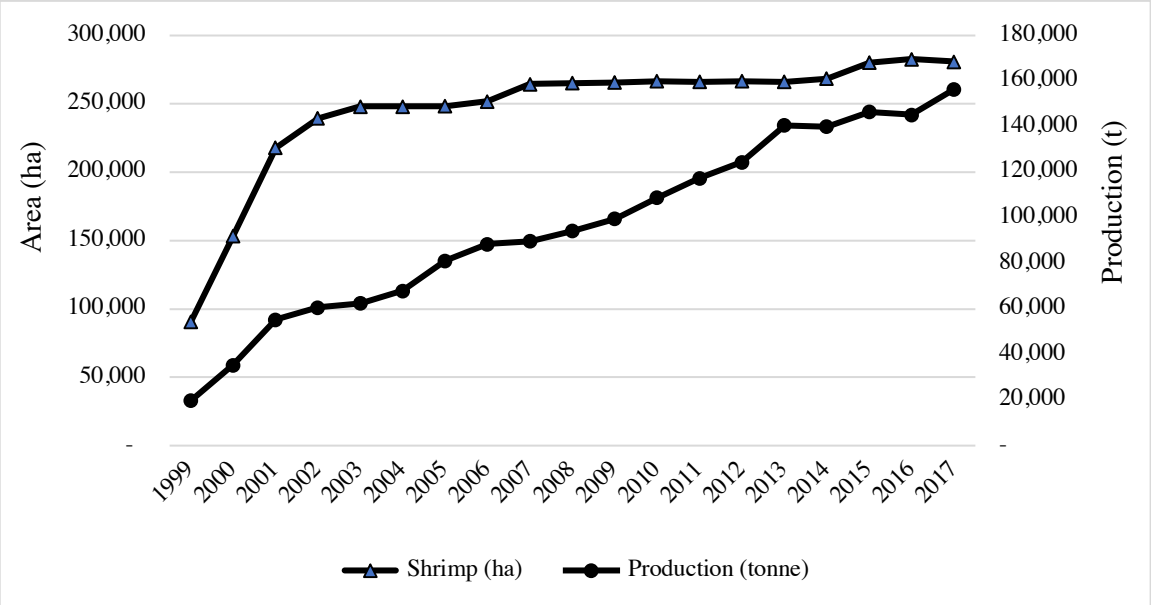


Fig 1. Shrimp farming and production in Ca Mau (Source: GSO Vietnam (2017)

In 2017, the value of shrimp farming in Ca Mau accounted for 80% of total provincial aquaculture and 49% of the agriculture sector in the province. The total exported value of shrimp products was about US$ 1 billion in 2017 with various international markets, such as America, Japan, Europe and China (DARD 2018). Shrimp farming development in Ca Mau has brought opportunities for local people by increasing incomes, reducing poverty and generating employment. Not only do the rich take advantage of this opportunity, but the poor can escape from poverty (Mai et al. 2010). From 1997 to 2003, job opportunities in the agriculture sector, mostly from aquaculture, in Ca Mau increased significantly from 85,000 to 312,000 (Mai et al. 2010). In the household income structure, income from shrimp farming was much higher than from rice, 25% compared to 8%,

respectively (Mai et al. 2010). Due to shrimp farming, the number of poor[4] families fell by more than 17,000 households, and the poverty rate fell from 15.5 to 7.8% between 2001 and 2004 (Mai et al. 2010).

Although the development of shrimp farming in Ca Mau has brought significant economic benefits, shrimp farming is considered to be the most serious cause of mangrove forest loss in the post-war period from 1976 to 1990 (McElwee 2004). Due to economic recession, poverty, food shortage and demand for reconstruction materials after the end of the war in 1975, people from many provinces migrated to Ca Mau to access mangrove forests for shrimp aquaculture, to collect aquatic products within estuaries or to fish in the Full Protection Zone (Ha et al. 2014). Therefore, mangroves were destroyed for timber and charcoal production, as well as being converted to agricultural land for rice cultivation and aquaculture without official permission (Ha et al. 2014). Additionally, under the *Doi Moi* reform in 1986, the Vietnamese government encouraged the development of shrimp farming for national demand and export (Hong and San 1993). From 1980 to the late 1990s, under active government promotion, high international shrimp prices and economic liberalisation, there was a rapid increase in the shrimp farming area in most of the coastal Mekong Delta. According to Van et al. (2015), 29,876 ha of mangroves in Ca Mau Province disappeared between 1979 and 1992 largely due to conversion to aquaculture. Areas of mangroves were also converted to agriculture. From 1976 to 1982, 17,645 ha mangroves in Ngoc Hien District (now separated into Nam Can and Ngoc Hien District) were converted to fields for the cultivation of soybean, rice and medicinal plants (Hong and San 1993). Sam and Binh (1999) estimated that between 1977 and 1983, about 24,000 ha of mangroves were converted to agriculture in Ca Mau

[4] In rural areas, a poor family was defined under Decision No 143/2001/QĐ-TTg dated 27th September 2001, with per capita income of below VND 1.2 million (equal to US$ 80)

Province. By 1988, about 71,700 ha were in use for shrimp farming, primarily in the southern and coastal parts of the province where brackish water and natural shrimp larvae were easily accessible (Mai et al. 2010). The Vietnamese government has planned to increase the shrimp farming area within the Mekong River Delta from 650,000 ha in 2014 to 670,000 ha by 2030. Although the types of land use that will be converted to shrimp farming are not specified in the plan, future threats to mangroves in the region remain, including in Ca Mau Province (Hai et al. 2020).

Although considered as an important ecosystem in providing both environmental and economic values, mangroves in Ca Mau have been destroyed for many reasons. Ca Mau was one of the two most impacted provinces during the Second Indochina War (1961-1975) with 52% of dense mangrove forests being destroyed (Hong and San 1993). Between 1979 and 1992, an additional 29,876 ha of mangroves disappeared largely due to conversion to aquaculture (Van et al. 2015). Thus, mangrove restoration has been a priority in this province with about 18,500 ha recovered under state sponsorship during the period 1975 to 1990 (Tuan et al.,2010; Hai et al, 2020). Recently, many restoration projects and programs have been implemented with international funding, such as the German state-owned development bank (KfW), International Climate Initiative (IKI), and German Environment Ministry (BMUB) (Hai et al, 2020).

Like other provinces in the southern regions, long-term management of restored mangroves in Ca Mau is better than other provinces in the northern Vietnam (Hong 2001). However, there is still an issue on how to encourage local communities to protect restored mangroves. One of the reasons for the problem is that farmers' awareness on the importance of mangroves is limited. In Ca Mau, one of the key reasons attributed to mangrove deforestation is the conversion to extensive and intensive shrimp farming

(Hong and San 1993; Van et al. 2015). Farmers believe that although integrated mangrove shrimp farming is important in terms of the environment, it does not generate high economic benefits (Mai et al. 2010). Thus, research on the importance of mangroves in providing economic benefits, environmental and social values is necessary to promote protection of restored mangroves.

# 3. Methodology

## 3.1. Shrimp farming development

Ngoc Hien district was chosen for the study of integrated mangrove-shrimp farming systems as the district has the largest extent of mangroves in Ca Mau Province. We selected Vien An Dong commune (total area is about 136 $km^2$) to conduct surveys as this commune has 1,219 households practicing the integrated mangrove-shrimp farming and this accounts for 44% of the total households practicing this system in Ngoc Hien district (approx. 743 $km^2$). For both intensive and extensive shrimp farming systems, we selected Phu Tan district as this district is one of the focal points of aquaculture development in Ca Mau Province. We selected Cai Doi Vam commune for both systems as this commune is diversified in shrimp system development. Fig.3 shows research locations for the study.


Fig. 3 Map of Ca Mau Province showing districts and data collection areas

For the number of households, the sample size was determined using the formula of Godden (2004):

$$n = \frac{\frac{z^2 p(1-p)}{e^2}}{1 + \frac{z^2 p(1-p)}{e^2 N}}$$

Where:

n: Required sample size

N: Population size

z: The standardized z-value associated with level of confidence (for example, z= 1.96 for the confidence level at 95% or z=1.28 for the confidence lever at 90%)

p: Population proportion (expressed in decimal form and popularly set at 0.5 when population proportion is unknown).

e: Margin of error (expressed in decimal form)

With parameters selected as: z = 1.28 (90 % confidence), p = 0.5, and e = 0.1 (margin of error of 10%), the number of households needed to interview in order to obtain results that reflect the target population was calculated to be 38. These households were randomly selected from three main groups namely rich, medium, poor by consulting with the leader of the commune. Results on sample data selection is in Table 1.

Table 1: Summary of sample data

| **Type of shrimp farming system** | **Location** | **Number of households producing shrimp** | **Number of interviewees*** |
|---|---|---|---|
| Integrated mangrove-shrimp farming | Vien An Dong, Ngoc Hien District | 1219 | 38 |
| Intensive shrimp farming | Cai Doi Vam, Phu Tan District | 130 | 38 |
| Extensive shrimp farming | Cai Doi Vam, Phu Tan District | 510 | 20 |

* Selected interviewees usually represented the heads of households, therefore, collected data from these interviewees represent household's perspectives.

1.2. Feasibility to implement payment for mangrove carbon services

Data were obtained via a series of interviews of three stakeholder groups, including potential sellers (forest management board and households), potential buyers (charcoal production companies, aquaculture cultivation companies and aquaculture processing companies) and intermediaries in many districts in Ca Mau province, including Ca Mau city, Ngoc Hien, Phu Tan, Nam Can district (Fig.3). A list of households in selected communes was provided by the community heads and then a systematic random selection was used. To obtain contact with other targeted participants, collaboration was developed with the Minh Hai Centre for Mangrove Forest Research and Technique Application

located in Ca Mau which is responsible for mangrove research. In order to identify stakeholders according to the targeted groups, representatives of local authorities were asked to link the questionnaire to possible stakeholders. The snowball method (Patton 1990) was then adopted by which respondents provided contacts with other related stakeholders potentially involved in payment for mangrove C scheme in Ca Mau province.

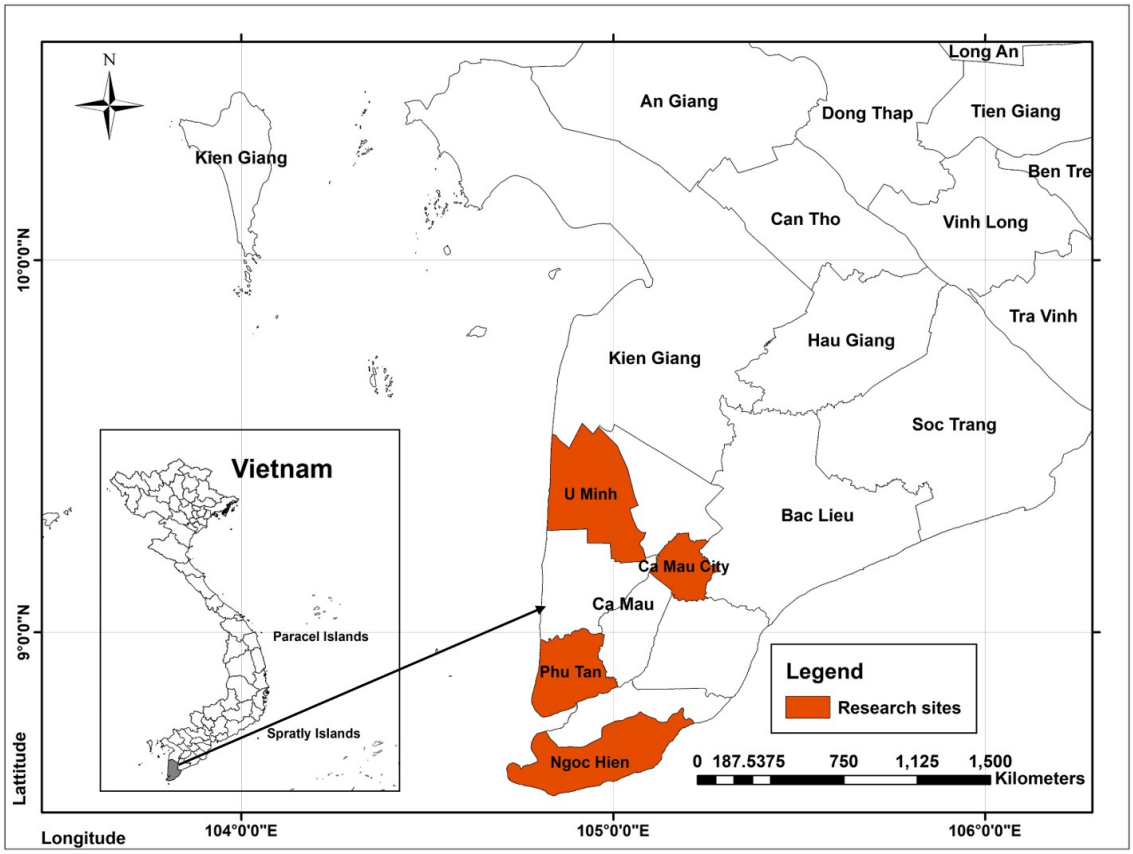


**Fig. 3** Map showing the location of the research sites in Ca Mau Province, Vietnam

The interviews included open-ended questions to avoid putting interviewers' perspectives on the participants' responses (Bernard 2013). A discussion guideline was developed to ensure broad comparability between different stakeholder groups. Generally, a questionnaire comprised four main parts, namely: (1) General information; (2) Information about current activities; (3) Awareness of climate change and environmental

roles of mangroves; and (4) Perspectives on payment for mangrove ecosystem services, focusing on blue carbon. In each stakeholder group, however, some specific questions were added to explore characteristics of the group (further about data collection is in Appendix). The number of interviewees from each group and the location of interviews are summarised in Table 2.

**Table 2** Summary of interviewed stakeholders

| **Interviewee group** | **PES scheme role** | **Location (commune/district)** | **Number of interviewees** |
|---|---|---|---|
| Households | Sellers | Vien An Dong, Tam Giang Tay | 40 |
| Forest management board | Sellers | Ngoc Hien, Phu Tan, Nam Can | 5 |
| Company | Buyers – Processing companies | Ca Mau city, U Minh | 9 |
| | Buyers – Intensive shrimp farming | Ngoc Hien, Nam Can | 8 |
| | Buyers – Charcoal production | Nam Can, Dam Roi, Ngoc Hien | 8 |
| Local authority | Intermediaries | Ca Mau city | 3 |
| | **Total** | | **73** |

## 4. Results

### 4.1 Results on shrimp farming practices in Ca Mau province

#### 4.1.1 General information of interviewed households

Households engaged in intensive shrimp farming had the highest level of education and a number of family members study in college. In contrast, households of integrated mangrove-shrimp farming had the lowest level of education (Table 3). This is because intensive shrimp farming households are generally richer than other shrimp farming households. Therefore, they have more opportunity to pursue education and to find employment in big cities rather than depend on agricultural jobs. A higher level of

education also brings knowledge and ability to apply advanced techniques in intensive shrimp farming activities.

Table 3: Household characteristics on education and work

| Type of shrimp farming | Level of education[5] | Number of family members in college | Number and proportion (%) of family members working outside |
|---|---|---|---|
| Mangrove-shrimp farming | 7.9 | 9 | 11 (29) |
| Intensive shrimp farming | 9.7 | 15 | 12 (31) |
| Extensive shrimp farming | 9.1 | 8 | 8 (40) |

There is not much difference between the different shrimp farming systems in terms of the proportion of household members working outside their residential locations. Members of integrated mangrove-shrimp farming households mostly leave for daily paid jobs while some people from intensive shrimp farms relocate to big cities and work as white-collar workers.

The most important source of income for all interviewed households is shrimp. Intensive shrimp farming households are less likely to depend on other sources of income, but extensive and especially integrated mangrove-shrimp households depend on various sources of income. All the integrated mangrove-shrimp farmers depend on timber for their livelihood, and 9 out of the 38 interviewed households earn income from livestock for their daily expenses (Table 4). No intensive and extensive shrimp households depend on income from forest timber. The results indicate that integrated mangrove-shrimp

[5] Level of education defined by The United Nations Educational, Scientific and Cultural Organization (UNESCO) is the highest level of school someone has completed.

farming is a suitable option for poor farmers, who must depend on various source of income.

Table 4: Sources of income of households

| Type of shrimp farming | Mangrove-shrimp farming | Intensive shrimp farming | Extensive shrimp farming |
|---|---|---|---|
| Other | 10 | 5 | 1 |
| Wage/Salary | 4 | 1 | 3 |
| Government allowance | 3 | 1 | 4 |
| Food crop | 4 | 0 | 1 |
| Livestock | 9 | 0 | 0 |
| Forest timber | 9 | 0 | 0 |

4.1.2 Cost-effectiveness of shrimp farming systems

Breakdown costs of production vary between the different systems (Table 5). For intensive shrimp farming, food and medicine for the shrimps are the two most important cost items making up 52.9% (US$ 30,876/ha/year) and 22.2% (US$ 12,926/ha/year), respectively, of the annual budget. For extensive and integrated mangrove-shrimp farming systems, the purchase of larvae accounts for 56.4% (US$ 887/ha/year) and 54.8% (US$ 371/ha/year) of the total annual costs, respectively. Unlike intensive and extensive shrimp farming, there are no labour costs for the integrated mangrove-shrimp farming as labour comes from the household of the owner-operator.

Table 5 Annual cost components per ha of shrimp farming activities

| Category | Intensive shrimp farming | | Extensive shrimp farming | | Integrated mangrove-shrimp farming | |
|---|---|---|---|---|---|---|
| | Amount (US$) | % | Amount (US$) | % | Amount (US$) | % |
| Sediment removal | 343.53 | 0.59 | 146.57 | 9.41 | 122.99 | 18.19 |
| Amendment costs | 1,531.08 | 2.62 | 14.80 | 0.95 | 4.19 | 0.62 |
| Larvae | 3,645.68 | 6.25 | 877.41 | 56.35 | 370.81 | 54.83 |
| Food | 30,876.14 | 52.90 | 112.76 | 7.24 | 13.19 | 1.95 |
| Labour costs (nursery, pond management) | 3,318.04 | 5.68 | 60.93 | 3.91 | 0.00 | - |
| Energy used (electricity, fuel) | 4,194.78 | 7.19 | - | - | 0.00 | - |
| Chemicals | 779.68 | 1.34 | 41.49 | 2.66 | 9.88 | 1.46 |
| Control of shrimp disease | 12,926.35 | 22.15 | 3.05 | 0.20 | 0.66 | 0.10 |
| Taxes (land lease) | 134.72 | 0.23 | 29.01 | 1.86 | 43.80 | 6.48 |
| Interest | 543.12 | 0.93 | 26.00 | 1.67 | 17.32 | 2.56 |
| Harvest cost | 73.38 | 0.13 | 245.15 | 15.74 | 88.53 | 13.09 |
| Other (mangrove) | - | - | - | - | 4.87 | 0.72 |
| Total | 58,366.50 | 100.00 | 1,557.17 | 100.00 | 676.24 | 100.00 |

The cost of production and revenue differ significantly between the shrimp systems (Table 6). Intensive shrimp farming is most costly, followed by extensive and integrated mangrove-shrimp farming. The total annual cost of intensive shrimp farming is US$ 58,367 per ha compared to US$ 1,557/ha for extensive shrimp farming and US$ 676/ha

for integrated mangrove-shrimp farming. This trend is similar for revenue, with the value of the three systems being US$ 84,672, US$ 2,851 and US$ 1,995 /ha/year, respectively. Intensive shrimp production is also the most profitable system with a profit of US$ 26,305/ha/year. There is not much difference between the integrated mangrove-shrimp and extensive systems, with profits of US$ 1,319 and US$ 1,294/ha/year, respectively. The integrated mangrove-shrimp farming has the highest rate of return (2.95), double the value of the intensive shrimp system (1.45), and relatively high compared to extensive shrimp farming (1.83).

Table 6 Cost-benefit analysis of shrimp farming activities

| **Type of shrimp farming** | **Production cost (US$/ha/year)** | **Revenue (US$/ha/year)** | **Profit (US$/ha/year)** |
|---|---|---|---|
| Mangrove - shrimp farming | 676.24 | 1,995.04 | 1,318.80 |
| Intensive shrimp farming | 58,366.50 | 84,672.38 | 26,305.88 |
| Extensive shrimp farming | 1,557.17 | 2,851.17 | 1,294.00 |

The integrated mangrove-shrimp farming supports poor farmers who have low financial capital and limited opportunities to apply high technical practices. Additionally, poor people practicing this system can also receive other economic benefits from mangrove services, such as payment for mangrove services or financial support from REDD+ programs in the future. As a low risk system, integrated mangrove-shrimp farming can mitigate potential social impacts caused by conventional shrimp farming activities. Furthermore, the farming system promotes mangrove protection which indirectly supports other environmental benefits. Therefore, integrated mangrove-shrimp farming should be promoted in developing countries to achieve a triple-win solution to economic,

environmental and social objectives, particularly when payment for the other environmental services is formalised. Payment for mangrove environmental services, including carbon service, can be an important incentive for local communities those operating integrated mangrove-shrimp farming system to protect mangroves.

## 4.2 Feasibility to implement payment for mangrove carbon services

### **4.2.1** Socioeconomic characteristics of farmers

Socio-economic profiles of mangrove-allocated household (Table 7) showed that 85% of the interviewees were males while only 15% of them were females, indicating that males usually make decisions in their families and their willingness to participate into a payment for mangrove blue carbon would represent their whole families. Results from interviewing households also revealed that most interviewees (95%) had only achieved a secondary educational level. This may impact the level of households' awareness on climate change and their knowledge on the importance of mangrove forests in terms of mitigating climate change.

The most important source of income for households was aquaculture (Table 8). All of the interviewees confirmed that their livelihood relied on mangrove-shrimp farms – the model integrates shrimp and mangrove ecosystem. Income from selling mangrove wood is the second important source of income with 30% of interviewees relying on this source of income. This indicates that mangroves are very important for the local community and that mangrove protection should be one of the households' priorities in maintaining their livelihoods.

Table 7 Socio-economic profiles of farmers

| Variable | Frequency | % |
|---|---|---|
| **Gender** | | |
| Male | 17 | 85 |
| Female | 3 | 15 |
| **Education level** | | |
| No formal education | 1 | 5 |
| Primary | 6 | 30 |
| Secondary | 12 | 60 |
| Higher | 1 | 5 |
| **Member of farmer association** | | |
| Yes | 5 | 25 |
| No | 15 | 75 |

Table 8 Source of income

| Source of income | Number of households | Proportion (%) |
|---|---|---|
| Other | 9 | 22.5 |
| Timber | 12 | 30 |
| Pension | 3 | 7.5 |
| Livestock | 8 | 20 |
| Government allowance | 2 | 5 |
| Food crop | 7 | 17.5 |
| Aquaculture | 40 | 100 |

4.2.2 Awareness of climate change and the importance of mangroves

Most interviewees in the four groups were aware that climate change is occurring in the province. Most mentioned that climate change phenomena were sea level rise, changes in precipitation patterns and temperature increase. While most interviewees were aware of climate change phenomena, there were differences in their perspectives on the level of impact of climate change on their production (Table 9). In both groups, 10% and 8% of households and companies, respectively, stated that climate change had no impact on their production. However, most companies stated that climate change did not greatly impact on their production. In contrast, most households confirmed that climate change had likely impacted (30%) or strongly impacted (25%) their production. Most farmers confirmed that climate change had likely impacted or strongly impacted their production. This result shows that farmers are more likely to support activities to reduce the impact of climate change, thus, they may strongly agree with the C-PFES scheme.

Table 9 Perception on impact of climate change and the importance of mangroves

| | **Stakeholder group** | **Unlikely (%)** | **Very slightly (%)** | **Slightly (%)** | **Likely (%)** | **Very likely (%)** |
|---|---|---|---|---|---|---|
| Perceived on the impact of climate change | Household | 20 | 15 | 55 | 60 | 50 |
| | Forest management board | 0 | 0 | 20 | 0 | 40 |
| | Company | 22 | 33 | 22 | 22 | 0 |
| | Local authority | 0 | 0 | 33 | 0 | 67 |
| Perceived on the importance of mangroves in climate change mitigation | Household | 20 | 25 | 35 | 10 | 10 |
| | Forest management board | 0 | 0 | 0 | 20 | 80 |
| | Company | 0 | 22 | 11 | 11 | 56 |
| | Local authority | 0 | 0 | 0 | 33 | 67 |

Results from Table 9 show that while this role of mangroves was repeatedly mentioned by local authorities (33%) and forest management boards (40%), it was rarely mentioned

by households (5%) and companies (12%). Very few households and company representatives had opportunities to participate in workshops or training programs where they could have obtained an understanding about the carbon sequestration role of mangrove forests. Most people in the latter two groups had not heard of mangrove blue carbon (Table 10). A small proportion of farmers and companies understand blue carbon and this will lead to challenges in implementing C-PFES. It is necessary to enhance their knowledge about blue carbon.

Table 10 Understanding about blue carbon

| **Stakeholder** | **Yes (%)** | **No (%)** |
|---|---|---|
| Household | 22.5 | 77.5 |
| Forest management board | 100 | 0 |
| Company | 16 | 84 |
| Local authority | 100 | 0 |

4.2.3 Willingness to participate in payment for blue carbon

Interview results of potential buyers showed that there were differences among the three groups in their willingness to pay for C-PFES (Table 11). Aquaculture production companies were the most supportive of paying for C-PFES (56%). Reasons given for their willingness to pay for C-PFES were as follows: government regulation (60%), securing current business (60%), and securing future business (40%). Some aquaculture production companies supported the implementation of C-PFES as they wanted to find opportunities to have organic certified products (20%). Furthermore, this was the only group who cared about the general environment with 20% willing to pay for C-PFES to protect the surrounding environment.

Nearly half (44%) of aquaculture processing companies were willing to pay for C-PFES mostly because it is government policy (75%). They also wanted to protect their current

business (50%) because their source of production (shrimps) strongly depends on mangrove protection. As shrimp export is the key product, 50% of these companies agreed to pay for C-PFES with a hope that they can have environmentally friendly certified products. About 25% wanted to polish their image to the general public by participating to protect mangroves. Only 29% of the charcoal production group were willing to pay for C-PFES - they explained that their production was not strongly impacted by climate change.

Table 11 Willingness to pay for C-PFES from potential buyers

| | **Category** | **Aquaculture processing company (%)** | **Aquaculture production company (%)** | **Charcoal production company (%)** |
|---|---|---|---|---|
| Willingness to Pay for C-PFES | Yes | 44 | 56 | 29 |
| | No | 56 | 44 | 71 |
| Reason for agreeing with C-PFES | Compliance with government regulations (Decree 99) | 75 | 60 | 100 |
| | Securing business | 50 | 60 | 50 |
| | Opportunity to have certified environmental products | 50 | 20 | 0 |
| | Contributing to protect general environment | 0 | 20 | 0 |
| | Other | 0 | 0 | 0 |

## 5. Discussion and conclusions

### 5.1 Mangrove restoration and climate change mitigation

Mangroves have a major role in C mitigation via the capacity to protect carbon stores and prevent emissions. They are one of the most carbon-rich ecosystems in tropical regions with extraordinarily high carbon stores. in comparison with the mean C storage of other major forest domains (Alongi 2012).

Carbon mitigation can also occur via restoration of previously deforested areas, and here the situation is less clear. Mangrove restoration programs in tropical regions provide the potential for C sequestration due to the ability to recover some historic C losses (Serrano et al. 2019). The amounts could be large and make significant contributions to global carbon mitigation efforts. For example, restoration of 10% mangrove loss in Australia (1150 $km^2$) would enhance soil C by 0.65 ± 0.46 Mt $CO_2$eq annually (Serrano et al. 2019). If the mangrove area in Vietnam was restored to the 1943 area (408,500 ha), this calculation based on Hieu et al. (2016), there could potentially be an annual rate of sequestration of 6 Mt $CO_2$eq. Globally, if coastal wetlands were restored to the 1990 area, the annual carbon sequestration would increase to around 160 Mt $CO_2$eq (Herr and Landis 2016). However, some of these estimates of restoration potential are confused by an understanding of carbon *storage*, based on millennial accumulation of carbon in mangrove ecosystems, and carbon *sequestration* which is based on the growth of mangroves and removal of carbon dioxide from the atmosphere. In addition, mangroves are associated with large amounts of soil carbon, but being in sedimentary environments, carbon can accumulate as a result of erosion and depositional processes.

The integration of mangrove restoration in existing economic activities, such as mangrove-shrimp farming, may generate a triple win solution in terms of environmental,

economic and social outcomes for local communities. Mangrove-shrimp farming has been termed “mangrove-friendly aquaculture” by some authors because it conserves mangrove forests (Luu 2000; Primavera et al. 2000; Udoh 2016).

However, mangrove restoration programs have not always been successful (Hai et al. 2020). Results from the research showed that although many mangrove restoration projects reported high survival rates (from 70 to 90%) in the short-term, most of them only achieved 30-50% survival rate, and sometimes 0% in the long-term. The results are in line with an assessment in the Philippines by Primavera and Esteban (2008) who concluded that long-term survival rates of mangrove restoration programs were from 10-20%; and with Kodikara et al. (2017) who found that success in restoration of 23 mangrove projects in Sri Lanka ranged from 0% to 78%, of which nine projects had no surviving plants after 5 years.

Key issues leading to failure of mangroves are the lack of long-term management of restored mangroves, lack of consideration of the soil and hydrologic conditions and stressors that caused the mangrove loss, inappropriate species selection and lack of incentives to engage local residents in the long-term management of restored areas (Hai et al. 2020). Resolving these issues is a priority in future mangrove restoration projects.

Currently, many mangrove restoration projects focus on emerging issues such as climate change mitigation and thus the main purpose of projects has focused on C sequestration by selecting mono-species to optimise growth rate and therefore maximize the C sequestration rate. However, monocultures can be risky due to loss from disease or environmental change over long-term periods as demonstrated in a mangrove restoration project in Senegal (Livelihoods Fund 2019). Additionally, mangroves will be susceptible to various components of climate change, including sea level rise and extreme events, thus projects will also need to account for these risks in project planning. Therefore, to

persuade donors to invest in mangrove restoration activities, and to achieve future success of projects, multiple benefits of mangroves should be included as an important outcome in project design and implementation.

### 5.2 Mangrove restoration for carbon mitigation in the local context

Although local communities understand the environmental roles of mangroves, they have limited knowledge about blue carbon and carbon markets, more generally. This is because C is an intangible and invisible service, and this makes it difficult to be defined and therefore is poorly understood in daily lives (Liverman 2009; Whitmarsh et al. 2011; Twyman et al. 2015). Additionally, since benefits of mitigation activities are uncertain, entail substantial lag times, and accrue at global rather than local levels, discussion by the public on GHG emissions and related mitigation actions has often focused on collective responses by government bodies and civil society (Schellnhuber et al. 2012). Thus, climate change is conventionally recognised as a large scale issue, and thus it is usually proposed to resolve issues through regional and/or national policy initiatives (Tang et al. 2010).

The limitation of local communities in understanding blue carbon, climate change mitigation, and carbon markets makes it difficult for C-PFES to be implemented at the large scale, especially as C credits are usually traded internationally. Thus, raising awareness for local communities is necessary for the implementation of C-PFES at the local scale. It is a critical issue and needs to be resolved as international and national scenarios take a big-picture approach and mostly overlook the fact that projects will need to be implemented locally.

While this study examined the feasibility of involving local emitters in payment for mangrove C, the role of international carbon markets in purchasing mitigation was not

explicitly considered. The scale of this activity is likely to be large, considering the amount of mitigation that will be required if the corporate and government sectors are to meet their 2050 emissions reduction targets. There has been some early activity in carbon projects. For example, 11,923 Plan Vivo Certificates (PVCs) have been certified for mangrove protection and restoration in Mikoko Pamoja, Kenya. Of these 9,880 PVCs has been paid by many organisations with a total payment of US$ 76,253 from 2014 to 2019 (Anne et al. 2019). Although not eligible for inclusion in international C markets, Verra, one of the main international carbon standards, has during 10 years since 2009 certified a mangrove restoration project in Senegal that has already sequestered more than 160,000 $tCO_2eq$ (Livelihoods Fund 2019). Understanding the feasibility of involving international donors in the payment for mangrove C in Ca Mau will be necessary to open opportunities for any payment schemes to be successful in the future. Additionally, the same issues are applicable in other provinces and regions where mangrove projects might be feasible.

The C mitigation benefits of mangroves are often over emphasised. For example, the Senegal mangrove restoration project has been considered to be successful with an initial prediction of 600,000 $tCO_2eq$ sequestration over its 20 year lifespan (Livelihoods Fund 2019). However, assessment of the project 10 years after implementation showed that there has been 160,000 $tCO_2eq$ sequestered since 2009 (Livelihoods Fund 2019). Thus, there may be an over-expectation of achieving the project target, as it is unlikely that rates of sequestration will greatly increase in the next decade.

Although there is an over expectation of mangrove C mitigation as a result of overestimating soil C sequestration, some standards, such as VCS have taken this into account and take a very conservative approach. While there are opportunities for mangrove C to join C markets with the involvement of soil C, it is noted that VCS does not allow allochthonous C to be included in estimates of site sequestration because it may

embed the risk to duplicate C sequestration accounted for adjacent ecosystems (Macreadie et al. 2019).

### 5.3 Policy suggestions

Results from the research showed that there is limitation of current policy on C-PFES in Vietnam which only focuses on C-PFES for provinces with high emission companies. In fact, it is feasible to implement mangrove C-PFES in provinces without high emission companies, such as Ca Mau province. However, it may difficult at the local level to implement C-PFES scheme with a weak commitment to participate from local buyers. Thus, the policy on C-PFES in Vietnam should be opened to broader potential buyers. If there are no buyers for C service of mangroves, this value remains theoretical within the constraints of the current arrangements. Alternative arrangements, such as treating emissions reductions at a national level and allowing cross-province investment in carbon mitigation projects, or allowing international entities to invest in emissions reduction projects, are important policy considerations.

A new pilot policy on payment for mangrove carbon should be tested in Ca Mau province because this scheme may supplement the current pilot policy on C-PFES in Vietnam, where forest owners in provinces without high emission companies have opportunities to receive payment from C-PFES programs. Additionally, C-PFES applied in Ca Mau Province may be more successful than other C-PFES pilots applied for terrestrial ecosystems. In theory, PES will be economically viable if local communities (PES sellers) are "fully compensated for forgoing profits that can be made through destructive environmental practices" (Thompson et al. 2017). However, synthesizing 44 PES programs worldwide, Hejnowicz et al. (2014) concluded that only 12% of PES programs provided sufficient income to meet household needs or generated an alternative income

stream. However, this report shows that mangrove C-PFES can provide both incentives from shrimp products and payment from selling C credits for local communities.

According to Primavera (2000), overlapping bureaucracies, policy conflict and weak law enforcement may result in a decline of quality and quantity of mangrove forests because many entities are responsible in managing the ecosystem. Thus, it is necessary to develop a clear collaboration between different government agencies (both at national and provincial levels) in C-PFES scheme (Fig. 3). In fact, the current pilot policy does not clearly mention the roles of other in-line government agencies, such as the Ministry of Natural Resources and Environment, and Ministry of Industry and Trade. In other PFES schemes implemented in Vietnam, these agencies are only involved in the project development steps, but they are not involved in the implementation steps leading to difficulties in monitoring and evaluation of PFES programs. For the C-PFES scheme, monitoring the level of emissions, and evaluation of the benefits for companies participating in C-PFES schemes will be important considerations.

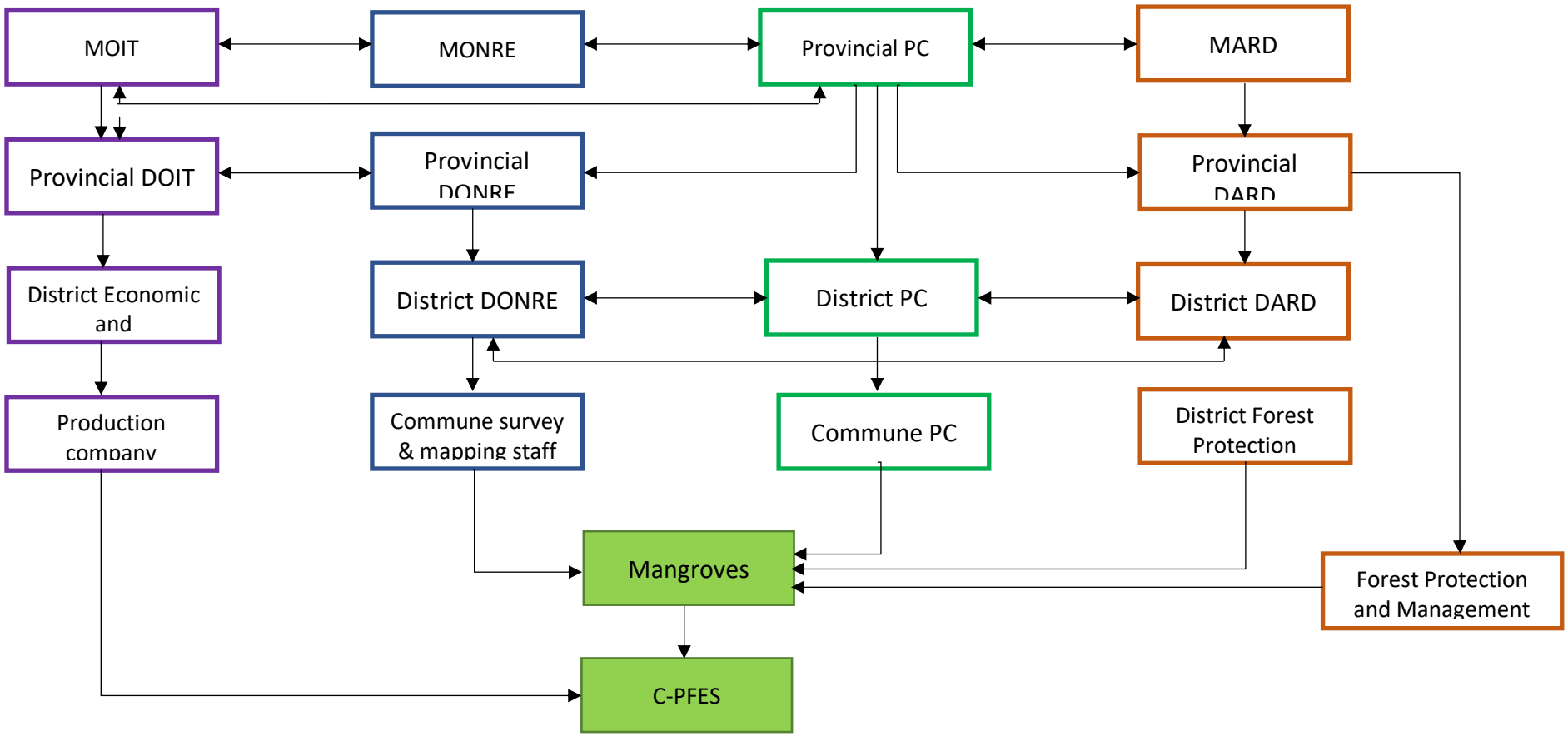


**Fig. 3** Institutional structure of C-PFES scheme in Vietnam
(MOIT: Ministry of Industry and Trade; MONRE: Ministry of Natural Resources and Environment; MARD: Ministry of Agriculture and Rural Development; DOIT: Department of Industry and Trade; DONRE: Department of Natural Resources and Environment; DARD: Department of Agriculture and Rural Development; PC: Provincial Committee

## 6 Concluding remarks

For the first time, this project has provided a broad picture of mangrove restoration in Vietnam under government and international sponsorship. The research results showed that although there has been a lot of effort for mangrove restoration in Vietnam (with total mangrove restored area of ca. 200,000 ha), many projects were unsuccessful. Research also analysed key reasons attributed to the failure and proposed solutions for future success of mangrove restoration projects in Vietnam.

Of the solutions for mangrove restoration projects, protection of restored areas while also ensuring local livelihoods is critical for long-term success. The report proposed to develop a mangrove-shrimp farming model to achieve sustainable development, including economic, environmental and social aspects. This model will create incentives for local communities in coastal regions to protect mangroves and avoid illegal conversion of mangroves to aquaculture land – the key reason for mangrove deforestation in Vietnam.

Mangrove restoration can generate important environmental services, including C mitigation which is an emerging product in current international agreements on climate change. This report investigated the feasibility to implement C-PFES in Ca Mau province, the province with important mangrove ecosystems but which is beyond the current policy of Vietnam in applying C-PFES.

This report is also a pioneer example on how carbon mitigation in forestry sector can be applied at local level in the context of international and national discussions. Results of the research areas are also relevant for other areas where mangrove are prevalent and communities are seeking opportunities to protect mangroves via C-PFES programs.

Although mangrove restoration promises to be an important approach for climate change mitigation, the report discussed the over emphasis on the capacity of storing a large amount of C from mangrove restoration projects, as well as the overall capacity of C sequestration by mangroves. This research provides a more realistic assessment of the role of mangroves in current C mitigation markets. However, mangrove restoration should be still encouraged because besides providing C benefits, mangroves will also generate co-benefits. Thus, mangrove restoration programs should be promoted not only for climate change mitigation, but also to include other values.

ANNEX 1. Summary interview questions for different types of shrimp farming practices in Ca Mau province

| | |
|---|---|
| 1 | General information: Socio-economic characteristics of households such as educational level, migration, economic status, sources of income |
| 2 | Current shrimp farming activities<br>*What types of shrimp farming systems do your family practise currently?*<br>*If there is integrated mangrove–shrimp farming system, what is the ratio of mangrove area per total pond area?*<br>*Has the ratio of mangrove area changed per total pond area over recent years? And why did you change the ratio of mangrove area per total pond area?*<br>*What ratio of mangrove area and total pond area do you think is the best for shrimp farming?* |
| 3 | Shrimp farming change over time<br>*Has the size of shrimp farm/number of shrimp farm/types of shrimp farm changed over the last 5 years? If yes, why did you stop the old shrimp farm system?*<br>*Are there any difficulties when you changed to the new systems? Please specify*<br>*Who advised you to change the old systems to the current (new) systems?* |
| 4 | Costs of shrimp farming activities<br>*Please provide information about initial costs of shrimp farming activity, including pond construction, guard house construction (small boat, net), other*<br>*Please provide information about annual costs of shrimp farming activity, including sediment removal, amendment costs, larvae (shrimp, crab, fish, other), food (for shrimp, crab, fish, other), labour costs (nursery, management), energy used (electricity, fuel), taxes (land lease), interests, supplement plantation (for integrated mangrove-shrimp farming)*<br>*Please provide information about harvest costs of shrimp farming activity, including harvest costs of shrimp (labour, equipment, other), harvest costs of forest products (for integrated mangrove-shrimp farming)* |
| 5 | Revenues of shrimp farming activities<br>*Please provide information about revenue from shrimp farming, including revenues from shrimp, crab, fish, timber, fuel wood, charcoal, others* |
| 6 | Changes in production over year and market of products<br>*Products of which farming system is easier to sell to the market? And why?*<br>*What is the trend of system's productivity over years? And main factors for those changes (such as pond area increase/decrease, technical changes, larvae quality, diseases)*<br>*What is the income trend over years? And main factors for income changes over year (such as pond increase/decrease; price increase/decrease)* |

ANNEX 2. Summary interview questions for feasibility to implement payment for mangrove service in Ca Mau province

| |
|---|
| 1. General information: General and personal information such as, name of respondent, age, education level, position in the company/organisation (if any), social economic characters (for farmers) |
| 2. Information on current activities<br>a. For potential seller<br>*Are you allocated mangroves for protection? If Yes, How many hectares?*<br>*What activities do you do to protect mangrove forests?*<br>*Do you receive any benefits for protecting mangroves?*<br>b. For potential buyer<br>*What is the main products of your company?*<br>*What is your company income?*<br>*What types of energy does your company use for production?*<br>*Do you think your production emit $CO_2$ to the environment?*<br>c. For intermediary (representatives of local authority)<br>*What is your administration role in the Department?*<br>*Does your Department regularly measure emission levels (for PDONRE, PDOIT)?*<br>*Does your Department promulgate any policies related to climate change mitigation? Please specify.* |
| 3. Awareness on climate change and environmental roles of mangroves<br>*Are there any climate change phenomena that have recently happened in the province? If "yes", please provide detail information*<br>*From what source of information, are you aware of climate change phenomena?*<br>*What are positive/negative impacts of climate change on your production?*<br>*In what level does climate change impact your production (from 1-no impact to 5-strongly impact)?*<br>*What are environmental roles of mangroves? Please specify.* |
| 4. Perspectives on payment for mangrove carbon service<br>*Have you ever heard about "blue carbon"? If Yes, from what source of information?*<br>*Do you know about the Decree No.99 on PES?*<br>*Are you willing to participate in the C-PFES scheme? What are reasons for willingness to pay?*<br>*How much are you willing to pay (for potential buyers)?**<br>*What are opportunities and challenges for the implementation of C-PFES (for local authorities)?*<br>*What is your additional responsibility when receiving payment from C-PFES (for potential sellers)?*<br>*What markets (national/international) should carbon credits be traded (for local authorities and potential buyers)?* |

**Note: *** For this question, 3% of buyers' profit was taken to set out different options (>3% of profit, <3% of profit). This was based on a study conducted by Do et al. (2018), where 5% of buyers were selected but for hydropower plants, water supply companies and eco-tourism companies that already had paid for PFES program in Vietnam. Since C-PFES is a new scheme, a lower payment of 3% is selected as being more reasonable.

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