

Community Mangrove Aqua-Silviculture (CMAS Culture): An Innovation and Climate Resilient Practice by the Sundarbans Mangrove Forest Dependent Rural Communities of Bangladesh

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Authors' contributions

This work was carried out in collaboration between the authors. Author MHK designed the study, collected the primary data through intensive field visits and questionnaire survey, analysed the collected data, write the draft manuscript. Author MAB supervised the whole research process, provided instruction for data analysis and edited the manuscript several times. Both authors read and approved the final manuscript.

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ABSTRACT

To adapt to the emergent global climate impacts, the local communities of Khulna, Satkhira and Bagerhat districts in South-Western Bangladesh have spontaneously promoted a number of social innovation using their innovative ideas and traditional knowledge. The present study highlights on this practice called as Community Mangrove Aqua-Silvi-Culture (CMAS) to cultivate some floral and faunal species of the Sundarbans mangrove ecosystem. CMAS is a plot of swampy land with 1 to 1.5 feet deep water bordered by a dyke of 0.5 to 1.5 feet height from the water level. The mangrove plant species in CMAS includes Goalpata (*Nypa fruticans*), Goran (*Ceriops tagal*), Keora (*Sonnerata species*), Hargoza (*Alanthus ilicifolius*), and Baen (*Avicennia Species*). Besides, there is a canal of about 2-2.5 feet depth that runs along the farm dykes where fish (Telapia, Vetki, Amadi, Tengra, Carps), shrimp (Bagda) and crabs are cultured. For in depth analysis of CMAS, face-to-face interview was conducted in 18 CMAS farms to know about the cultivation method, cost-benefit aspects, environmental and social impact of this unique culture. The farm owners opined that after 13 to 14 months of plantation, which is the shortest in comparison with traditional practice, *Golpata* and *Goran* can be harvested usually in January to February. On the other hand,

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farming seasonality of fish and shrimps varies species to species. However, most of the fish species can be harvested in between May to June in each year. Interestingly, CMAS culture doesn't need much care and maintenance costs. It is expected that the detailed analysis of CMAS will help the Sundarbans depended local communities more climate resilient.

Keywords: Bangladesh; climate change impacts; forest dependency; livelihood security; Sundarbans.

1. INTRODUCTION

Bangladesh has ranked sixth among those ten countries in the world those are the most vulnerable to climate change [1] due to a number of hydrological, geological and socio-economic factors [2]. Its geographic location is a flat delta with very low elevation and characterized by extreme climate variability. Seasonal monsoon causing acute temporal and spatial distribution of water, high poverty incidence and climate-dependent crop agriculture mainly make up the utterly volatile regime of vulnerability [3]. Climate change phenomena such as temperature rise, sea-level rise, erosion, precipitation and drought impact the primary variables like physical, biological and human systems of the country [3]. These, in turn, impact the secondary variables like aquatic, terrestrial and marine environments. However, the whole of Bangladesh is not equally vulnerable to climate change. The most climate change sensitive part of the country is the coastal region. To climate scientists, coasts are usually projected to be exposed to increasing risks climatic extreme events. IPCC AR4 [4] stipulates that the highly populated deltaic coastal areas in South, East and South-East Asia will be at the greatest risk due to increased flooding from the sea and the rivers.

The Government of Bangladesh (GoB) has already recognized coastal zone as areas of enormous potentials. In contrast, these areas are lagging behind in socio-economic development and vulnerable to different natural disasters and environmental degradation [5]. A number of hydro-geo-physical features like tropical geo-location, flat deltaic topography with sea-facing low elevation, mostly at sea level and unstable tropical atmospheric conditions have pushed the coastal territory of Bangladesh to extreme vulnerability of stronger disasters akin to cyclone, tidal surge, tsunami, beach erosion, and salinity intrusion. Exclusively, her coastal belt being funnel-shaped, most of the cyclones bred in the Bay of Bengal. With the increase of sea-surface-temperature resulting from unabated global warming helps spawn cyclones in the Bay, with

soaring rate of recurrence and intensity every year. Moreover, the prevalent socio-economic limitations like extreme poverty and less infrastructural development help reinforce casualty in any disaster crops up there. Hence, the coastal people very often have to face mayhem- massive loss of life, untold long-term sufferings, and damage of property and environment.

In Bangladesh, mangroves are located along the whole coast of the country. While previously extensive, they are now confined to the south-west Sundarban area and offshore islands [6]. The Sundarban mangroves are situated at the delta of three major rivers—Ganges, Brahmaputra and Meghna shared between Bangladesh and India. They form the world's largest single tract of mangrove ecosystem that in Bangladesh covers a core area of 5970 km², with a peripheral buffer zone of an additional 3640 km² [7]. The Sundarban mangroves, bordered by the Baleswar River to the east and the Harinbanga River to the west, extend up to shorelines of the Bay of Bengal to the south.

Biologically, Bangladesh Sundarbans holds rich and diverse life forms like 334 species of plant, 165 of algae, 13 of orchids, 315 of birds, 49 of mammals, 35 amphibian and 291 fishes [4]. Among the mangrove floral species, Sundri (*Heritiera fomes*), Keora (*Sonneratia apetala*), baen (*Avicennia officinalis*), Passur (*Xylocarpus mekongensis*), Goran (*Ceriops decandra*), Golpata (*Nypa fruticans*) are dominant ones. The world famous faunal species of the Sundarbans includes the Royal Bengal Tiger (*Panthera tigris*). Sundarban provides a range of provisioning services of food, timber, and other raw materials; regulating services of storm protection, erosion control and carbon sequestration; cultural services supporting tourism and recognized heritage; and supporting habitats important for local fishery and as nursery grounds for offshore ones [6,8-13]. Because of their strategic importance, the Sundarban mangrove was declared a forest reserve in 1878 under the Forest Act of 1865.

Despite the recognised importance and legal status, the Sundarban mangroves have been degrading at an alarming rate (Fig. 1) from conversion to shrimp farming, land reclamation, and over-exploitation for firewood and fisheries [6,14,15]. In Bangladesh, shrimp farming has expanded in the coastal areas, particularly at western region of the cost of local resources including artisanal fishing and forestry [16]. Besides, this region is increasingly exposed to frequent storm surges and cyclones [17], affecting human livelihoods, and security [4]. In the backdrop, for ensuring the very survival, the local communities have spontaneously

developed many adaptation measures in livelihood sectors including agricultural one employing their traditional knowledge and innovative ideas and started practicing them sporadically on smaller scale. Community-Based Mangrove Aqua-Silvi-Culture (CMAS Culture) is one of them. On the contrary, being motivated by very high price in both local and global market, many of the coastal communities have started shrimp cultivation on croplands taking away sea water by any means that has already started to have adverse impact on the local ecology, traditional agricultural practices and the Sundarbans.

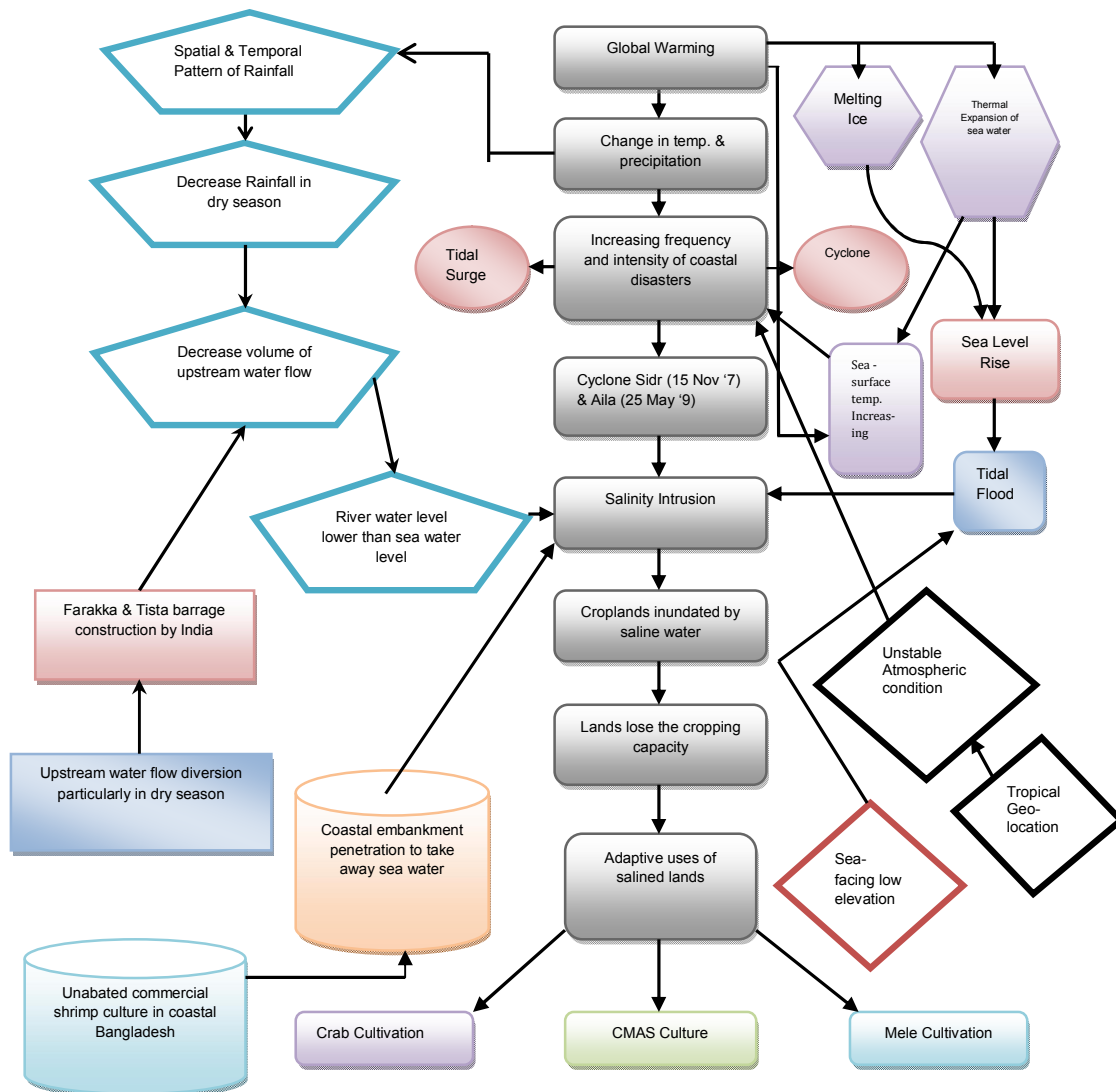


Fig. 1. Natural and anthropogenic drivers, impacts of and responses to climate change and salinity intrusion at coastal Bangladesh and their linkages

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Previous studies have documented the status and use of ecosystem services provided by Sundarban mangroves [6,8,9,10,12], but few have quantified those services and estimated their monetary value [18,13,19]. However, there is a significant research gap in exploring the innovative initiatives taken by the Sundarbans dependent local communities towards climate resilient and sustainable practice. Therefore, this study was aimed at to explore the status, cost-benefit analysis and environmental sustainability of CMAS culture practice in the South-Western coastal area of Bangladesh.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted on two upazila (Fig. 2) of two coastal districts. They include Koyra Upazila of Khulna District and Assasuni Upazila of Satkhira District. The upazila is hemmed in on the north by Paikgacha upazila, on the east by Dcope upazila, on the south by the Bay of Bengal and on the west by Assasuni and Shyamnagar upazilas of Satkhira District. Administratively, Koyra Upazila was first established as *Thana* which came into existence on 4th April, 1980 and has been upgraded to

upazila in 1983. It is said that the Upazila has been named Koyra after the name of the old village where the union and the upazila headquarters are located. The administrative units of the upazila include 7 unions, 72 mauzas and 131 villages.

The total population of the upazila stands at about 165,473 where male is 49.68 percent and female is 50.32 percent. Population density is about 861 per sq.km whereas growth rate is 1.7 percent per year. The religious composition is Muslim 74 percent, Hindu 25.35 percent, and others 0.36 percent [20].

The second largest of eight upazilas of Satkhira District in respect of area is Assasuni which is situated to the north-east of the district occupying an area of 402.36 sq. km. The geographical location of the upazila lies in between from 22°21' to 22°40' north latitudes and from 89°03' to 89°17' east longitudes. The upazila is enclosed on the north by Satkhira Sadar and Tala Upazilas, on the east by Paikgacha and Koyra upazilas of Khulna District, on the south by Shyamnagar upazila and on the west by Debhata and Kaliganj upazilas.

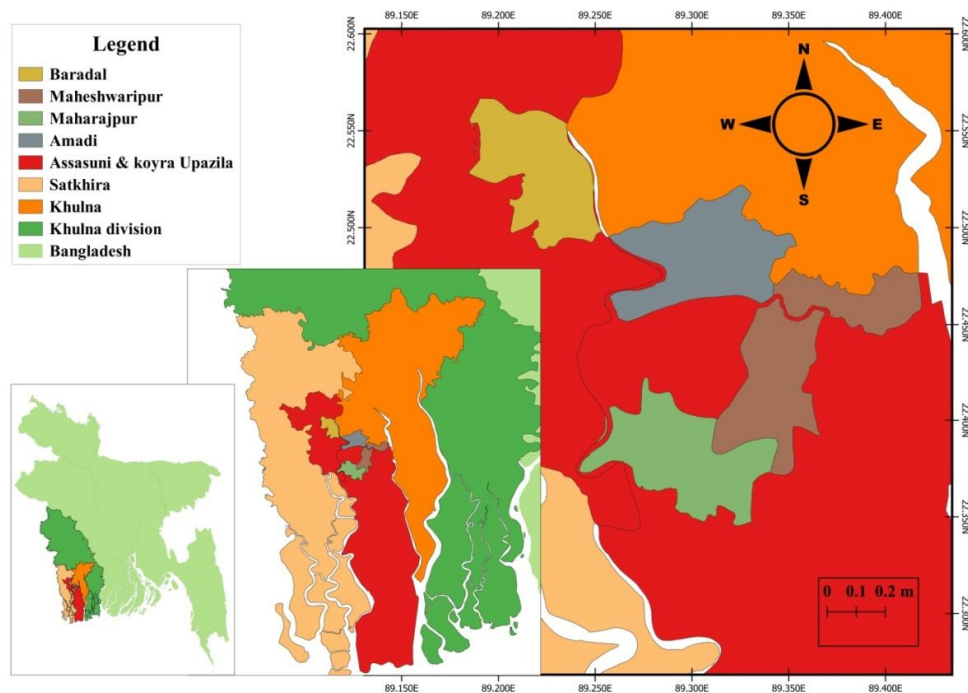


Fig. 2. Map of the study area

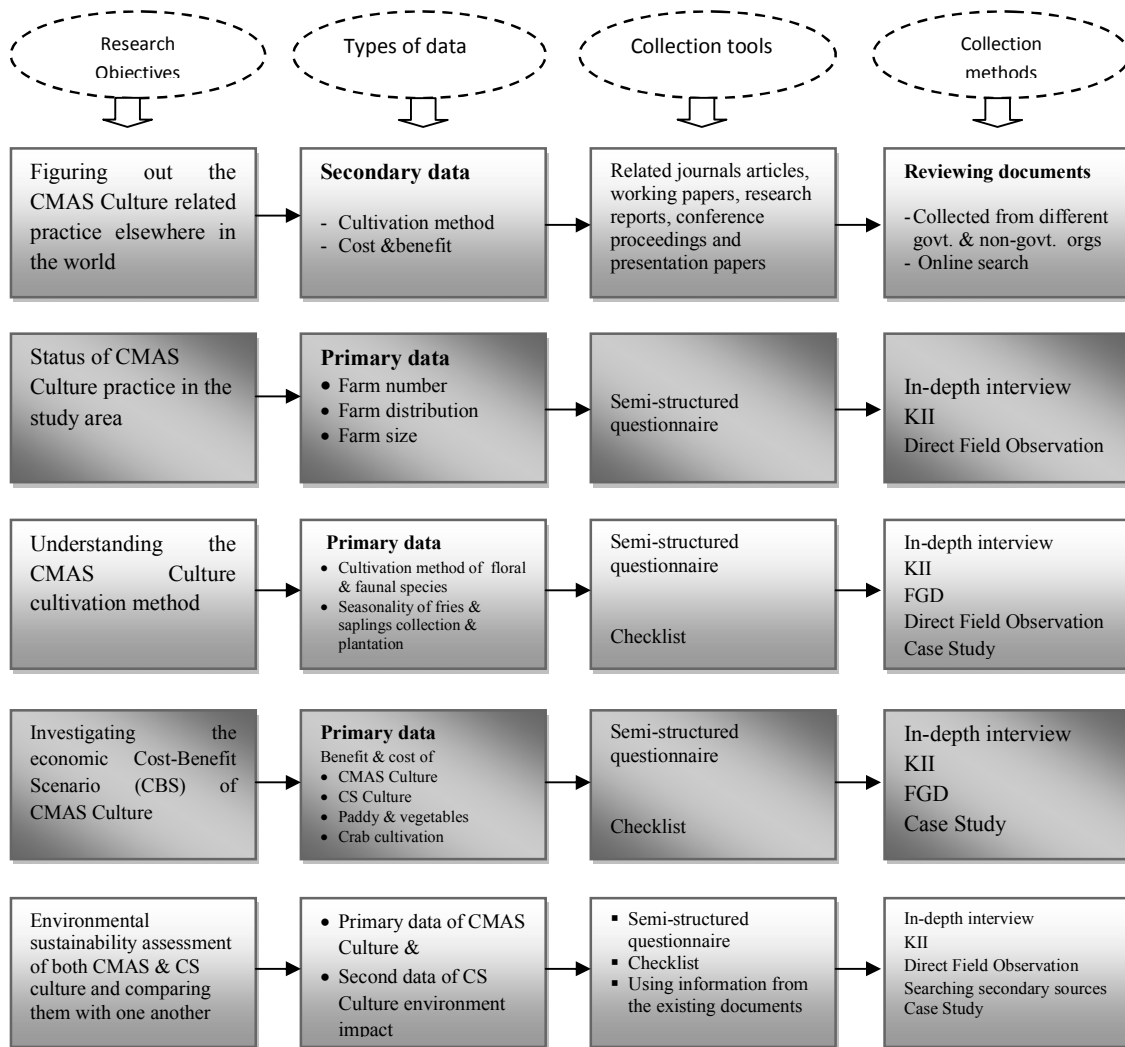


Fig. 3. Framework of data types, collection tools and techniques for each of the objectives of the study

2.2 Primary Data Collection

2.2.1 In-depth interview

Individual in-depth interview has played the vital part as a data collection tool in the present study which has virtually used census method. In the study area (two upazilas), a total of 18 CMAS Culture farms have been found. All of the farm owners were valued respondents of this study who have been accordingly brought under in-depth interview process to have clear concept about everything related to CMAS Culture in particular cultivation method, cost-benefit scenario, environmental and social impact of the culture. Again, to compare the CMAS Culture with its other competing uses like commercial shrimp culture, crab cultivation and even with

paddy and vegetables cultivation. With this purpose, in-depth interview of 5 farm-owners from each of these cultivation types have been accomplished. All the in-depth interviews have used semi-structured questionnaires. In addition, data collection from the respondent has been a continuous process in this study as communication is made with them over telephone when necessary.

2.2.2 Focus group discussion

A group of 10 members including the CMAS Culture farm-owners and the age-old people of the local community having vast experience as to local hydrology, geology and geomorphology and mangrove species cultivation have been taken for the focus group of the present study. An in-

depth discussion has been conducted with them using a checklist. It was interesting that on each issue, the group members were initially divided in their opinions but finally they would come up with an indifferent response. Besides, Group Discussion (GD) also conducted with each of the community associations to discern their experience and perception of CMAS Culture at three unions of Koyra Upazila, Khulna. Furthermore, two case studies with comprehensive field observation were also conducted.

2.2.3 Secondary data collection

An inadequate amount of information was garnered from secondary sources of data as relatively little exists relating to the present study. However, secondary data have been collected from books, journals, working papers, conference proceedings and research reports of different govt. organizations, national and international NGOs which deal with community-based adaptation measures to hazards and disasters in coastal Bangladesh and elsewhere in the world. On the whole, a careful look at the documents of international conferences of Community Based Adaptation (CBA) has been accomplished.

To achieve different objectives of the study, various types of data were collected in a wide variety of methods using diverse tools (Fig. 3).

3. RESULTS AND DISCUSSION

3.1 Definition of CMAS Culture

In south-western coastal region of Bangladesh particularly in some parts of Khulna, Satkhira and Bagerhat districts, have been trying to cultivate a few floral and faunal species of the Sundarbans mangrove ecosystem on lands, early utilized for other purposes like agriculture, using fresh or brackish water available over the past decade. The present study is dealing with this practice and has termed the practice as CMAS Culture that stands for Community Mangrove Aqua-Silvi-Culture.

The study has also made an initiative to provide an operational definition of CMAS Culture-the definition around which the whole study revolves and focuses. However, CMAS can be defined as follows—

'CMAS Culture refers to the practice of integrated cultivation of some mangrove faunal species such as crabs, oyster, fishes

(Shrimps, Pershe, vetki, Tengra, Baila, Telapia etc.) and floral species, for instance, Golpata, at the same time on any swampy land of brackish water.'

3.2 CMAS Culture Related Practice: Global Scenario

Literature review from different sources such as referred journals, books, conference proceedings, seminar presentation papers, working papers have been searched and reviewed to know whether any practice as like as CMAS Culture exists in any part of the Earth. The review of the available literature reveals that not exactly as CMAS Culture rather related practices exist in some parts of the south-east Asia. These are briefly discussed below:

3.2.1 Practice of integrated mangrove forest and aquaculture systems in Indonesia

In Indonesia, the integrated practice of mangrove plants and aquatic species is called *Silvofishery*. There are two basic silvofishery models used in Indonesia. One of the models consists of mangroves within the pond with a ratio of 60-80 percent mangroves and 20-40 percent pond canal for aquaculture. This is called *Empang Parit* in Indonesian language. The rest one consists of mangroves outside the pond with similar mangrove to water ratio. There are a variety of designs within these basic models. The *Silvofishery* farm ranges in size from one hectare to thousands of hectares at each site. The fact is that this integrated silvo-aqua-culture is practiced in the mangrove area. It represents the greatest level of reforestation or maintenance of existing forest.

Farm construction in Empang Parit: The farm consists of an unexcavated central platform that alternates between being flooded and exposed and a canal that runs along the pond dikes where fish, shrimp, and crabs are cultured. The density of mangrove trees planted in the platform ranges from 0.17 to 2.5 trees per m². The mangrove density influences the quantity of litter production and organic load. These in turn have an impact on the diversity of non-mangrove flora and fauna growth that may form an important part of the diet of cultured species. The mangrove tree density also influences the type of aquaculture. Farmers may opt for less dense mangroves for fish culture (e.g., 0.2 trees per m² for milkfish) but not for shrimp and crab culture because these species prefer the shelter afforded by

mangroves. The individual farmers operate silvofishery ponds varying from 1.5 to 10 ha.

Cost-Benefit Ratio: Farmers in Indonesia earn an average gross income of US\$580 per ha per year (range = \$313-946). The net profit averages \$356 per ha per year. The figures suggest greater production effort per unit area by farmers with smaller farms.

Disadvantages: The *empang parit* model has a number of disadvantages compared to the brackish-water open pond. These are: (a) greater construction cost per unit area, (b) greater difficulty to manage, (c) reduced water circulation and greater potential for stagnant areas with low oxygen levels, (d) limitation on species cultured (e.g., seaweed would be shaded by trees, reducing growth), (e) mangrove trees reduce the penetration of sunlight to ponds lowering the productivity of phytoplankton and benthic algae, (f) potential toxicity of tannin from mangroves. The selection of the most appropriate *Silvofishery* model will be site-dependent and influenced by the status of the mangrove ecosystem.

3.2.2 Practice of integrated mangrove forest and aquaculture systems in Philippines

In Philippines fishing villages are located in arable land plains along fringes of coastal lines. Sea is the main resources base of the villages. Adjacent to or near to the villages there are also large areas of tidal flats where mangroves have naturally developed. These areas are very much potential for aqua-mangrove integrated farming. The tidal flats with mangroves are also utilized for the culture of mud crabs which can provide the fishing communities with alternative livelihood option or source of additional income. In enhancement planting, horizontal branches of old trees are pruned to create an opening to permit sunlight enough to nourish young plants [23].

3.2.3 Practice of integrated mangrove forest and aquaculture systems in Vietnam

Integrated mangrove-aquaculture farms are usually found at Camau Province of Vietnam. On each farm, forest cover accounts for approximately 60-80 percent of the total land area and the remaining 40-20 percent comprised of aquaculture canals (average: 3 m wide 0.3-0.7 m deep) and levees. Each farm is operated by traditional mixed forest-aquaculture. It is a tidal sluice gate fishery based on both natural shrimp

recruitment and stocking of black tiger shrimp and mud crab. Natural shrimp recruitment and harvest occurred, every 15 days, on consecutive flood and ebb tides for 4-5 days and nights of the spring tide period.

On the flood tide, the sluice gate is opened for 3-6 hrs and shrimp post larvae (PL), juvenile shrimp and fish swim through the mesh of a bag net positioned in the sluice gate (mesh approximately 1.5-2.5 cm) into the pond while adult shrimp (mainly *Metapenaeus ensis* and *M. lysianassa*), mud crab and fish (mullet, rabbit fish, tilapia) are caught in the bag net. Following recruitment, the sluice gate is closed and once the tide turns, the gate is reopened and the canal system partially drained on the ebb tide with shrimp and fish caught in the bag net. Following recruitment and harvesting the sluice gate is closed for 10 days during which time the recruited aquatic species have a grow-out period of 10-14 days before the next recruitment/harvest.

Average price per kilogram mud crab from the extensive system was fixed at VND 50,000 kg-1. The local market price for crabs fluctuated considerably and is highly seasonal dependent with price peaks during the Chinese New Year (January/February) and the Lunar Festival (September). For the extensive system a sum of VND 500,000 crop-1 mainly covers costs in relation to canal excavation. The annual productivity of the two systems varied significantly: extensive system 137 kg ha⁻¹ yr⁻¹

3.2.4 'Tambak' system in Indonesia

The *Tambak* System combines rice paddy production with finfish and shrimp aquaculture. The fish and shrimp are reared in the paddy fields after the rice has been harvested. The constructed dikes, which usually protect the paddy fields from the incoming tides, are intentionally breached after rice harvest so that sea water can enter at high tide. Larval fish and shrimp are captured and reared to maturity. After the fish or shrimp are harvested, the fields are re-prepared for the next rice crop. This production system traces its roots back many hundreds of years, and may be one of the earliest forms of aquaculture practiced in Asia [21].

3.2.5 The *Gei Wai* system in Hong Kong

Another traditional aquaculture system evolved in Hong Kong, perhaps centuries ago. *Gei Wai*

basically utilizes the positive attributes of natural mangrove forests as nursery and breeding grounds for fish, crabs, mollusks, and shrimps. Wide channels, around 1-3 m in depth, are excavated around what becomes a small island of healthy mangrove forest.

The channels allow the several hectares or more of each Gei Wai pond to hold sufficient waters at low tides to sustain the captured shrimp and fish. At high tides renewed sources of nutrients enter the ponds through constructed sluice gates to sustain pond life anew. Up to 1900 kg of shrimp can be raised and harvested annually from one Gei Wai.

In the mid-1990's, there was only one remaining area of Hong Kong, called Mai Po, which borders Deep Bay, where gei wais were still found. These few remaining gei wais are protected as a nature reserve by the Hong Kong Government. Mai Po continues to serve as an important site for long-distance migratory birds and wildlife.

The World Wide Fund for Nature Hong Kong has managed this site since 1984, utilizing the sale of its harvested shrimp to help subsidize the expenses involved in site management. One of the greatest recent threats to the Mai Po reserve and its gei wais is the intrusion of mounting water pollution from mainland China. Fish and shrimp varieties and populations have already declined.

3.2.6 Community mangrove Silviculture in Thailand

Ban Chi Mee village is located in Kapoe District, Ranong Province of Thailand. Since 2005, the villagers of Ban Chi Mee, Ban Dan and Ban Bang Lam Poo have been actively managing 686 rai of mangroves for the community to use. The community that uses the mangroves made up of approximately 210 households from the three villages: Ban Chi Mee (150 households), Ban Dan (30 households), and Ban Bang Lam Poo (30 households). They used the resource for collecting fish, crabs, and they collect mangrove wood for household building use.

After the tsunami in 2005, these three villages decided to work together to conserve the mangroves because they noticed growing environmental problems and declining resources. A series of charcoal concessions were granted by the government to private investors to cut down the mangroves. Several times a year the community does management activities, for

example mangrove plantation days on father's and mother's day. The community participates very actively in these activities, and plantation days typically draw about 80% participation from the community. The community also runs a mangrove nursery with ten varieties of mangroves. Seedlings are sold for five baht each and profits made from the nursery cover most of the mangrove management costs (petrol for boats, transport to network meetings etc). The community also manages a *Nypa* forest within the mangroves, where they plant and harvest *Nypa* to sell as thatching [22].

3.3 An Overview of CMAS Practices in Bangladesh

The commencement of the combined cultivation was merely motivated by the curiosity of a few local innovative minds and the practice was on very small scale. Accordingly, expectation of having a good harvest from the practice was not a reality at all. Rather they intended to examine the possibility of cultivation. When the farms started yielding beyond expectation, the pioneering farmers added further attention and care to farming. Still the CMAS Culture is seemingly confined to three coastal districts of Khulna, Satkhira and Bagerhat. Particularly over the last decade, CMAS Culture practice has perceptibly spread over three upazilas of the districts mentioned thereof including Sharankhola Upazila of Bagerhat, Koyra Upazila of Khulna and Assasuni Upazila of Satkhira although the practice is not evenly distributed across the upazilas. Yet, it is to be mentioned that the practice of CMAS Culture is on the rise with the passage of time as it has been already emerged as one the more profitable cultivations the coastal vulnerable have ever practiced in Bangladesh.

3.3.1 A profile of CMAS culture practice in the study area

3.3.1.1 Farms distribution in the study area

It is earlier mentioned that the study area consists of two adjacent upazilas from two contiguous districts—one is Koyra Upazila from Khulna District and another is Assasuni Upazila from Satkhira District. In the study area, CMAS Culture has manifestly covered only four unions including three (Maharajpur, Amadi and Maheshwaripur) from Koyra Upazila and one (Borodol) from Assasuni Upazila. Again, whole of the unions don't experience the cultivation. Two

villages (Naksha and Harinagar) from Amadi Union, two villages (Maheshwaripur and Khorja) from Maheshwaripur Union, one village (*Motbari*) from Maharajpur Union and one village (Jamalnagar) from Borodol Union have come under this culture. Therefore, an aggregate of only six villages (out of 373 ones) of four unions (out of 18 ones) from two upazilas have CMAS cultivation at present.

3.3.1.2 Farm size and number

In the study area, there were a total number of 18 farms of CMAS Culture. The size of all the farms of the study area aggregates about 338.5 decimals. Average farm size is about 18.81 decimals. Farms' variation in size is sky-scraping because the size of the largest farm is 49.5 decimals whereas the smallest farm is only 1 decimal. The study reveals that about more than 50 percent of the farms are very small in size particularly within 10 decimals whereas only 21 percent farms are of large size varying from 40 to 70 decimals. The main cause behind the small size of the farms is that the locals are yet to take the cultivation seriously and still they didn't start practicing the culture with commercial purpose as the study implies.

3.3.1.3 CMAS culture in Koyra & Assasuni upazila: A comparative discussion

Koyra and Assasuni Upazila vary widely from one to another in terms of CMAS Culture practice. The field survey divulges that Koyra upazila possess about more than 79 percent of the total number of CMAS Culture farms whereas Assasuni Upazila owns only 20 percent of the total farms. Interestingly, the size of around 80 percent of the farms owned by Koyra Upazila amounts to only about 33.33 percent of the total farms size that ultimately indicates that the farms owned by Assasuni are much bigger in size than those held by Koyra.

Water availability all the year round is a precondition for undertaking this farming. The study discloses that the farms of Assasuni Upazila which are very big are on alluvial lands located along rivers and receive water supply from the river almost all the year round. On the other hand, most of the farms in Koyra Upazila are homestead surrounding shallow ditch-based.

3.3.1.4 Site selection

Site selection for farm development is one of the most important issues in CMAS Culture. Soil and

water are the main considerations in the site selection process in CMAS Culture. The study makes known that the lands of yielding, mud-spattered and water-logged soils with all time availability of brackish or fresh water access are selected by farmers as sites for CMAS Culture farm development. In the present study, the most of the farms are located by the coastal rivers which always contain water and moreover periodically derive water from the rivers. The rest ones are located at homestead adjoining ditches.

3.3.1.5 Species selection

Species selection mainly depends on the water quality of the farm site because all types of mangrove floral and faunal species can't survive or grow well in freshwater body. Again, there are some freshwater species of fish, molluscs and crustaceans which can't be cultivated in brackish water farm. According to the study, for the fresh water farm, Goalpata, Bagda and Horina shrimp, Tengra, Telapia, Khorkono and the like are usually selected. On the contrary, for brackish water farm mangroves like Goalpata, Keora, Goran, Baen and mangrove fish like Golda, perse, vetki, mudcrab and so on are usually opted for cultivation.

3.3.1.6 Farm construction

CMAS farm is a plot of swampy land with 1-1.5 feet deep water bordered by dyke of 0.5-1.5 feet height from the water level (Fig. 4). There is an unexcavated central platform that usually remains flooded. The mangroves including Goalpata, Keora and the like are planted on the platform. Besides, there is a canal of about 2-2.5 feet depth that runs along the farm dykes where fish, shrimp and crabs are cultured.

The field survey has experienced only one type of model in the study area where the farm consists of a plot of swampy land with 1-1.5 feet deep water bordered by dyke of 0.5-1.5 feet height from the water level. There is an unexcavated central platform that usually remains flooded. Sometimes, mostly during dry season, the platform exposes. The mangroves including Goalpata, Keora and the like are planted on the platform. Besides, there is a canal of about 2-2.5 feet depth that runs along the farm dykes where fish, shrimp and crabs are cultured (Fig. 5). According to 100% of the respondents (farm owners), the farms usually hold water all the year round and hence they don't need to supply water to the farming ponds.

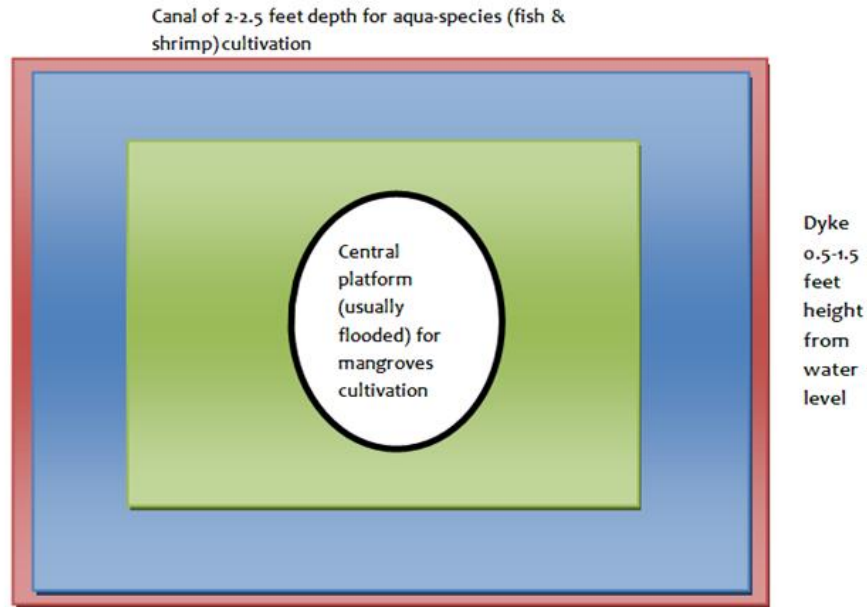


Fig. 4. Model of CMAS culture farm



Fig. 5. A Farm of CMAS culture in the study area

3.4 Cultivation of Mangrove Trees

Goalpata (*Nypa fruticans*), Goran (*Ceriops tagal*), Keora (*Sonnerata species*), Hargoza (*Alanthus ilicifolius*) and Baen (*Avicennia Species*). Among them, the most common and dominant mangrove plant species cultivated in the CMAS Culture farms include the Goalpata followed by Keora.

3.4.1 Seed collection

About 50 percent of the CMAS Culture farm owners collect mangroves saplings from the nearby riverbank areas or from Khulna Port

adjacent areas whereas 30 percent farm owners gather the mangrove seeds floating in the river water carried by tide. Another 18 percent farm owners collect seeds from the forest when they go for mangrove resources extraction. Only two percent farmers buy mangrove saplings from the market or commercial nursery. The seeds of all relevant mangroves have to be collected from July to August. For the maintenance of the mangrove plant seedlings, Bamboo made fencing, seeds and seedlings need watering daily in the morning. Even prior to introduction in hardening beds, seeds require use of tap or brackish water. The seed beds should be

weeded out at an interval of time as necessary to keep the seedlings away from competition for survival. Daily inspection should be ensured to protect the seedlings from the attack of insects and pests.

3.4.2 Plantation in the farms

In the nursery, over a period of 1-1.5 month, the seedlings experience a minimum height of 1.5-2 feet when they are planted at the central part of the farm. The general planting season starts in August and ends in September. The density of mangrove trees planted in the platform varies from farm to farm depending on the farmers' preference on mangroves cultivation or fish cultivation. The mangrove density usually ranges from 0.5 to 1 tree per sq. meter. This is because the farmers impose preference on both mangrove and aquaculture equally. To encourage the establishment of the seedlings, at least 10–12 cm of the seedlings should remain above the water level.

3.4.3 Care and maintenance of the mangroves

Use of chemical fertilizer like urea and phosphate helps to have a very good harvest. To a greater extent, fencing is a must where livestock like cow, goats and sheep are reachable as they are fond of eating Goalpata leaves. Besides, if they can intrude into a CMAS Culture farm, they may cause a great harm destroying saplings and tender shoots of Goalpata. Bamboo and ropes are the main fencing materials for mangroves protection. The main concern to mangroves cultivation is that they are sometimes attacked by viral diseases. Use of insecticide and pesticide can protect them well.

3.4.4 Harvesting

After 13 to 14 months of plantation, Goalpata and Goran can be harvested and processed for sale in the market all the ones need minimum 5 years to be ready of harvest whereas *Possur* requires the lengthiest period of time as like as more than 8 years. In case of *Goalpata*, the season of harvesting is January to February as new shoots begins growing in March. *Goalpata* is cut at an angle of 45° angle and the other mangrove trees in the farms are cut at 180° angle. After completion of all the steps (Fig. 6), CMAS culture provides the following ecosystem services:

Provisional services:

Goalpata: House roofing, fencing, basket, bags, firewood, rope, edible fruits, hat, mat,

rain coat, alcohol, medicinal use (Vermicide, analgesic), Fishing, transport fuel
Keora: Cot, Fuelwood, showcase, chair, fencing, table, roofing, ceiling, house column
Hargoza: Fuelwood
Possur: Cot, Almirah, Showcase, Ceiling, House column, chair, table, roofing
Baen: Fencing, Box, Roofing, Cot, Fuelwood

Regulating services

Carbon sequestration, protection from land and riverbank erosion

Supporting services

Acting as wind barrier, provide breeding ground for aquatic species, Biodiversity conservation

3.4.5 Economic cost and return

Yearly average gross income from per *Bigha* mangrove cultivation yields about BDT 56250 whereas total cost only amounts to BDT 1800 leaving a net benefit of about BDT 54450 Accordingly, the ratio of cost-benefit equals to 1:32.

3.5 Aquatic Species Cultivated in Farms

The shrimp species include Bagda while the fish species encompass *Telapia* (94.44%), *Perse* (88.89%), *Vetki* (33.33%), *Amadi*(27.78%), *Tengra* (27.78%) , *Carps* (27.78%) and *Datony* (22.22%).

3.5.1 Seasonality of farming

Farming seasonality of fish and shrimps in the CMAS Culture farms varies from species to species. Fries release period of all fish and shrimp species in the farm is mainly confined to February from December of every year. Similarly, harvesting season is almost the same with a slight variation and mostly confined to June from May. This is because almost all the fish and shrimp species spawn fries at the same period. Besides, from late May on ward, there is very high probability of tropical cyclone coupled with tidal surge and tidal floods. If any of the catastrophes occurs, fish and shrimp of the farms wash away leaving a huge loss for the farmers. This is why, in most parts, fish and shrimps are harvested before the hitting of natural disasters mentioned thereof (Table 1).

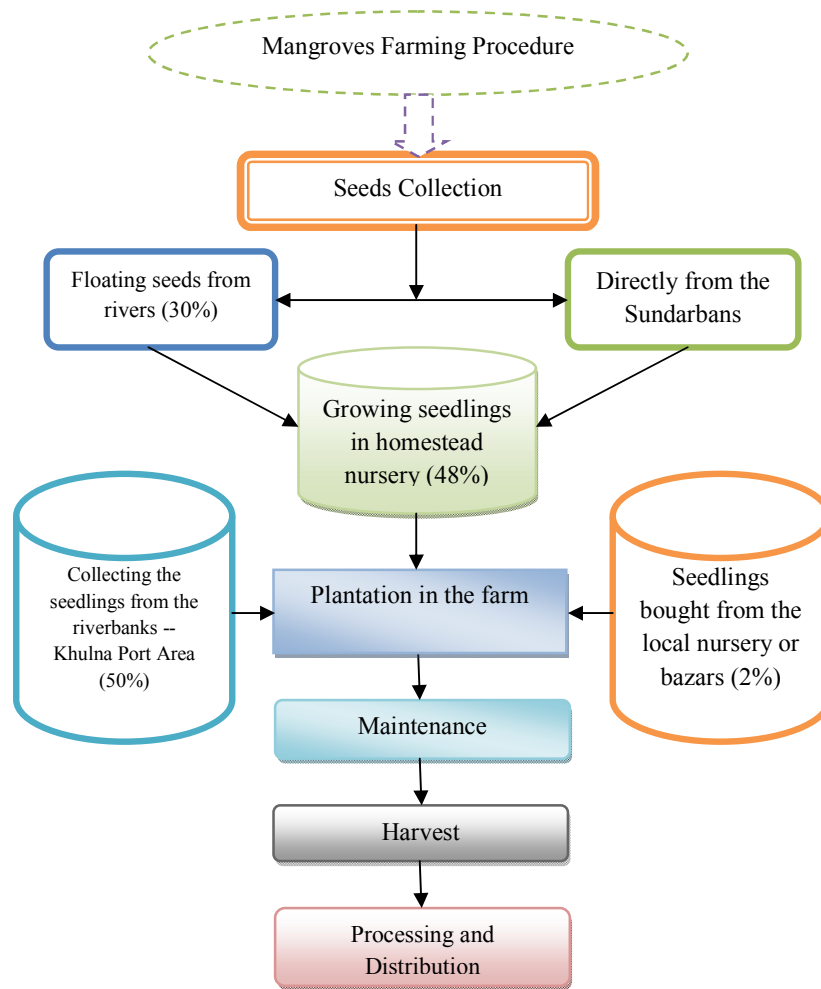


Fig. 6. General farming procedure of the mangroves in CMAS culture

Table 1. The Farming seasonality of the fish species cultivation

Name of fish	Period of fries release	Fish harvesting period
Telapia	December	April-May
Parse	February	May
Bagda	February	June
Vetki	February	May
Amadi	January	May
Tengra	February	May
Carp	December	August
Datony	February	June



Fish species in brackish water farms
 Fish species in fresh water farms

3.5.2 Care and maintenance

Aqua-farming (Fig. 7) in CMAS Culture doesn't need as much care and maintenance as other types of farming requires. Care and maintenance of this farming is very simple and therefore, it needs a minimum amount of money. Farm water

doesn't essentially need to be exchanged at a particular interval of time. Water is changed at any time when it becomes easily possible. The shrimp and fish usually live on natural feeding during the entire grow out period. Yet, feeding and chemical fertilizers application ensures better yields. The chemical fertilizers which are

usually found to use in the farms include Urea and Phosphate. Shrimp and fish feeding are available to buy. The best home-made feeding for fish is rice bran. In the study area, most of the farmers depend on natural feeding and hardly use chemical fertilizers in their farms. The farms need to be recurrently patrolled so that no intruders can catch fish and shrimp and cut the mangroves. From time to time, the farm dykes require to be heightened as they face lowering with the passage of time. Generally, initiative is hardly made to for fencing the farms. Isolated farms essentially need to be fenced where there is a probability of a considerable degree of theft of fish and shrimps. Fencing materials usually include bamboo, jute stalks, ropes and sometimes nets. In some exceptional cases, the fish and shrimps are attacked by viral diseases that need the use of medicines and insecticides. Care continues until they grow to market size. The study reveals that on an average care and maintenance of the aqua-farming yearly cost about BDT 5000 per *Bigha*.

3.5.3 Harvesting

The Table 1 shows that almost all the fish and shrimps need 3-4 months for their maturity to a marketable size. In fact, harvesting and releasing follow a cycle. Partial harvesting of marketable shrimp commences just following the initial stocking with fries. From the frequent field visits, it was found that, all of them, the shortest and the longest period fish species include *Perse* and *Carp*s respectively.

3.5.4 Economic cost and return

Calculation of cost and return in monetary term plays a crucial role in taking any decision on climate change adaptation practice. Therefore, this research made efforts to uncover the cost and return scenario of aqua-farming part of the CMAS Culture practiced in the study area. According to the field survey it was revealed that community-based mangrove mangrove-aqua farming is a highly profitable practice. Yearly average gross income from per *bigha* aqua-farming yields was about BDT 1, 83, 000 whereas the total cost only amounts to BDT 14,750 offering a net benefit of about BDT 173250. Accordingly, the ratio of cost-benefit equals to 1:12.

Again, expressing in percentage, if we consider the gross economic return as 100 percent, the total cost only equals to seven percent accounting about ninety three percent of gross

income as net income. Beyond doubt the net profit is very high in comparison to other practices. A few factors have acted behind the emergence of this lucrative profitable practice. This practice includes very low care and maintenance cost, highly dependency on natural feeding of fish and shrimp and limited use of chemical fertilizers. Another most important factor is minimum labor cost. CMAS Culture farms need patrolling all day and even at night. Generally, self-labor is employed in this sector and the labor cost is not calculated in monetary value that lowers the total cost greatly. Besides, much of care maintenance cost is shared by both segments of CMAS Culture including Community Mangrove Aqua-farming (CMA) and Community Mangroves Cultivation (CMC).

Again, yearly average gross income of all the aquatic species cultivated in the CMAS Culture is widely varied from one species to another. The Fig. 8 shows that the major contributors to the gross average yearly income of CMS include Bagda, Golda, Perse and Vetki whereas, an individual species, the highest yearly income is derived from Bagda cultivation which is followed by Vetki. The percentages that Bagda and Vetki possess in terms of covering the total farming area are 66.67 percent and 33.33 percent respectively whereas their contributions are highest and second highest to the gross yearly income from CMA. On the other hand, *Telapia* and *Perse* cover about 94.44 percent and 88.89 percent respectively and their contributions to gross annual income of CMA include about fourteen and below five percent correspondingly.

The fact that the study has uncovered behind the reverse relationship of total farm area coverage and contribution to gross income in case of *Telapia* and *Perse* is that the cultivation cycle of Bagda and Vetki are comparatively short and market price is very high. The price of per kg *Telapia* normally ranges from BDT 100-180 whereas the price of per kg market price of Bagda ranges from BDT 550-900. According to Bangladesh Statistical Pocket Book-2010, the market price of Bagda shrimp is BDT 560/kg. This is because of Bagda is the second highest exporting goods and *Telapia* is local marketable goods.

3.5.6 Present value of cost (PVC) and present value of benefit (PVB) of CMAS culture

The opportunity cost of capital is the return that would be received if the funds presently in

investment were invested in the private sector (say in a business or in the bank). Bank interest rate in agricultural sector usually ranges from 8-12 percent. Hence, finding the PVB and PVC of CMAS Culture, ten per cent discount rate is taken into account.

In the CMAS Culture, the total cultivation cost (BDT 16550) is incurred at the beginning of the project ($t=0$), but the benefits (BDT 239,250)

arise one year later, after the cultivation cycle is finished ($t=1$). The calculated Present Value of Benefits (PVB) at ten percent discount rate was BDT 2,17,500 whereas the present value of costs was BDT 16,550. Therefore, the net benefit is BDT 200950. At a discounted value, the net present value of benefit is BDT 202,454. Considering the present value of benefit and cost, the Benefit-Cost Ratio (BCR) of CMAS culture in Bangladesh is 13.14.

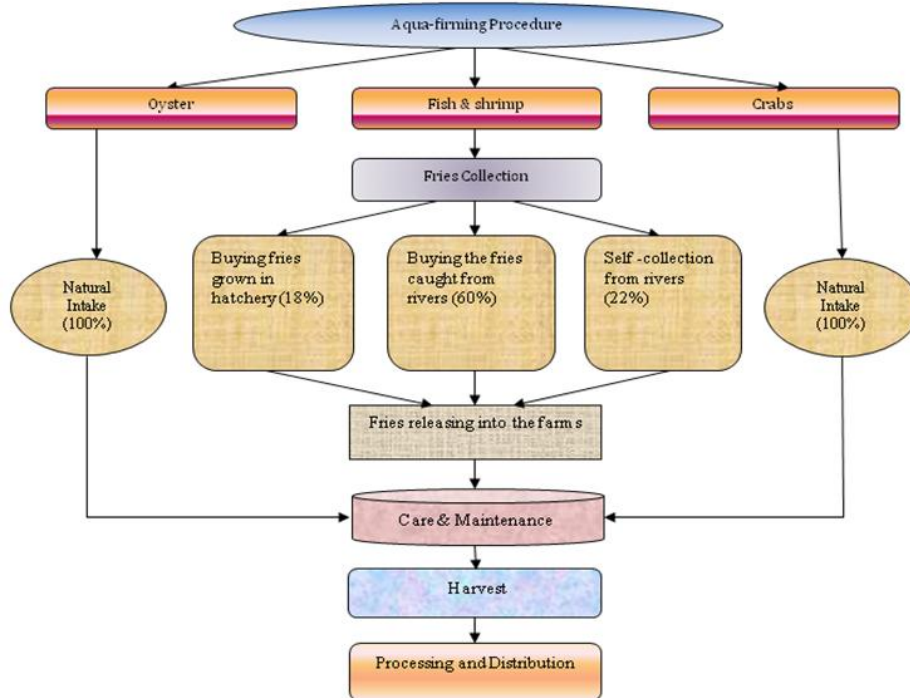


Fig. 7. Production cycle of aquatic species in CMAS farm

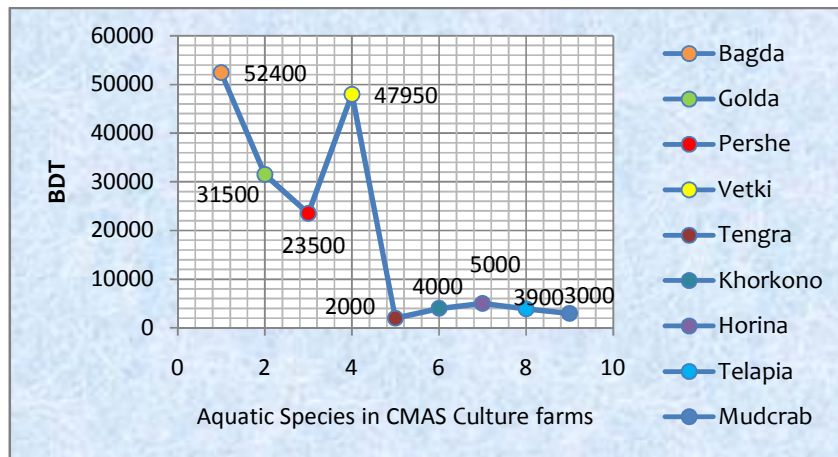


Fig. 8. Species-wise average yearly gross income from mangrove cultivation (Per Bigha)

Table 2. The cumulative gross income from the CMAS culture

Year	Aquaculture	Goalpata	Goran	Keora	Hargoza	Baen	Possur	Value (BDT)	Cumulative value (BDT)
1 st	✓							183000	183000
2 nd		✓	✓					22750	205750
3 rd				✓				50000	255750
4 th					✓			30000	285750
5 th						✓		60000	345750
6 th								-	345750
7 th								-	345750
8 th							✓	80000	425750

4. CONCLUSION

The Sundarbans dependent local people has been innovating different adaptation practices against the climate change impacts. Consequently, the objective of this study was to gain an insight into the actual condition of the Community Mangrove Aqua-Silvi Culture (CMAS) presently practiced in some villages of the Koyra Upazila of Khulna District and Assasuni Upazila of Satkhira District in Bangladesh. The findings of the study show that CMAS culture is more economically profitable and socially acceptable than other practices. Given the physiographic and socio-economic conditions coupled with vulnerabilities and disasters statistics of the coastal region, CMAS culture deserves to be recommended as one of the best coastal adaptation practices. The CMAS culture practice is still in the subsistence level not in the intensive or commercial farming in nature.

The environmental problems associated with shrimp farming have been widely reported throughout the period of 1990s. Bangladesh have been suffering from environmental degradation including; increased salinity of soil, canals and ponds within dams; reduction in grazing land and a consequent reduction of livestock; destruction of mangrove forest, adverse affects on the potential crop-mix, cropping intensity, crop calendar and overall cropping pattern in the shrimp growing areas [9]. Therefore, CMAS culture is one of best social innovation by the climate vulnerable but forest-dependent coastal communities of Bangladesh. The findings of the study will play a vital role for the policymakers to take further actions to build a climate-resilient society in Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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