Managing Mangrove Dominated Muddy Coasts through Integration of Local and Scientific Knowledge in Kien Giang, Vietnam and Brebes, Indonesia

Thesis submitted by
NGUYEN Tan Phong, M App Sci (JCU)

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College of Science and Engineering
James Cook University

Townsville

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ABSTRACT

The literature showed that local knowledge and scientific knowledge, when integrated adequately and properly, produce enormous benefits for natural resource management in comparison to the different knowledge systems being applied independently.

Muddy coasts, characterised primarily by fine-grained sedimentary deposits, have been over-exploited or increasingly made vulnerable to climate change, storm surge, and sea level rise. Both scientific knowledge and local knowledge systems have been used in mangrove dominated muddy coast management. Both systems, each having advantages, have had limited success in mangrove dominated muddy coast management, with a low level of local involvement, and minimal integration of the different knowledge systems. A question is whether or not sustainable management of mangrove dominated muddy coasts can be sustainably managed by integration of local and scientific knowledge with a high level of participation.

The overall aim of this research is to identify mechanisms for integrating local and scientific knowledge for managing mangrove dominated muddy coasts in a sustainable way. The mechanisms identified address the adverse effects of climate change using sustainable management of mangrove dominated muddy coasts, while protecting local livelihoods. The field research was undertaken in Kien Giang, Vietnam and Brebes Regency, Indonesia between May 2013 and May 2016. The research applied mixed methods (survey methods and participatory action research methods) to achieve the overall aim. The term ‘scientific knowledge’ as used in this thesis is scientific understanding of coastal dynamics, published sources of information, the results of the previous studies in Kien Giang Province, and conventional practices or management policies issued by government agencies. Local knowledge is built up over generations by those living near the site in question.

The mixed method approach contributes greatly to developing a more complete picture of human activities and coastal management, thereby, achieving research goals in a timely manner.

Scientific understanding was use to systematically collate, link and justify local knowledge for investigating the relationship between human activities and coastal erosion. Improper technical guidance on the configuration of mangrove allocations, mangrove

protection and afforestation methodologies, and permitted thinning and selective harvests led to the creation of substantial gaps and disconnections in the established mangroves, making the entire coastline vulnerable to coastal erosion and degradation. Poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels, although not recognised locally as significant contributors to coastal erosion, have jeopardised the structural integrity of the mangroves and contributed to coastal erosion. The interaction of anthropogenic activities and physical processes are significant contributors to erosion. In the second case, local knowledge was brought together with relevant scientific knowledge into developing ecologically based, cost effective strategies for successfully controlling coastal erosion in Kien Giang Province, Vietnam. Ecologically based and cost-effective strategies included seven different types of Melaleuca fences, a method of gradual expansion with ten treatments constructed gradually over time and ecological mangrove restoration using five local mangrove species for transplantation.

Developed from the results and conclusions from the research activities in Kien Giang, a six stage practical framework adds a new dimension to the literature in relation to the integration of local and scientific knowledge in natural resource management. While the integrated knowledge was a new knowledge in the current integration frameworks and was made available for local use, in the framework proposed in this research, detailed consideration of the successes and failures in relation to the application of the product of different knowledge systems in the local context provides new knowledge, adding to the production of different knowledge systems. In addition, the integration framework promotes a high level of integration of local and scientific knowledge, local ownership, and sustainability that are the ultimate objectives that development projects are seeking, and assists in overcoming the challenges facing the current management strategies for managing mangrove dominated muddy coasts sustainably.

The framework was applied in Brebes Regency, Indonesia for investigating its current strategies for managing mangrove dominated muddy coasts. Inefficient nursery operation, wrong choice of mangrove species, improper afforestation techniques, and poor coastal protection measures contributed to limited success in coastal erosion control in Brebes.

Inadequate monitoring and evaluation of coastal protection program resulted in significant challenges for further mangrove afforestation. Lessons from the mistakes were not learnt, leading to failures being repeated and ineffective management of the eroding muddy coasts in Brebes.

Likewise, the results of the previous chapters and the practical framework were applied for developing sustainable management of mangrove dominated muddy coasts in Kien Giang and Brebes. In Kien Giang, sustainable management of mangrove dominated muddy coasts in Kien Giang is guaranteed using the current 30/70 mangrove allocation policy and developing and implementing technical guidelines for allocated and private mangrove areas. The 30 (use) /70 (protection) configuration of mangrove areas for allocated mangrove areas and the 70 (maximum use) / 30 (minimum protection) for private coast lands in Kien Giang, if undertaken properly, would assist significantly in establishing a continuous mangrove belt along the Kien Giang coastline. In Brebes, the strategic plan for establishing a continuous mangrove belts for adaptation to climate change and livelihood protection includes restoration of abandoned ponds, stabilisation of two delta areas, and configuration of active ponds at a ratio of (at most) 80 % (on the landward side for aquaculture activities) / (at least) 20 % (on the seaward side for voluntary mangrove establishment). Although not ideal, twenty percent is the minimum that the communities were willing to designate to voluntarily establish mangrove areas for protection.

In summary, the research achieved successfully the overall aims and objectives and reasonably answered the research questions. Significantly, the framework developed in this research provides theoretical and practical contributions to the literature regarding the integration of local and scientific knowledge in natural resource management. The framework contributes to overcoming the challenges that development projects face, and also contributes to developing sustainable management processes for the mangrove dominated muddy coasts of Kien Giang, Vietnam and Brebes Regency, Indonesia.

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CHAPTER 1[1]

INTEGRATION OF LOCAL AND SCIENTIFIC KNOWLEDGE AND MANAGEMENT OF MANGROVE DOMINATED MUDDY COASTS

This chapter first overviews local and scientific knowledge systems and their integration in the natural resource management discipline. Current strategies for mangrove dominated muddy coasts are then critically reviewed to understand the effectiveness and levels of integration of local and scientific knowledge in each strategy. The overview and the critical review result in knowledge gaps in sustainable management of mangrove dominated muddy coasts being identified. The research's overall aim, questions, and objectives are developed to overcome the knowledge gaps identified for improving management of mangrove dominated muddy coasts in the future.

1.1. Local and scientific knowledge systems and their integration in natural resource management

Human knowledge systems are composed of two types: formal scientific and traditional (Rahman 2000). Formal scientific knowledge is explicit, codified, and more easily transmittable (Rahman 2000). Traditional knowledge is also referred to in some situations as indigenous or local knowledge (Rahman 2000; Food and Agriculture Organization 2005). Local knowledge is based on experience, often tested over centuries, adapted to local culture and environment, dynamic and changing, but seldom documented (Warren & Rajasekaran 1993; Nakashima et al. 2012). It plays an important role in decision making in agriculture, education, and natural resource management at the local level. It also provides the basis on which strategies for problem solving are developed for local communities (United Nations 1992; World Bank 1998). Because of its importance, this type of knowledge has been officially and repeatedly acknowledged as a fundamental basis for developing natural resource strategies in many of the agendas of United Nations conventions (International

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Panel on Climate Change (IPCC) 2007; IPCC 2010 a; IPCC 2010 b; United Nations Convention on Climate Change 2010).

Traditional ecological knowledge, another form of traditional knowledge, integrates knowledge, practices and beliefs that are tested over time and transferred from one generation to another (Johannes 1989; Berkes 1993; Berkes et al. 2000). Local ecological knowledge, a broader definition of traditional, indigenous or native ecological knowledge, is the cumulative body or system of shared knowledge and understanding by local resource users in regard to environmental factors and ecological dynamics (Davis & Wagner 2003). Local ecological knowledge has three attributes: a) a shared system of knowledge and understanding of the environment; b) development through direct experience within a specific physical setting; and c) transmission through generations (Davis & Ruddle 2010). There are various examples of applying local ecological knowledge into coastal and fisheries management. Local ecological knowledge was used to develop strategies for conservation and research of the Goliath grouper (*Epinephelus itajara*) and spawning aggregations in the South Atlantic Ocean of South Brazil (Gerhardinger et al. 2006). This type of knowledge was used as knowledge building for the benefit of managing marine protected areas in Brazil (Gerhardinger et al. 2009), and has been included in fisheries plans for better fishery management in New Zealand (Hill et al. 2010). It was also used to inform the determination of ecologically and biologically significant areas for inshore coastal management in Nova Scotia, one of eastern Canada's maritime provinces on the Atlantic (Bundy & Davis 2013).

Not all scientific knowledge is always applicable to local communities (McDougall & Braun 2012), while local knowledge provides a fundamental basis for developing natural resource strategies (United Nations Convention on Climate Change 2010; United Nations 1992; World Bank 1998). The integration of local and scientific knowledge into sustainable natural resource management is not new. History has clearly shown many successful interactions between western scientific understandings and local knowledge for interpreting ecological systems (International Council for Science and UNESCO 2002; Nakashima et al. 2012). Examples include scientific knowledge and knowledge of fishers, integrated through a fuzzy logic expert system and computer programs to enhance a proper understanding of the spatial dynamics of herring shoals (Mackinson 2001); the use of GIS integrating traditional knowledge and scientific knowledge in supporting artisanal fisheries management in southern Brazil (De Freitas & Tagliani 2009); sustainably managing isolated semi-arid papyrus swamps in Loboi, Kenya through a combination of local ecological knowledge and management practices (Terer et al. 2012); and integration of knowledge through the use of the fuzzy logic and geographic information system technology to gain reliable information for managing soil salinity in the lower Amudarya river basin in Uzbekistan (Giordano & Liersch 2012).

The integration of local and scientific knowledge produces two obvious benefits for environment management. One benefit is to help corroborate scientific data and fill the gaps of scientifically generated data (Scholz et al. 2004). The other is that scientific knowledge is used to test causation that aims to complement local knowledge (Moller et al. 2004). However, the integration is inherently complicated, and faces a number of challenges. Difficulty in applying integrated knowledge for sustainable environmental management has been recognised as one of the major challenges (Raymond et al. 2010; Ericksen et al. 2005). The integration needs processes that are problem solving, systematic, reflexive and cyclic in considering different views (Raymond et al. 2010), and with true public participation (Stojanovic et al. 2004; Charnley et al. 2007; Cliquet et al. 2010; United Nations 2012).

1.2. Management of mangrove dominated muddy coasts and the integration of local and scientific knowledge

1.2.1. Introduction to muddy coasts

Muddy coasts, often centres of human settlement and commerce (Mann 1988; Lotze et al. 2005), have been negatively impacted by human and natural factors. A muddy coast is defined as ‘a sedimentary-morphodynamic type characterized primarily by fine-grained sedimentary deposits - predominantly silts and clays - within a coastal sedimentary environment. Such deposits tend to form rather flat surfaces, and are often, but not exclusively, associated with broad tidal flats’ (Wang et al. 2002 b, p. 9). Muddy coasts are often associated with the following physical environments: tidal flats, enclosed sheltered bay deposits, estuarine drowned river valley deposits, inner deposits of barrier-enclosed lagoons, supra-tidal (storm surge) deposits, swamp marsh and wetland deposits, mangrove forest and swamp deposits, chenier plains, mud deposits veneering eroded shore platforms, ice-deposited mud veneer, and sub-littoral mud deposits (Wang et al. 2002 b).

Muddy coasts, especially in Southeast Asia have been over-exploited for agriculture, aquaculture, industry, and settlements (Han 2002; Primavera 2006; Ramesh et al. 2011). This over-exploitation has caused adverse direct and indirect impacts on muddy coasts (Valiela et al. 2001; Bhandari & Nakamura 2004; Thampanya et al. 2006; Ramesh et al. 2011; Siple & Donabue 2013; Anthony et al. 2014). These impacts have caused loss of important coastal habitats, breeding grounds for both marine and terrestrial animals, vegetation, and have caused erosion (Han 2002; Thampanya et al. 2006; Ramesh et al. 2011). Erosion can also be caused when there is a deficit of sediments delivered to the coast from major rivers. The deficit is frequently caused by construction of large reservoirs built on major rivers, resulting in reduced discharge and suspended sediment load. As a consequence, coastal erosion is accelerated and wetlands are not properly renewed, thereby exacerbating the vulnerability of the coastline (Fan et al. 2004).

The world's coastlines, including muddy coasts, have become increasingly vulnerable to climate change, especially sea level rise (IPCC 2007; IPCC 2010 a; IPCC 2010 b). The morphodynamics of muddy coasts can be impacted by storm surges and typhoons on high tides, and strong onshore winds (Bao & Healy 2002). One of the main impacts is erosion. Erosion occurs when muddy coasts are eroded by removal of surficial mud on the upper tidal flats because of stronger currents (Wells et al. 1990) or by transportation and re-deposition of sediments on the outer sectors of the tidal flats by storm surges and typhoon-generated waves (Wang et al. 2002 b; Lee et al. 1994). Coastal erosion can be caused by sea level rise (Asian Development Bank 2010). Erosion of muddy coasts in places has caused significant economic loss, ecological damage and social unrest (Ramesh et al. 2011).

1.2.2. Approaches to managing mangrove dominated muddy coasts

Both published materials and technical reports were critically reviewed to understand past practices for the management of mangrove dominated muddy coasts. The world's coastlines, including muddy coasts, have been managed with similar broad strategies: administrative coastal management and planning techniques, technical approaches, and integrated coastal zone management techniques (Kay & Alder 2005).

Literature was classified into two categories: local knowledge based approaches and science based approaches in relation to the content and methods being used. The classification was undertaken using thematic analysis (Ayres 2008 a). The categories were then critically reviewed to understand their effectiveness, and levels of integration of local and scientific knowledge in the categories.

The term 'scientific knowledge' as used in this thesis is scientific understanding of coastal dynamics, published sources of information, and the results of the previous studies in Kien Giang Province. Local knowledge is built up over generations by those living near the site in question. Local knowledge is often individually owned.

1.2.2.1. Local knowledge based approaches

Local knowledge based approaches promote the use of local knowledge in management and planning of mangrove dominated muddy coasts. These approaches can be community based mangrove projects or use mangrove co-management models.

- Community based mangrove projects:

In community based mangrove projects, local communities are involved in managing mangroves for livelihood improvement, especially in areas where mangroves have been degraded or lost. Under direct supervision of local government agencies or international donor agencies, the majority of community based mangrove projects aim to promote the well-being of community members as the primary objective and mangrove protection as a secondary goal (Datta et al. 2012). Community based mangrove projects have been common in many coastal countries such as Cambodia (Bann 1997), Sri Lanka (Wattage & Mardle 2007), and Tanzania (Wells et al. 2010). In community based mangrove projects, often funded by international non-governmental organizations, local involvement has often been limited to consultation and information provision in the planning processes. Frequently, management plans and work plans have been prepared by project recruited consultants using information regarding local issues from discussions or interviews with local communities, and implemented locally by local communities (Anderson et al. 2012). The use of this technique has the advantage of integrating local knowledge, beliefs, traditions and customary practices into local management and planning to promote feasible and effective coastal management (Kay & Alder 2005). This technique cannot be fully functional until communities are actively engaged and adequately consulted (Kay & Alder 2005).

- Co-management models

Co-management is joint management of shared properties or a shared power arrangement between the government and resource users (Carlsson & Berkes 2005). Co-management is a problem solving process, where relevant stakeholders work in partnership to solve resource management problems. Examples of co-management projects may be found in many parts of the world (Tuyen et al. 2010; Carr & Heyman 2012; Liberty et al. 2012; Mathew et al. 2013). Based on participatory processes with negotiated agreements between government and community, co-management assists local government agencies in fulfilling their duties, gives greater power to local communities in managing coastal resources (IUCN 2010), and provides local communities legal access to (non-timber) forest products in return for co-management of mangroves and mangrove dominated muddy coasts (GIZ 2014).

Although significantly contributing to socio-economic development in local communities, co-management cannot be fully functional until communities are actively engaged and adequately consulted (Kay & Alder 2005). One main challenge is how independent this technique can be without legal and financial support from governments at all levels (Kay & Alder 2005). In addition, using the framework of Pretty (1995)[2], in

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[2] ***Seven types of participation by Pretty (1995):***

1) **Manipulative participation**: Participation is simply a pretence, with 'people's' representatives on official boards, but who are unselected and have no power.
2) **Passive participation**: People participate by being told what is going to happen or what has already happened. It involves unilateral announcement by an administration or project management without any listening to people's responses. The information being shared belongs to external professionals.
3) **Participation by consultation:** People participate by being consulted or by answering questions. External agents define problems and information gathering processes, and so control analysis. Such a consultative process does not concede any share in decision making, and professionals are under no obligation to take on boards people's views.
4) **Participation by material incentives:** People participate by contributing resources, for example, labour, in return for food, cash or other material incentives. Farmers may provide fields and labour, but are involved in neither experimentation nor the process learning. It is common to see it called participation. Yet people have no stake in prolonging technologies or practices when the incentives end.
5) **Functional participation:** Participation seen by external agencies as a means to achieve project goals, especially reduced costs. People may participate by forming groups to meet pre-determined objectives related to the project. Such involvement may be

community based projects, local participation in planning is generally limited to information provision (level 2), or being consulted (level 3), while local participation is about providing resources, for example labour in return for livelihoods (level 4), in the co-management models. It means that local knowledge approaches have faced two key challenges for their full functionality, namely limited and inadequate local participation in planning processes, and sustainability.

1.2.2.2. Science based approaches

Science-based approaches were subdivided into four main themes that include specialist knowledge tools, establishment of coastal mangrove protected areas, integrated muddy coastline management, and strategic policies for managing mangrove dominated muddy eroding coasts.

- Specialist knowledge tools

Specialist knowledge tools use conceptual, analytical and numerical models, and inventory methods (mapping, data acquisition techniques using high quality imageries) to understand muddy coastal fine sediment dynamics, muddy coastal processes, and resource management.

In muddy coastal fine sediment dynamics, representative studies of hydrodynamics, sediment budgets, primary production, nutrient fluxes, and mineralisation, sediment transport, and sediment geochemistry include Bass et al. (2007); Chant (2011); Ameura et al. (2013); Stokes & Harris (2015); Todd et al. (2014); and Xu et al. (2015). Key studies of muddy coastal processes (properties and classification of muddy coasts, geographic

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interactive and involved shared decision making, but tent to arise only after major decisions have already been made by external agencies. At worst, local people may still only be coopted to serve external agencies.

6) **Interactive participation:** People participate in join analysis, development of action plans, and formation or strengthening of local institutions. Participation is seen as a right, not just the means to achieve project goals. The process involves interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes. As groups take control over local decisions and determine how available resources are used so they have a stake in maintaining structures or practices.
7) **Self-mobilisation:** People participate by taking initiatives independent of existing institutions to change systems. They develop contacts with external institutions for resources and technical advice they need, but retain control over how resources are used. Self-mobilisation can spread if governments and NGOs provide an enabling framework of support. Such self-initiated mobilisation may or may not challenge existing distribution of wealth and power.

distribution of muddy coasts, biochemical factors influencing deposition and erosion, natural biological processes and controls) were Delafontaine et al. (2000); Wang et al. (2002 b); Healy (2002); Simenstad & Yanagi (2011); Karditsa et al. (2014); and Sun et al. (2015). Leading studies of effects of human and natural factors on muddy coasts (resource management) included Han et al. (2000); Wang et al. (2000); Zhang & Wang (2000); Bao & Healy (2002) Anthony et al. (2014).

The tools are laboratory based or inventory driven. Despite being useful tools for specialists working in the field of muddy coast management, they may not encourage community participation, or integrate traditional knowledge, and culture. There are also challenges in determining how the data and information from these tools are retrieved and processed, and integrated into decision making processes (Stojanovic et al. 2010).

- Establishment of coastal mangrove protected areas

Coastal mangrove protected areas have been established to protect mangroves and muddy coasts from erosion and other climate change effects (Schmitt & Duke 2015), or to legally protect a range of coastal and marine biodiversity such as mangroves, corals, sea grasses, and benthic organisms (IUCN 2008). These protected areas are normally classified as ‘no take’ zones or strictly protected areas, with interventions in these protected areas needing permission from the relevant government agencies.

The establishment of protected areas can be compared with the technique of administrative coastal management and planning proposed by Kay & Alder (2005). The first advantage is that by using this technique, governments are able to improve the management of muddy coastal areas by encouragement, through force, or through the application of research and information. The second advantage is ensuring that proper coastal management and protection is undertaken within specified timeframes and with provided resources (Kay & Alder 2005). However, this technique does not promote active participation by affected stakeholders, especially local communities. Local participation is generally limited to providing information, with people passively participating in the development process, being ‘educated’, or by involuntarily complying with what is a top-down technique (Pretty 1995).

- Integrated muddy coastline management

Integrated muddy coastline management practices can be used to protect marine and coastal protected areas, and coastal mangrove protected areas. This type of management contains comprehensive lists of interactions legally required to effectively manage these protected areas in a holistic and integrated way for conservation and prudent local use of natural resources, in support of sustainable development (IUCN 2008). In these frameworks, specialist knowledge tools are technically used to clarify links between human activities and changes in natural systems. Procedural steps are put in place to promote local consultation and participation in managing muddy coasts in a way that balances demands for socio-economic development with needs for coastal protection for effective and efficient adaptation to climate change, and sea level rise (Ruhl & Craig 2011; Feka 2015). Integrated muddy coastline management shares many similarities with shoreline management planning as reported in a range of contexts (Department for Environment, Food and Rural Affairs (DEFRA) (2006); Jakobsen et al. (2007); Harty (2009); Albers et al. (2013); de Jong (2011), and integrated coastal zone management (World Bank 1996). The main challenges for implementation of this type of management are insufficient policy clarity and political will, weak science, and poor coordination with stakeholders and communities (Schmidt et al. 2013), and insufficient community participation in land use planning, especially on private coastal lands (Nguyen 2015 c).

- Strategic approaches for managing eroding mangrove dominated muddy coasts

Strategic approaches, that are established to manage mangrove dominated muddy coasts that were eroded, include engineering solutions, ecological engineering solutions, managed realignment, and no active intervention.

a) Engineering solutions:

Engineering solutions use structures to control or mitigate adverse effects of coastal erosion by reducing the wave energy reaching the shore through dissipation, refraction, or reflection of incoming waves (Nordstrom 2000; Weigel 2002). There are two types of structures: shoreline, and offshore or detached (Dugan et al. 2011). Shoreline structures include seawalls, revetments, and bulkheads, groynes, groyne fields (a series of groynes), and jetties or breakwaters (Dugan et al. 2011). Seawalls, revetments and bulkheads are constructed parallel to the shore to protect coastal development and infrastructure from erosion (Weigel 2002; Dugan et al. 2011). Groynes, groyne fields, jetties or breakwaters are constructed perpendicular to the shoreline (frequently in more sheltered settings) and have as their primary purposes maintaining the width of the updrift beach by modifying alongshore sediment transport processes (Dong 2004).

Offshore structures are emergent and low-crested structures or detached breakwaters (Nordstrom 2000). Offshore structures include geo-tubes or tubular structures, reef balls (concrete artificial reef modules), and stable underwater mud berms (Koffler et al. 2008; Dugan et al. 2011). The offshore structures are generally constructed parallel to the shore in more exposed settings or in deeper water at a certain distance from the shoreline (Nordstrom 2000; Dugan et al. 2011).

Sea walls and geo-tubes or tubular structures are two common methods for protecting mangrove dominated muddy coasts from erosion, especially in Southeast Asia. Sea walls, referred to as sea dykes in Vietnam, have been constructed along the majority of the coasts of Vietnam (Vietnamese Prime Minister 2009), mainly to protect local properties and production lands located behind the sea dykes. Geo-tubes or tubular structures were constructed in 2007 to reduce erosion on the muddy coast of Sungai Haji Dorani, Malaysia (Lee et al. 2014).

Engineering solutions frequently have adverse impacts on the processes of deposition and erosion of sediments (Miles et al. 2001), tidal currents, mudflats, and vegetated marshes (Marsworth & Long 1986; Douglass & Pickle 1999; Anthony & Gratiot 2012). However, this technique requires purely technical expertise and rarely considers community participation, local knowledge, and the local culture and economy. In practice, engineering solutions are mainly implemented by local government agencies, and local communities are involved as information receivers in regard to locations, implementation schedules, and possible resettlements.

b) Ecological engineering solutions:

Ecological engineering attempts to combine engineering principles with ecological processes in reducing negative environmental impacts caused by built infrastructure or providing a more natural habitat for species other than people (Bergen et al. 2001; Borsje et al. 2011). Ecological engineering solutions in muddy coastal environments include mangrove planting or a combination of mangrove planting and engineering solutions (Bergen et al. 2001; Woodroffe 2002; Winterwerp et al. 2005; Dafforn et al. 2015; Thampanya et al. 2006).

Many examples of ecological engineering for erosion control are found in Southeast Asia. In Vinh Tan commune of Soc Trang Province, and Vinh Trach Dong commune of Bac Lieu Province, the lower Mekong Delta of Vietnam, T-shaped double-line bamboo fences were constructed offshore in 2012 to accumulate sediment. To date, sediment has been reported to have accumulated slowly (Albers et al. 2013; Schmitt & Albers 2014). On Cong Rach Dinh, Khanh Tien commune, U Minh district of Ca Mau Province of Vietnam, double-cylinder concrete poles were constructed offshore to trap sediment and mangroves were transplanted to protect the coast. The results were that sea mud accumulated and there was a high survival rate of transplanted mangroves (Tung 2013).

In Sungai Haji Dorani project in Selangor on the Malaysian Peninsula, gabion breakwaters and geo-textile tubes were constructed offshore in combination with planting of mangrove between the breakwaters and the coastline (Stanley & Lewis 2009). Off the coast of Chachoengsao Province, Thailand, low crested revetment, sand-filled geo-containers and double line bamboo fences were constructed in combination with mangrove planting to control coastal erosion (Saengsupavanich 2013).

Ecological engineering solutions can have conflicting demands (Holling 1996). A sufficient understanding of assemblages of marine and coastal species in coastal habitats is required. Ecological research is needed to understand aspects of ecological engineering solutions (Chapman & Underwood 2011). Like engineering solutions, ecological engineering solutions have been mainly employed by government agencies or internationally funded aid projects, with local communities involved as labourers.

c) Managed realignment

Managed realignment is also known as managed retreat or set back (French 2001; French 2006), and involves the movement of the defence line landwards to a new position or to high land (French 2001; French 2006). Managed realignment functions to promote colonisation of macro-benthic fauna, create habitats, establish intertidal mudflats and salt marshes, trap sediment, and provide sediment stability (French 2006; Morris 2012; Morris 2013). Managed realignment is considered as a sustainable way of protecting the estuarine hinterland for the establishment of salt marshes or to reduce the negative impacts of sea level rise (French 2006). However, the economics of sediment management and the long term impacts of coastal retreat, soil structure, chemistry and the amount of sediment deposition and floral and benthic faunal colonisation need to be adequately studied to gain an overview of the managed realignment strategy (French 2006; Morris 2012). One challenge is lack of communication between local communities and government agencies in the implementation (French 2006).

d) No active intervention

The no active intervention approach, known as the ‘do nothing’ strategy, involves no capital investment in coastal protection (DEFRA 2006). This approach allows nature to take its course, resulting in many coastal areas being eroded and flooded. This technique is often the least feasible because of the negative economic and social impacts, but remains a viable option in protected areas. Most frequently this technique is used when current strategies have not been effective in controlling erosion, or when coastal erosion is unlikely to have any substantial effects on local properties and livelihoods. Like managed realignment, it is not generally acceptable to local communities dependent on muddy coastal resources for livelihoods.

The majority of the science based approaches use specialist knowledge, and are laboratory based or inventory driven, leaving little opportunity for the involvement of local communities in implementing activities. Where local knowledge is required, local participation is generally passive with community members being told (level 2) or given answers to questions, often designed by outsiders (level 3) (Pretty 1995). In other words, the science based approaches have two significant issues: limited local participation and consultation during planning and management, and insufficient use of local knowledge for design and planning processes.

In summary, muddy coasts dominated with mangroves have been increasingly threatened by human induced and natural factors. Mangrove dominated muddy coasts need to be sustainably managed, particularly for mitigation and adaptation to negative effects of climate change, sea level rise, and coastal erosion. The science based and local knowledge based approaches, each having advantages, have had limited success in mangrove dominated muddy coast management, with a low level of local involvement, and minimal integration of the different knowledge systems. Integration of local and scientific knowledge have been proven to create benefits for environment management. As indicated by Stojanovic et al. (2004), true community involvement and meaningful consultation would facilitate smooth integration of local and scientific knowledge in planning and decision making processes. A question remains as to whether mangrove dominated muddy coasts can be sustainably managed by integration of local and scientific knowledge if there is a high level of participation by stakeholders.

1.3. Research questions and objectives

The overall aim of this research is to identify mechanisms for integrating local and scientific knowledge for managing mangrove dominated muddy coasts in a sustainable way. These mechanisms will assist in addressing the adverse effects of climate change using sustainable management of mangrove dominated muddy coasts, while protecting local livelihoods. The overall aim will be achieved by addressing the following research questions:

1) How can local knowledge be integrated with scientific understanding in managing mangrove dominated muddy coasts sustainably?

2) ***How can the integration of local and scientific knowledge improve the management of mangrove dominated muddy coasts and develop local livelihoods?***

Four objectives were established to answer two research questions:

Objective 1: Investigate the management of mangrove dominated muddy coasts in Kien Giang, Vietnam.

Objective 2: Develop a practical framework for integrating local and scientific knowledge in sustainable management of mangrove dominated muddy coasts.

Objective 3: Test the practical framework for investigating management of mangrove dominated muddy coasts in Brebes, Indonesia.

Objective 4: Develop plans for the sustainable management of mangrove dominated muddy coasts in Kien Giang, Vietnam, and Brebes Regency.

1.4. Conclusions

In addition to the overview of benefits and requirements of integration of local and scientific knowledge in natural resource management, the chapter reviewed techniques specifically designed to sustainably manage mangrove dominated muddy coasts for their effectiveness and applicability, and considered what is required to progress toward sustainable management of mangrove dominated muddy coasts. These techniques share two similar issues: limited local participation during design and planning, and a minimum level of integration of local and scientific knowledge in planning and management. The chapter introduced two research questions and four objectives established in pursuit of the overall aim of this research.

The following chapter identifies research processes for achieving the objectives and the overall aim identified.

CHAPTER 2

RESEARCH DESIGN AND IMPLEMENTATION

This chapter discusses how the research on the integration of scientific and local knowledge for sustainably managing mangrove dominated muddy coasts was methodologically and strategically designed, and how the research was implemented to achieve its overall aim, to comprehensively address the research questions, and to meet satisfactorily its objectives.

2.1. Research process

The research on the integration of scientific and local knowledge for sustainably managing mangrove dominated muddy coasts was divided into three phases: pre-empirical phase, empirical phase, and development and application of the framework. Kien Giang Province, Vietnam and Brebes Regency, Indonesia were selected as research sites because my primary supervisor and I had prior knowledge of these sites (Yin 2003). Kien Giang was selected because I was involved in developing pilot demonstration projects in stabilising eroding mangrove dominated muddy coasts. Brebes was a site visited by my primary supervisor and myself before the research commenced. Actively eroding and accreting mangrove dominated coastal sites were selected in both locations (11 communes in Kien Giang, 6 villages in Brebes) in this study to reflect issues in relation to mangrove dominated muddy coastal management (Fig 1).

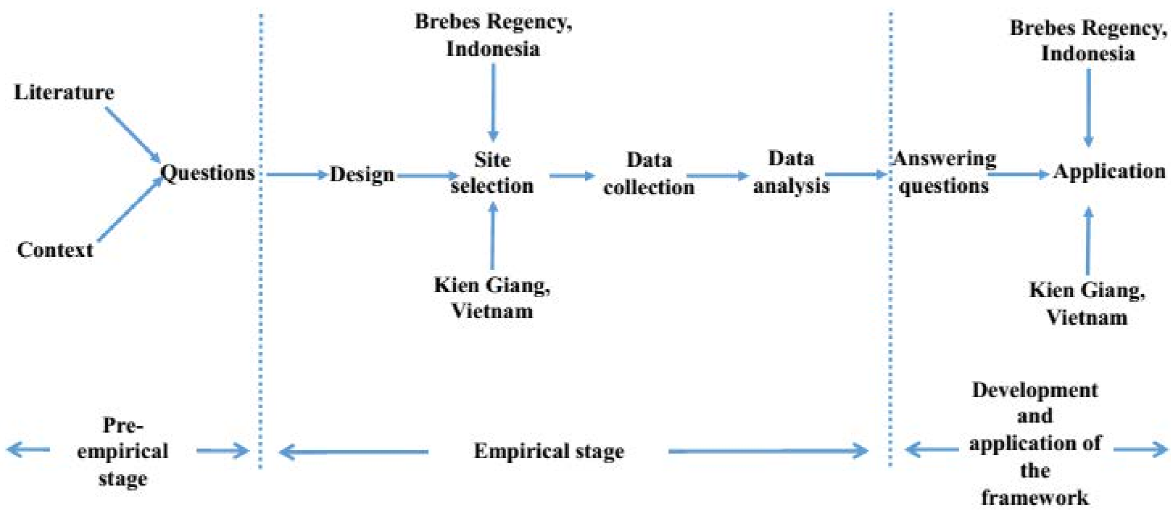


Fig 1: Research process (adapted from simplified model of research, Punch 2005)

2.2. Research design

A research design is established to ensure that the evidence obtained assists in answering research questions as satisfactorily and clearly as possible (Creswell 2009). The research design, where human participants are involved, is characterised by three different components: philosophy, strategies for inquiry, and research methods (Creswell 2009).

2.2.1. Philosophical worldview – positivism and constructivism

Positivism is broadly defined as an approach which applies scientific methods to conceive human affairs through objective inquiry (Hollis 1994). In positivism, a researcher often uses experiments, surveys and statistics, or test causal hypothesis to produce precise quantitative data for rigorous, exact measures and objective research (Neuman 2011).

Constructivism generates or inductively develops a theory or pattern of meaning through the processes of interaction among individuals (Creswell 2009). Constructivism emphasises the importance of exploring how different stakeholders in a social setting construct their beliefs (Guba & Lincoln 1989), and seeks to develop a consensus among participants about how to understand the focus of inquiry, the 'truth' (Schwandt 1994; Schutt 2009; Creswell 2009).

I have chosen positivism and constructivism as two main philosophical worldviews to undertake this study for the following reasons. Positivism is regularly used in social science and philosophy (Hollis 1994). Constructivism has been recognised as a worldview guiding contemporary social science research (Hershberg 2014). Constructivism assists in looking for a complexity of views (Creswell 2014) to understand the 'truth' (nature of the problem - ontology). The complexity of views includes the influences of institutional and contextual factors (development and evolution of formal institutions, historical and cultural settings in which stakeholders live and work, and behaviours of stakeholders in muddy coastal management) for managing muddy coasts in Kien Giang and Brebes.

2.2.2. Strategy for knowledge inquiry - Mixed methods

Research is a puzzle solving process (Creswell 2009), and institutional and contextual factors in Kien Giang and Brebes are significantly complex. In consideration of possible limitations and biases that quantitative and qualitative approaches might cause, the use of mixed methods assists in neutralising, and cancelling potential bias associated with a single method (Creswell 2009), and exploring or addressing different facets of a broad question from various perspectives (Spicer 2012).

Mixed methods are often referred to by different terms; for example, integrating qualitative and quantitative approaches (Glik et al. 1986), interrelating qualitative and quantitative data (Fielding & Fielding 1986), methodological triangulation (Morse 1991), mixed model studies (Datta 1994), multiple methods (Spicer 2012), or mixed method research (Caracelli & Greene 1993). All the terms illustrate the idea of combining or integrating different methods (Creswell et al. 2003). In designing mixed methods, various methods are used as supplemental research strategies to collect data that would not otherwise be obtained by using one main method (Morse 2003). The use of mixed methods enables a researcher to develop a more complete picture of human behaviour and experience, thereby, achieving research goals in a timely manner (Morse 2003). In contrast, a triangulation of methods involves use of more than one method to examine a particular research question and / or to cross-check results for consistency and to enhance confidence in the research findings (Spicer 2012). Three types of mixed methods are identified: sequential mixed methods, concurrent mixed methods, and transformative mixed methods (Creswell 2009).

In this study, I applied concurrent mixed methods, where quantitative and qualitative data were collected at the same time, then converged and merged in the interpretation of the overall results (Creswell 2009).

2.2.3. Research methods

The two overarching methods used in this study included a collective case study approach and participatory action research.

2.2.3.1. Collective case study approach

A qualitative case study is a research approach that aims to generate an in-depth, multi-faceted understanding of a complex issue or a phenomenon within its context using a variety of data sources (Baxter & Jack 2008; Crowe et al. 2011). A qualitative case study is an established research design in social sciences (Crowe et al. 2011). There are three main types of case study: intrinsic, instrumental and collective (Stake 1995). An intrinsic case study is often used to explore a unique phenomenon, while in an instrumental case study, a particular case is used to gain a broader appreciation of an issue or phenomenon. In a collective case study, multiple cases are simultaneously or sequentially used in an attempt to generate a still broader appreciation of a particular issue. This research was essentially an instrumental case study in seeking to address the issue of muddy coast management. The research also had elements of a collective case study because the environment of Brebes is in many ways similar to Kien Giang Province, and there is the possibility that results obtained from Kien Giang could be to some extent replicated in parts of Brebes Regency, Indonesia. The reverse is also true.

2.2.3.2. Participatory action research

Participatory action research is a subtype of action research, a common type of social research (Neuman 2011). Participatory action research is defined as a way of working together to improve a situation. This form of research is collaborative, critical, participatory and developmental through transparent, public and systematic systems, and culturally appropriate, flexible, open-ended and dynamic processes (Crane & O'Regan 2010). This type of research promotes the active participation of researchers and participants in the co-construction of knowledge and emphasises co-learning processes, leading to individual, collective and / or social change (McIntyre 2008). This methodology emphasises democratic processes where social inequality, conflict and injustice are mitigated, and knowledge creation and collective action are promoted (Neuman 2011). In other words, participatory action research promotes active participation, empowerment, co-learning, relational ethics, cultural competency and partnerships (McTaggart 1991; Manzo & Brightbill 2008; Kelley & McKee 2012).

Interaction among individuals in a participatory way is an important process in knowledge generation (Creswell 2009). I have been involved in managing coastal and marine resources in Vietnam for more than 17 years. In particular, I was deeply involved in managing mangrove dominated muddy coasts in Kien Giang between 2008 and 2011. I worked with local communities in Brebes between 2012 and 2015 through the Indonesian Rainforest Foundation, which implemented projects of mangrove dominated muddy coastal protection in Brebes. My deep involvement, although possibly causing difficulty in reaching objectivity in this study, an important aspect of a theory of knowledge (epistemology) (Neuman 2011; Campell & Russo 1999), enabled me to develop rapport with the relevant stakeholders at the two sites in Vietnam and Indonesia, and understand viewpoints, relevant institutions, and interests shared by different stakeholders. In addition, I applied participatory action research in this study. I, as a researcher, and stakeholders, as co-researchers worked in developing the knowledge of the nature of reality (the truth) in a collaborative, critical, participatory, and developmental manner. Application of participatory action research assisted in ensuring my objectivity in the study (Fig 2).

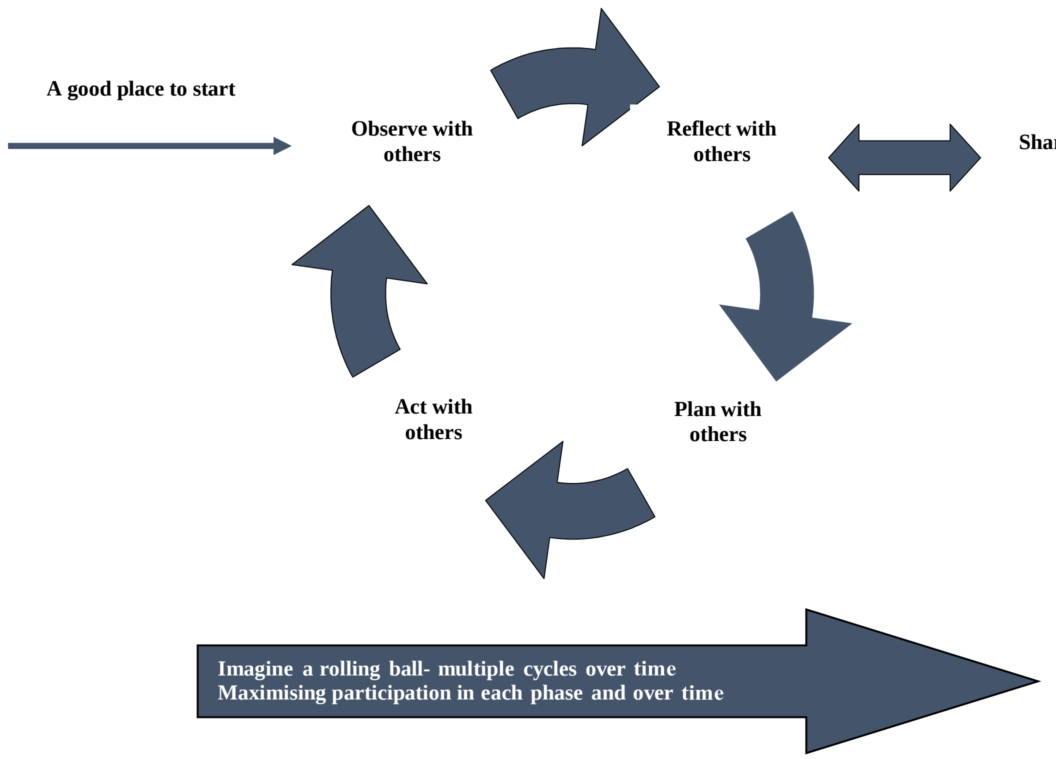


Fig 2: The participatory action research cycle (adapted from Crane & O'Regan 2010, p.11).

2.2.4. Data collection approach

Literature review and participatory bottom up approaches were used to collect data in this study. General data in relation to muddy coastal management and development were collected at the provincial (regional) level.

The literature review provided an overall understanding of current policies, legislation, and guidelines at the provincial (regional) levels. The resulting data were analysed and categorised into themes. Themes, identified from the literature review, were then discussed with the research participants using semi-structured interviews, participatory community meetings, field visits, participatory diagramming, and peer debriefings. This is a 'bottom up' data collection approach (Laverack & Labonte 2000), which assisted in understanding the applicability and feasibility of provincial (regional) policies and problems at the local community level.

2.3. Research implementation

2.3.1. Kien Giang Province, Vietnam

2.3.1.1. The Kien Giang coast

Kien Giang Province, located in the lower Mekong Delta of Vietnam, has approximately 208 kilometres of mangrove dominated muddy coastline (Conservation and Development of the Kien Giang Biosphere Reserve Conservation Project (CDBRP) 2010 a; CDBRP 2010 b) that stretches over four coastal districts, one town, and one city (Fig 3). CDBRP was funded by the Australian Aid Program, AusAID, and implemented by the German Agency for Technical Cooperation (GIZ) in cooperation with the Kien Giang Provincial People's Committee (Kien Giang PPC).

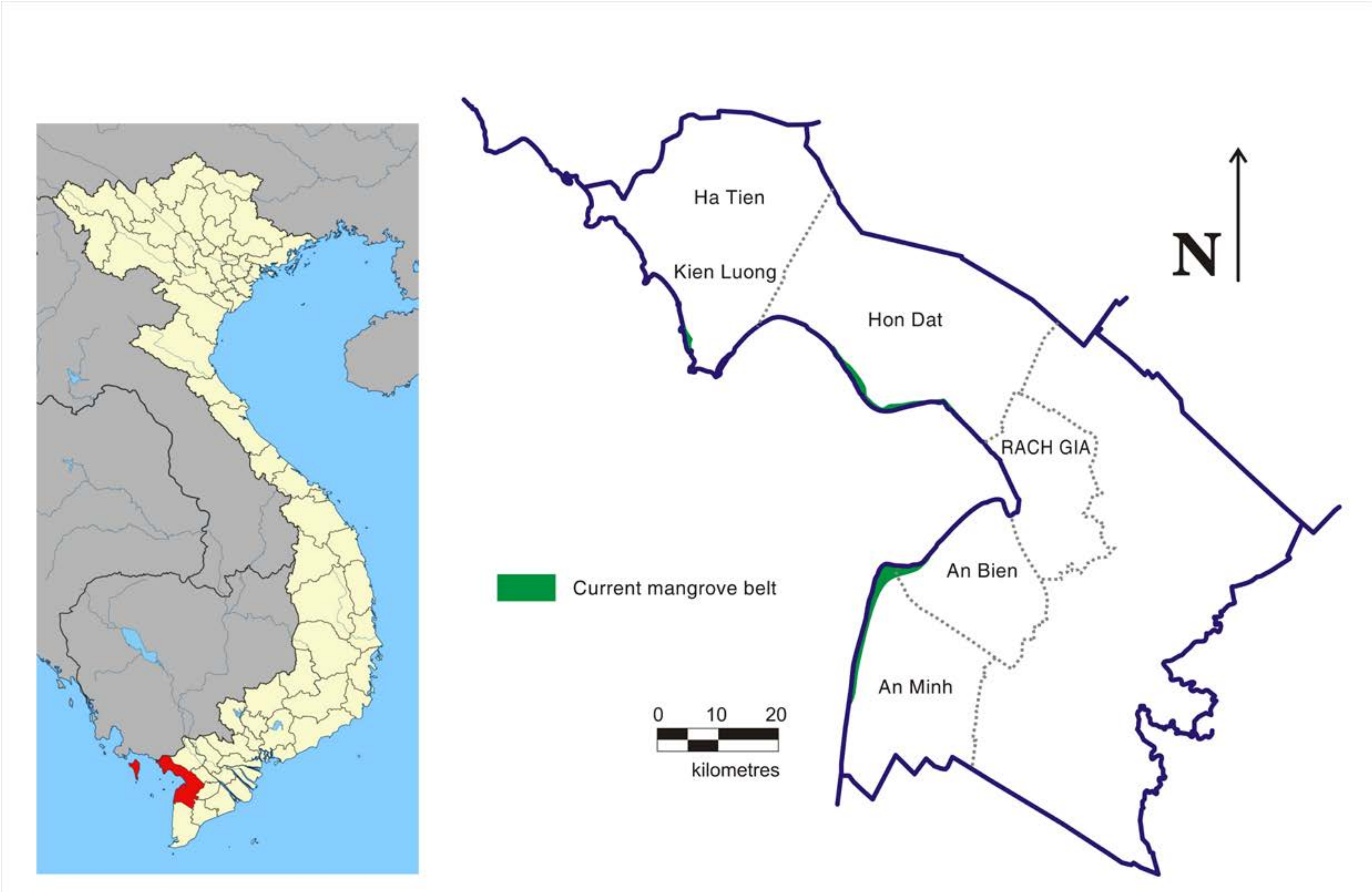


Fig 3: The current mangrove areas for the Kien Giang coastline, Vietnam. The left map is Google map.

The muddy coastline is rich in mangrove species, with 27 of the 39 species reported to be found in Vietnam (CDBRP 2010 a; CDBRP 2010 b). More than 70% of the length of the Kien Giang shoreline comprises mangrove areas (CDBRP 2010 a; CDBRP 2010 b). There are several mangrove areas in Kien Giang totalling 6,951.8 hectare (Department of Agriculture & Rural Development of Kien Giang Province (DARD) 2010 a). The mangrove areas are managed by two Management Boards: the An Bien – An Minh Management Board and the Hon Dat – Kien - Ha Management Board, with support provided by the district level Departments of Forest Protection, the District People's Committees, and Management Protection and Management People Units which were established voluntarily by local people in villages.

The Kien Giang mangrove areas are classified into two categories: the primary mangrove belt and secondary mangrove belt. The primary mangrove belt, situated between the current mature trees of *Avicennia marina* and accretion and / or eroding coastal areas, helps dissipate the energy of strong waves and winds, protect land, stop erosion and promote sedimentation. The secondary mangrove belt is located between the primary mangrove belt and the earth sea dyke (which is described in detail in the following section). This secondary mangrove, a mixture of *Rhizophora apiculata* and *Sonneratia alba* trees, functions to dissipate the energy of the winds, to protect the current earth sea dykes, and the production lands behind the sea dykes. Inter-tidal mudflats and open sea water areas located in front of the primary mangrove belt function as protection zones of the primary mangrove belt (Kien Giang PPC 2011 a).

The earth sea dykes, mangroves, intertidal mudflats and sea water areas in front of intertidal mudflats are integral parts of the Kien Giang coastline, but are managed by different government agencies. Sea water areas are managed by the District People's Committees and are used for aquaculture purposes (Kien Giang PPC 2011 a). The intertidal mudflats, mangroves, and the sea dyke system are managed by the two Management Boards (Kien Giang PPC 2005; Kien Giang PPC 2011 a). Demarcation was undertaken using concrete posts to clearly mark the boundaries between the mangroves managed by the Management Boards and sea water areas managed by District People's Committees. Demarcation was completed in An Bien and An Minh districts, but has not been done in Hon Dat district, Kien Luong district, and Ha Tien town (DARD 2012).

2.3.1.2. Current coastal issues in Kien Giang Province

In 2009, 30 % of the total 208 kilometre coastline of Kien Giang was reported as being severely eroded and the mangroves degraded (CDBRP 2010 b). The Kien Giang coast has been actively eroding at what is considered an alarming rate since then (Kien Giang PPC 2011 b). Uncontrolled shoreline mangrove harvesting, the unexpected infestation of plant eating insects, mangrove roots being buried by litter accumulation, and direct mangrove removal for channel, dyke and industrial construction were reported as likely causes of coastal erosion in Kien Giang (CDBRP 2010 a; CDBRP 2010 b). Many coastal sections located within the mangrove areas were reclaimed for residential areas, industrial zones, tourism destinations, private land and administrative areas with permission issued by Kien Giang PPC.

Sea levels have been projected to increase by at least 65 centimetres over the next 100 years in the lower Mekong Delta region (Ministry of Natural Resources and Environment of Vietnam 2010; Asian Development Bank 2013). The effects of sea level rise, climate change and coastal erosion on the province will be severe in the future, unless the negative impacts and natural hazards are mitigated (Kien Giang PPC 2012).

2.3.1.3. Current strategies for managing the Kien Giang coast

Current strategies for managing the coast in Kien Giang involve the protection of current mangroves, and mangrove development through afforestation. The current mangroves have been protected through enforcement of relevant laws issued by the Government of Vietnam (Vietnamese National Assembly 2004), by establishment of coastal mangrove protected areas, and by involving local communities that depend on coastal resources (Vietnamese Prime Minister 2001; Kien Giang PPC 2005; Kien Giang PPC 2011 a). Local communities are involved in protecting and using mangroves for improving livelihoods in the secondary mangrove belt. The protection strategies were put in place to protect the coast, adapt and mitigate climate change effects, improve livelihoods for local farmers and fishers, and stop the illegal harvest of mangroves for fuel wood and timber (DARD 2012; Kien Giang PPC 2011 a).

Actively eroding coastal areas were protected by concrete sea dykes (DARD 2011; DARD 2012). Sea dykes were first constructed using sediments excavated from both sides of the dykes in the 1970s along the entire coastline of Kien Giang for irrigation and national defence purposes. In the 1980s, the earth sea dykes were upgraded for national defence purposes. In the 1990s, the sea dykes were upgraded again to protect local properties from erosion, and to construct a rural road. Sluice gates have been constructed over rivers and channels to complete the sea dyke system. To date, 31 sluice gates have been constructed between Ha Tien and An Minh. A further 64 new sluice gates are proposed (Kien Giang PPC 2011 b).

Mangrove areas have been expanded as an adaptation response to climate change, sea level rise and coastal erosion through afforestation programmes mainly in intertidal areas. These afforestation programmes were launched by both the central government and the Kien Giang government (Vietnamese Prime Minister 2009; Vietnamese Prime Minister 2007 b; Ministry of Agriculture and Rural Development of Vietnam (MARD) 2008 a; MARD 2008 b; DARD 2011; Kien Giang PPC 2005; Kien Giang PPC 2011 a).

There were many attempts to address coastal issues in Kien Giang between 2008 and 2015. These programs were conducted mainly by external specialists, recruited by CDBRP (2008 a; 2008 b; 2009; 2010 a; 2010 b; 2011; 2012 a; 2012 b). The work has described the current status of, and potential threats to, the Kien Giang coastline into the near future and provided recommendations for future planning and management. Local people have been involved as local guides, not as co-investigators in these activities.

In 2009, a pilot project was established under a partnership between CDBRP, the Kien Giang Province and the community of Vam Ray, located in Hon Dat district to stop erosion in Vam Ray. This pilot project was generally considered a success in relation to mangrove restoration and management of actively eroding coastal areas (Kien Giang PPC 2009 b).

2.3.2. The coast of Brebes Regency, Indonesia

The second research location is the Brebes Regency, Indonesia. Located in the north-western part of Central Java province of Indonesia, Brebes Regency (Fig 4) has a muddy coastline of approximately 53 kilometres that includes more than 50 kilometres of mangroves

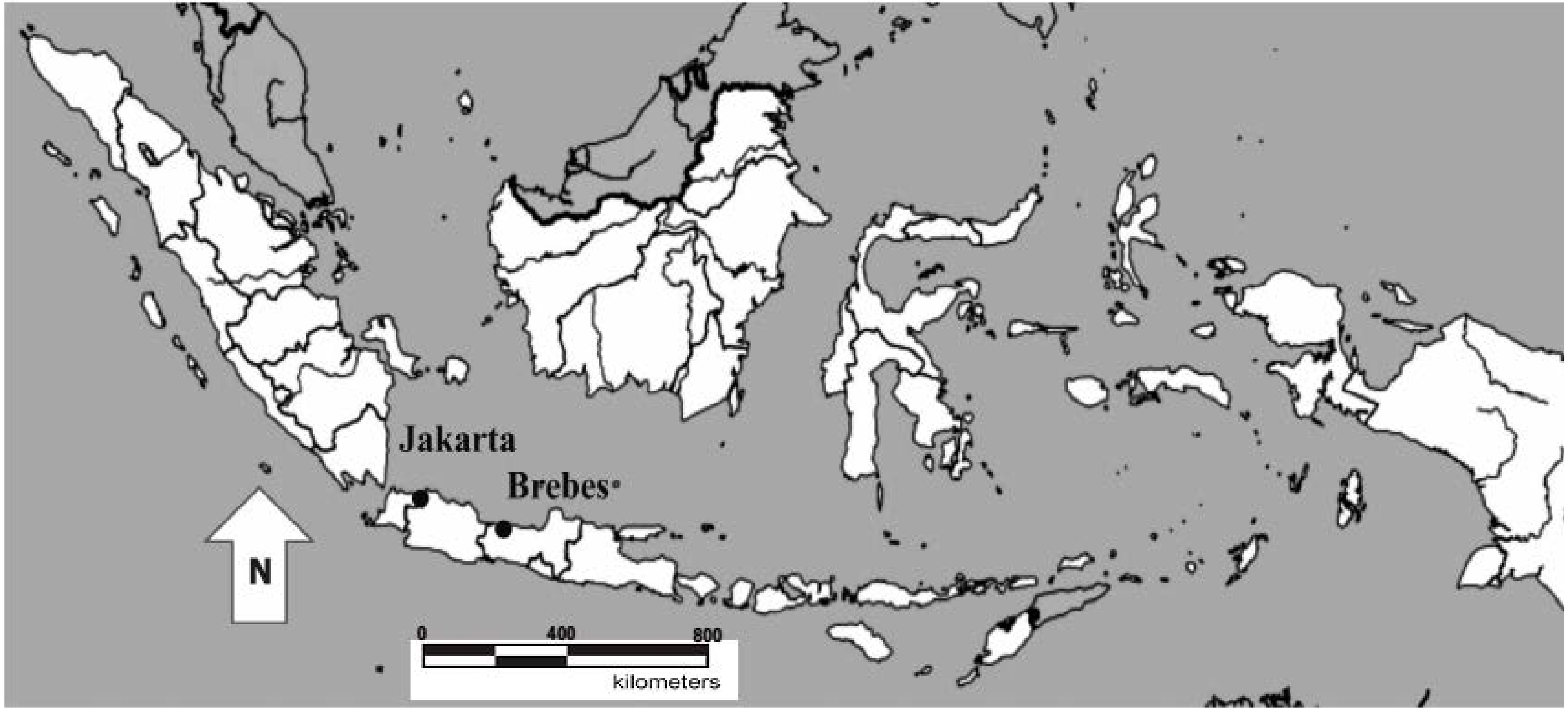


Fig 4: Location of Brebes Regency in Indonesia. Background is Google map.

Brebes Regency has an area of approximately 852 hectares of mangroves adjacent to five coastal communities (Limbangan, Karang dempel, Pulogading, Sawojajar, and Kaliwlingi) (Regional Development and Planning Board of Brebes Regency (BAPPEDA) 2009). The Brebes muddy coast is dominated by *Rhizophora mucronata* as a consequence of repeated transplantations of this species.

BAPPEDA is responsible for developing long term planning and development plans in Brebes. The Department of Environment, the Department of Marine Affairs and Fisheries, and the Department of Forestry are responsible for protecting and developing mangroves in cooperation with the five local communities. In addition, Mangrove Resource Rehabilitation and Conservation Groups have been officially established to promote coastal mangrove restoration and protection (Mayor of Brebes 2013).

Two thirds of the Brebes coast is actively eroding, with many abandoned ponds found along the coasts of Limbangan, Karang dempel, Sawajajar and Kaliwlingi (BAPPEDA 2009). Pulogading is an accreting area, where newly deposited mudflats have been leased by local government agencies to construct new ponds for aquaculture (Fig 5).

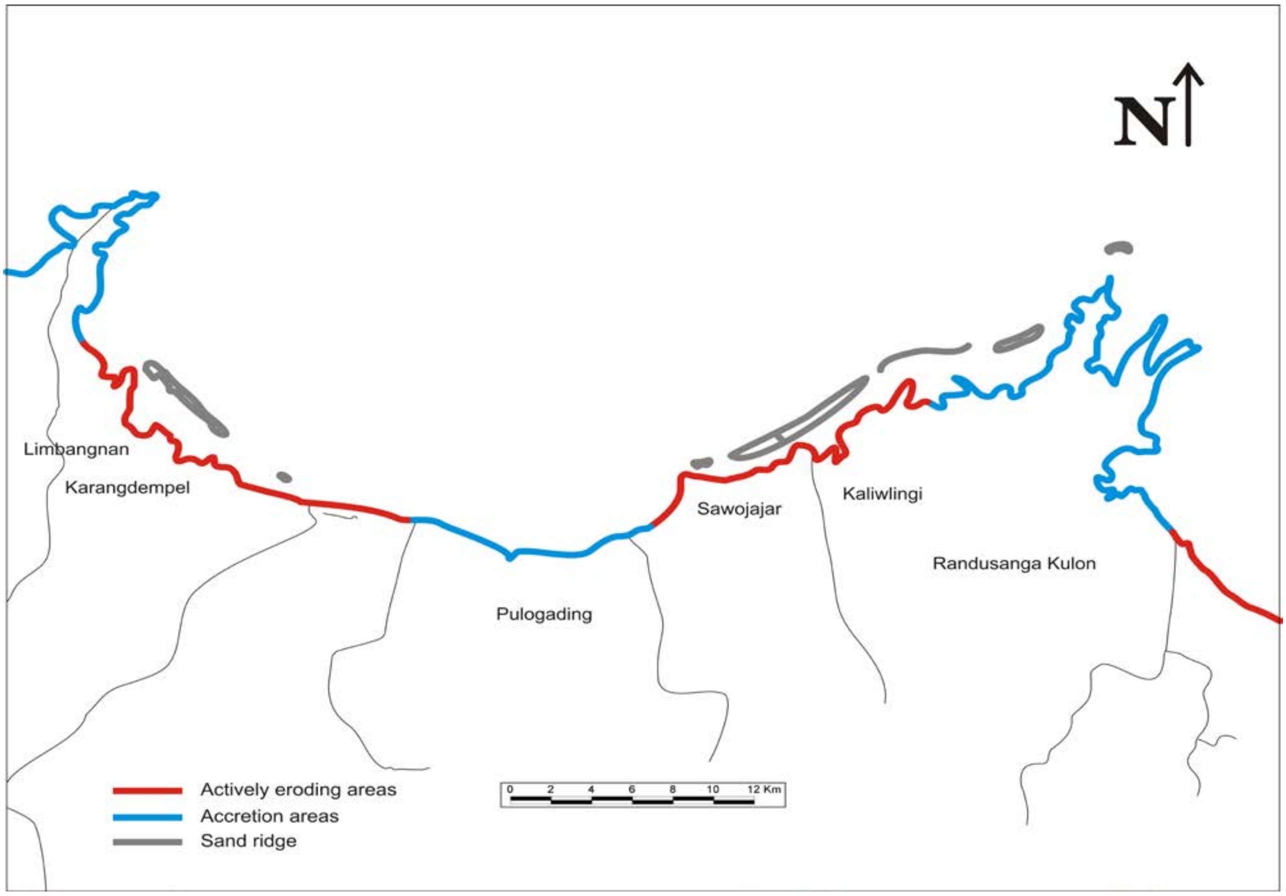


Fig 5: Changes in the Brebes, Indonesia, shoreline between 2009 and 2012, adapted from Mackay (2012).

2.3.2.1. Current coastal issues in Brebes Regency, Indonesia

The Brebes coast has been negatively impacted by natural events and human activities as well as frequently being affected by strong seasonal waves on high tides. Significant coastal erosion occurred in 2010 and became considered serious in 2012. Climate change and sea level rise were predicted to be two significant threats to the coastal communities (Mackay 2012).

Mangroves were over-exploited illegally for firewood and timber, and converted into areas for salt production and for shrimp farming (Mackay 2012). Mangroves have been further threatened by recent migrants who have come to coastal areas of Brebes for livelihood opportunities (Mackay 2012).

2.3.2.2. Current strategies for managing the Brebes muddy coasts

Sustainable management of the Brebes muddy coast has been emphasised in adaptation to climate change, sea level rise, and coastal erosion through various national programmes (State Ministry of Environment 2007; Ministry of National Development Planning of Indonesia 2013), and by Brebes Regency (Mayor of Brebes 2004; Mayor of Brebes 2011; Burhani 2011).

Local communities have been actively involved in sustainable management of the Brebes muddy coast through transplantation of *Rhizophora mucronata.* Triangular bamboo wave break fences were constructed offshore in Sawjajar and Kaliwlingi to protect the coasts and seedlings of mangroves transplanted from erosion. However, the bamboo fences were broken and had to be replaced every year. A rock wall was constructed using granite rocks, made into a wall to dissipate the energy from strong waves in Randusanga kulon. This rock wall was funded by Brebes Regency Forestry Protection Department.

2.4. Data collection methods

The sources of information and data included (a) staff working for provincial, regional and national governmental agencies, (b) field visits, (c) provincial legal records and (d) local partners and communities.

Methods for secondary data collection included secondary data analysis (a desk-top review) (Schutt 2009), and semi-structured interviews (Ayres 2008 b). In this study, reports and documents related to land use planning, mangrove restoration, sea dyke construction and aquaculture and agriculture from non-governmental organisations, government and regional agencies in Kien Giang and Brebes, were collected, reviewed, and analysed to obtain secondary data.

Semi-structured interviews were conducted with staff working for local government agencies to collect further relevant literature that were not made available. The agencies in Kien Giang, included DARD, the Department of Natural Resource & Environment of Kien Giang Province, the An Bien – An Minh Management Board, the Kien – Hai – Ha Management Board, the District People's Committees of An Bien, An Minh, Kien Luong and Hon Dat. The agencies in Brebes, included the Department of Environment, Department of Marine and Affairs, the Department of Fisheries, the Department of Forestry, BAPPEDA, and the Indonesian Rainforest Foundation.

Participatory community meetings (Kindon et al. 2008), field visits (participant observation), and photo voice (Kindon et al. 2008) were used to collect primary data. A series of participatory community meetings, with administrative assistance from the Women's Union, the Farmers' Union, local government agencies and the two Management Boards in Kien Giang, and Farmers' Union, and BAPPEDA in Brebes were held involving fishers and farmers from both eroding coastal areas and areas with extensive inter-tidal mudflats where erosion was not of concern. The meetings used the key themes specified in the literature review to discuss and to collect primary data (Table 1).

Further primary data were collected using convenience and purposive sampling methods (Neuman 2011). Convenience sampling was used to undertake exploratory preliminary studies, not to create a representative sample. Use of convenience sampling in community meetings and debriefings assisted in gathering useful information and data rather quickly and inexpensively, to establish a general understanding of the reality of muddy coastal management in Kien Giang and Brebes. Purposive sampling was used because this study needed participants who knew about mangroves and muddy coasts.

Field visits along the Kien Giang coast and Brebes coast were undertaken between July 2013 and November 2014, with administrative assistance from the relevant agencies in Kien Giang and Brebes. The field visits were undertaken using boats and small motorbikes. While emphasis was placed on erosion areas, almost all of the coastlines were visited. During the field visits, photographs previously taken in the areas, Google based maps of the area, maps of forestry planning and inventory, maps of land use planning (photo voice) were used to collect additional primary data.

Table 1: The fieldwork activities undertaken

No.	Location	No. of field visits	No. of people interviewed	No. of meetings	No. of debriefings
Kien Giang, Vietnam					
1	DARD		4	3	0
2	Binh Tri – Kien Luong	4	24	1	1
3	T 6 – Hon Dat	4	35	1	1
4	T 5 – Hon Dat	4	61	2	1
5	Vam Ray – Hon Dat	8	24	3	3
6	Hon Dat – Kien – Ha Management Board		3	1	0
7	Nam Yeu – An Bien	4	20	1	1
8	Nam Thai – An Bien	4	16	1	1
9	Tay Yen – An Bien	4	28	1	1
10	Thuan Hoa – An Minh	4	32	1	1
11	Dong Hung A – An Minh	4	27	1	1
12	Van Khanh – An Minh	4	34	1	1
13	Van Khanh A – An Minh	4	24	1	1
14	An Bien – An Minh Management Board		3	2	0
Brebes Regency, Indonesia					
15	Department of Environment		0	3	3
16	Department of Marine Affairs		0	3	3
17	Department of Fisheries		0	3	3
18	Department of Forestry		0	3	3
19	BAPPEDA		8	5	3
20	Kaliwlingi	4	35	2	2
21	Sawojajar	4	35	2	2
22	Pulogading	4	35	2	2
23	Karang dempel	4	35	2	2
24	Randusanga kulon	4	35	2	2

2.5. Data analysis and interpretation

In this study, methods for data analysis were reflective diaries, documentation, participatory diagramming (matrix / chart / flow chart), thematic analysis, and peer debriefings.

Reflective diaries were prepared to record ongoing thoughts and ideas through observations and personal experiences. Reflective diaries allowed the examination of reported events, reduced the likelihood of retrospection and increased recall accuracy (McGuinness & Simm 2005; Travers 2011).

Documentation, the first formal analytical step, was to record contacts, interviews, and written documents. Documentation assisted in keeping track of notes, outlined the analytical process, and promoted conceptualisation and strategies for developing concepts (Schutt 2009).

Participatory diagramming is a method to organise, analyse and translate the data collected and the process of data collection into decision trees / sequences of relationship so that informed decisions can be made (Schutt 2009; Neuman 2011; Kindon et al. 2008).

Thematic analysis is a descriptive strategy where qualitative data are identified, segmented, categorised, summarised and reconstructed to capture important concepts and patterns within the data set. The product of a thematic analysis is a description of concepts and patterns and the overarching design uniting these concepts and patterns (Braun & Clarke 2006; Ayres 2008 a). In this study, secondary and primary data were translated into matrices and diagrams to develop sequences of relationship between aquaculture and agriculture practice and mangrove degradation and coastal erosion.

Peer debriefing is a process where researchers and impartial peers conduct extensive discussions about preliminary data collection, methodological steps, findings, and analysis (Guba & Lincoln 1989; Lincoln & Guba 1985; McMillan & Schumacher 1997; Schutt 2009). In this study, peer debriefings were organised with communities. In peer debriefings, sequences of the relationships between aquaculture and agriculture practice and mangrove degradation and coastal erosion in Kien Giang and Brebes were discussed and reviewed. Peer debriefings provided opportunities to avoid methodological and researcher bias, to enrich the data, and to verify the relationships discovered in the data analysis.

2.6. Validity and reliability

Reliability and validity of the study findings were checked at every stage in the data and information collection process. Reliability and validity are core principles of mixed methods research. Reliability means consistency or dependability, while validity means authenticity (Neuman 2011). Reliability and validity were achieved through mixed methods (Creswell 2009; Neuman 2011). Information and data were also checked for their authenticity and dependability through local research partners' feedback and peer debriefings with the communities and government agencies.

2.7. Ethical considerations

2.7.1. Ethics approval, informed consent, confidentiality and security

Before the research was undertaken, a low negligible risk human research ethics application was lodged on 24 October 2013, and was approved H5410 on 11 December 2013.

As an administrative procedure, letters of introduction by the provincial departments and Regency were needed before any field work and interviews were conducted. The surveys focused on two types of groups: focus groups and broader groups of contractees, women and youth. People involved in interviews remained anonymous in the reporting. An informed consent form was developed and used for the surveys. Procedures included:

1) Self-introduction.
2) Explanation of current status of the project and purpose of the focus group.
3) Explanation of purposes of community workshops / participatory meetings / semi-structured interviews / field trips.
4) Outline of topics to be discussed.
5) Assurance of confidentiality because anonymity was not possible in group settings.
6) Reminder of the participants of their right to decline.

Verbal consent was sought at the beginning of the semi-structured interviews. Signing of documentation by individuals was not appropriate in this context. Instead, minutes of the community meetings were signed by community representatives or by a person nominated as meeting secretary by communities, and were used as data. Below is the list of minutes of the meetings (see appendices for more information).

a) Minutes of the meetings in Kien Giang, Vietnam:

1. Hon Dat district (12/12/2013; 15/12/2013; 16/12/2013; 01/03/2014).
2. Van Khanh commune, An Minh district (26/02/2014).
3. Van Khanh Tay commune, An Minh district 26/02/2014).
4. Nam Thai commune, An Bien district (27/12/2014).
5. Nam Yen commune, An Bien district (27/12/2014).
6. Thuan Hoa commune, An Minh District (28/02/2014).
7. Tay Yen commune, An Bien district (28/02/ 2014).
8. Dong Hung A commune, An Minh district (04/03/2014).

b) Minutes of the meetings in Brebes, Indonesia:

1. Sawojajar and Kaliwlingi 27/11/2013
2. Karang dampel and Limbangan (29/11/2013)
3. Karang dampel and Limbangan (6/12/2014).
4. Kaliwlingi, Randusanga kulon, Sawojajar, and Pulogading (7/12/2014).

2.7.2. Analytical research framework and chapter allocation

The analytical research framework is divided into eight chapters to adequately and comprehensively reflect the research process. Chapters 1 and 2 identify benefits and requirements of integration of local and scientific knowledge in natural resource management, recognise the urgency of using the integrated local and scientific knowledge for improving sustainable management of mangrove dominated muddy coasts, and develop the design and implementation in pursuit of the overall aim of the research. Chapters 3 and 4 examine and analyse the Kien Giang case. The practical framework is developed using the results and conclusions from the previous chapters (Chapter 5). The practical framework is applied for understanding the effectiveness and efficiency of the current strategies for managing mangrove dominated muddy coasts in Brebes and for developing sustainable management of mangrove dominated muddy coasts in Kien Giang and Brebes (Chapters 6 and 7). Lessons learnt are synthesised and concluded at the end of the research (Chapter 8). The analytical research framework and chapter allocation are summarised in Fig 6.

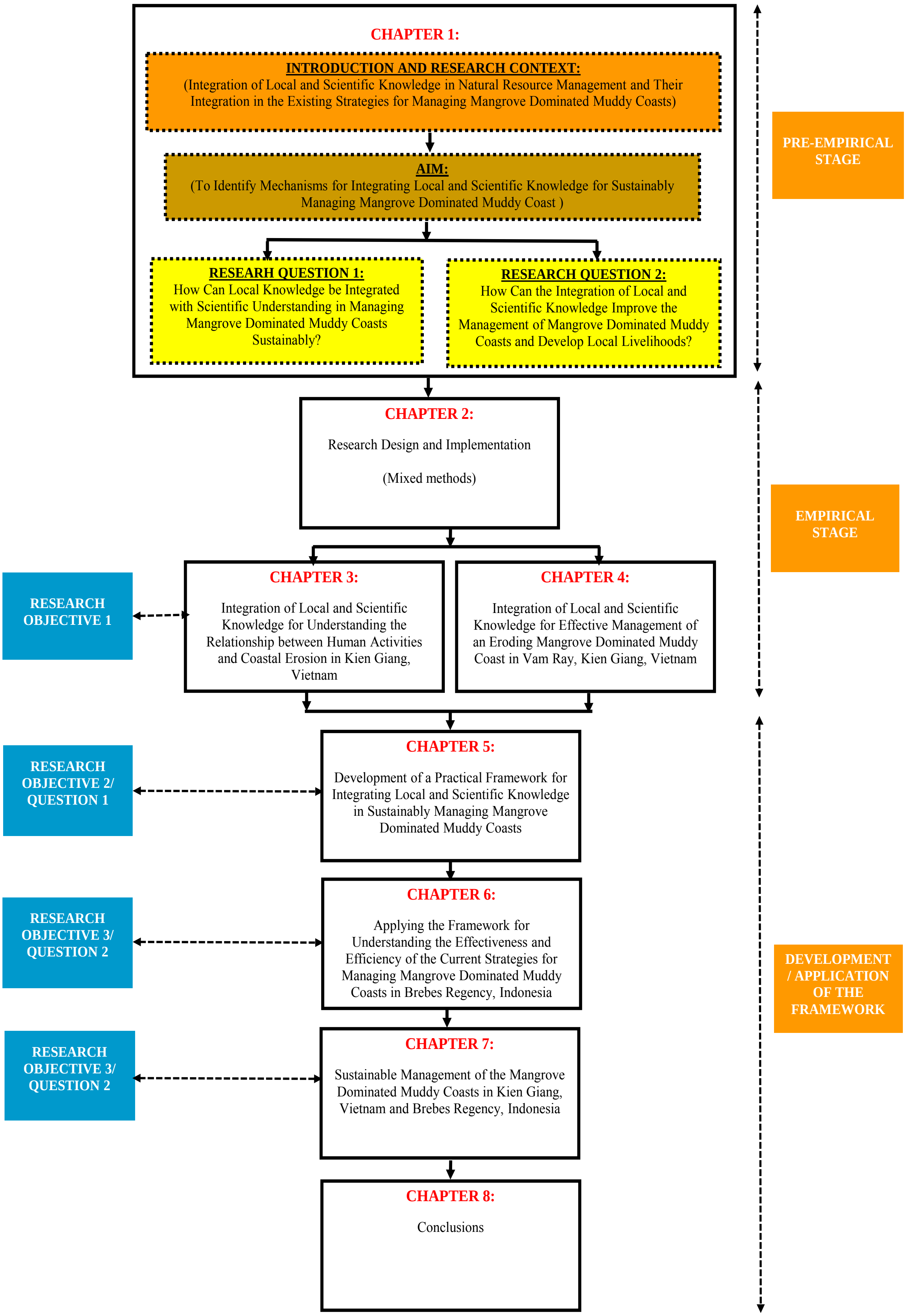


Fig 6: Analytical research framework and chapter allocation.

2.8. Conclusions

This chapter presented the research design and implementation. The research design involves discussions of philosophical foundations and worldview of choice (constructivism), the strategy for knowledge inquiry (mixed methods), research methods, data collection methods, research processes, and the analytical research framework. In relation to research implementation, techniques for sampling (convenience and purposive samplings) and methods were presented to provide an overview of data collection, analysis, and interpretation. Validity and reliability were emphasised at every stage of data collection, analysis, and interpretation. Ethical issues were also considered carefully to ensure confidentiality and respect through informed consent. The structure of the thesis follows the development of a practical framework from analysing the management of muddy coasts (in Kien Giang), testing that framework (in Brebes), and then applying the framework to future management in Kien Giang and Brebes.

The next chapter describes the integration of local and scientific knowledge for understanding the relationship between human activities and coastal erosion in Kien Giang, Vietnam.

CHAPTER 3[3]

INTEGRATION OF LOCAL AND SCIENTIFIC KNOWLEDGE FOR UNDERSTANDING THE RELATIONSHIP BETWEEN HUMAN ACTIVITIES AND COASTAL EROSION IN KIEN GIANG, VIETNAM

This chapter illustrates how scientific knowledge has been successfully integrated with local knowledge to understand the relationship between human activities and coastal erosion in Kien Giang, Vietnam.

3.1. Introduction

Muddy coastal areas have been used to expand agriculture, aquaculture, industry and settlements (Han 2002; Primavera 2006), especially in Southeast Asia (Food and Agriculture Organization of the United Nations 2007; Ramesh et al. 2011). This expansion into coastal areas has adversely impacted the muddy coasts (Othman 1994; Masalu 2000; Paez-Osuna 2001; Valiela et al. 2001; Alongi 2002; Han 2002; Food and Agriculture Organization of the United Nations 2003; Food and Agriculture Organization of the United Nations 2007; Bhandari & Nakamura (2004); Martin et al. 2005; Thampanya et al. 2006; Primavera 2006; Clark 1996; Ramesh et al. 2011; Sohel & Ullah 2012; Cong et al. 2014) and contributed greatly to coastal erosion (Han 2002).

Coastal mangroves have been dramatically degraded and deforested in Kien Giang Province (Fig 3) as a consequence of being heavily exploited for aquaculture purposes in the 1980s. In 2009, 30% of the 208 kilometre coastline of Kien Giang was reported as being severely eroded (CDBRP 2010 a; CDBRP 2010 b). Kien Giang Province is investing considerable resources into developing strategic solutions such as: the upgrade of current earth sea dykes with concrete; the transplantation of mangrove species that assist in protecting the coast; adapting to and mitigating climate change effects; and improving

[3] This chapter has been written as two manuscripts for publication: **Human Activities and Coastal Erosion on the Kien Giang Coast, Vietnam,** submitted to the Journal of Coastal Conservation in September 2015, **An assessment of 'Allocated Mangrove Areas' for Coastal Protection and Livelihood Improvement in Kien Giang, Vietnam,** to be submitted to Journal of Land Use Policy in July 2016.

livelihoods in local communities (DARD 2009 b; DARD 2010 b; DARD 2011; DARD 2012; Kien Giang PPC 2005; Kien Giang PPC 2009 a; Kien Giang PPC 2011 b). However, the early solutions have not been effective in protecting mangrove areas (CDBRP 2010 a; CDBRP 2010 b). Many areas of Kien Luong, Hon Dat, An Bien and An Minh districts have been severely eroding at an alarming rate despite the implementation of control measures (CDBRP 2010 a; CDBRP 2010 b; DARD 2012; Nguyen et al. 2010).

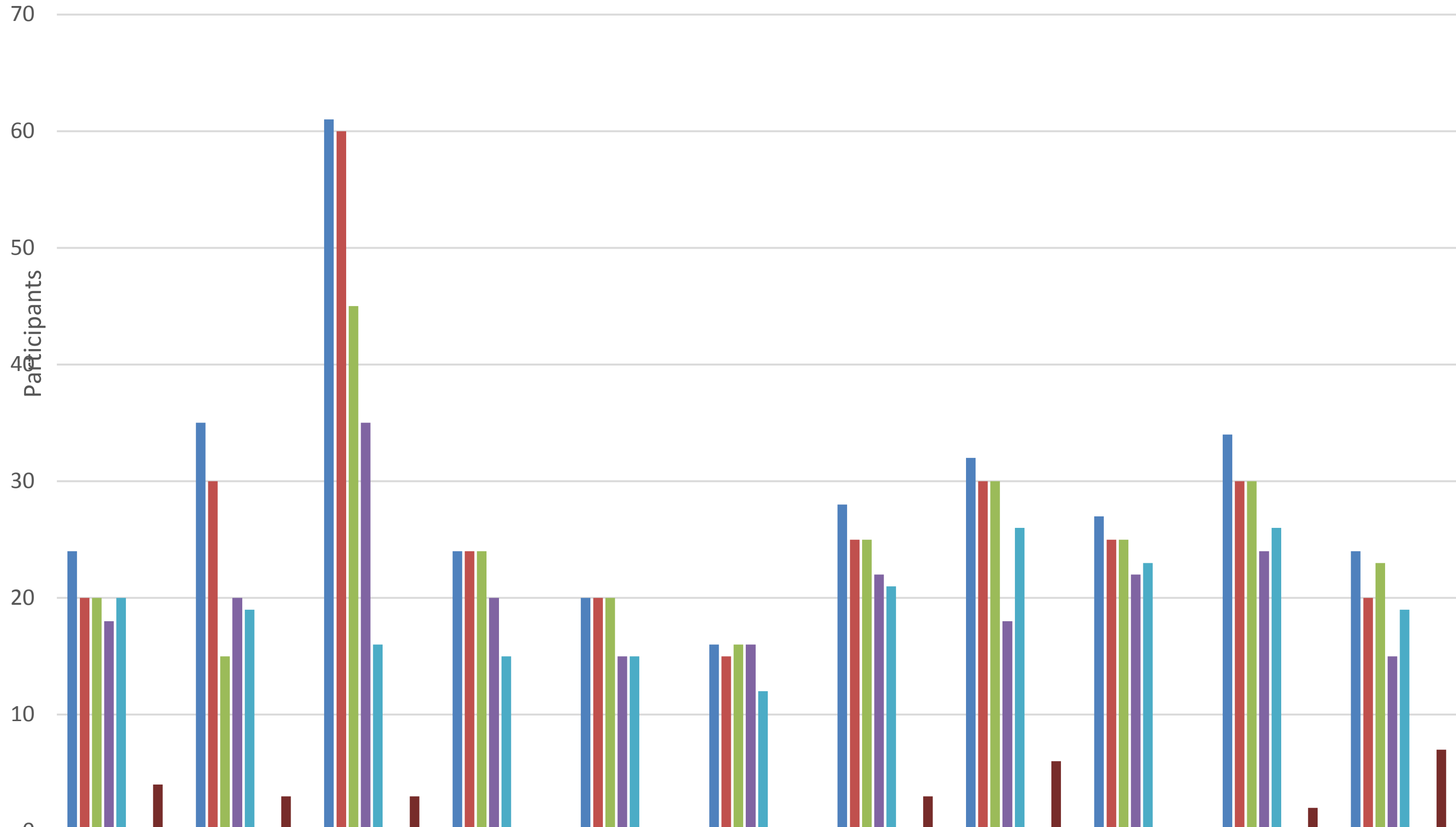
In Vietnam, sea level has risen at a rate of approximately 3 millimetres per year between 1993 and 2008 (World Bank 2010). Sea level has been projected to increase by at least 65 centimetres in the next 100 years in the Mekong Delta region (Ministry of Natural Resources and Environment of Vietnam 2010; Asian Development Bank 2013) and the effects on the province will be severe (Kien Giang PPC 2012).

3.2. Knowledge of coastal erosion in Kien Giang, Vietnam

Different knowledge systems were introduced and analysed in community meetings, field visits, semi-structured interviews, and peer debriefings in Kien Giang. Literature showed that erosion of muddy coasts can be caused by changes in sedimentation patterns and other natural processes as well as by anthropogenic influences (Augustinus 1989; Yan et al. 1989; Wells et al. 1990; Lee et al. 1994; Amos 1995; Liefting 1998; Wang et al. 2002 a; Wang et al. 2002 c; Cong et al. 2014; Fan et al. 2004), and in places has caused significant economic loss, ecological damage and social unrest (Ramesh et al. 2011).

Previous scientific studies applied modelling (regional climate modeling, hydrological and coastal modelling) (Asian Development Bank 2011), field investigations and observations, SPOT imagery and aerial photographs, and a rapid video survey (CDBRP 2012 a; CDBRP 2012 b) to understand coastal issues including coastal erosion. Changes in sedimentation, climate change and sea level rise, uncontrolled shoreline mangrove harvesting, the unexpected occurrence of plant eating insects, mangrove roots being buried by litter accumulation, and direct mangrove removal for channel, dyke and industrial construction were reported as likely causes of coastal erosion in Kien Giang.

The literature review and stakeholder reviews were thematically analysed using thematic analysis as described in Chapter 2. Eight issues were identified - climate change, sea level rise, flooding and inundation, changes in sedimentation, aquaculture and agriculture techniques, sea dyke and sluice gate construction, and mangrove cutting for timber use - as being critical to the Kien Giang coastline. The eight issues were further explored in semi-structured interviews and participatory community meetings. In the semi-structured interviews and participatory community meetings, local community members could select as many issues locally identified as causing coastal erosion as they wished. Of eight issues named above, aquaculture and agriculture techniques, and sea dyke and sluice gate construction were not believed to contribute at all to coastal erosion. Mangrove cutting for timber use was not thought to pose any significant harm to the Kien Giang coastline (Fig 7). That is, members of the local community only recognised external factors as causes of coastal erosion, none of their own actions.



	Binh Tri commune	T 6 commune	T 5 commune	Vam Ray commune	Nam Yen commune	Nam Thai commune	Tay Yen commune	Van Khanh commune	Thuan Hoa commune	Dong Hung A commune	Van Khanh Tay commune
Total participants	24	35	61	24	20	16	28	32	27	34	24
Climate change	20	30	60	24	20	15	25	30	25	30	20
Sea level rise	20	15	45	24	20	16	25	30	25	30	23
Flooding / inundation	18	20	35	20	15	16	22	18	22	24	15
Changes in sedimentation	20	19	16	15	15	12	21	26	23	26	19
Aquaculture techniques	0	0	0	0	0	0	0	0	0	0	0
Agriculture techniques	0	0	0	0	0	0	0	0	0	0	0
Mangrove cutting for timber use	4	3	3	0	0	0	3	6	0	2	7
Sea dyke / sluice gate construction	0	0	0	0	0	0	0	0	0	0	0

Fig 7: Local perceptions of the causes of coastal erosion in Kien Giang Province.

Shared responses received from local communities were that the apparent sea level had risen recently, especially extreme levels were seen during high tides and the rainy season, when the north-east wind is dominant. An increased number of aquaculture ponds were broken by strong waves on high tides, causing a significant economic loss. Erosion has become even worse along the Kien Giang shoreline since 2009, especially in areas which had previously been severely eroded.

Local communities were uncertain as to how climate change and changes in sedimentation affected or caused coastal erosion. They selected these issues because they were regularly told about the negative effects of climate change and changes in sedimentation on the Kien Giang coast in meetings organised by local government agencies in their communities, through daily radio and television programs, or in workshops held by scientists, who undertook their studies in relation to sedimentation on the Kien Giang coast.

3.3. Local recognition of different knowledge systems in relation to coastal erosion

Local communities were not adequately involved in scientific studies undertaken between 2008 and 2012. On many occasions, local people were involved as local guides, not as co-investigators. Although successfully describing the current status of and potential threats to the Kien Giang coastline in the near future and providing recommendations for future management planning, donors' reports failed to identify underlying causes of the problems facing Kien Giang. Limited local involvement and insufficient recording of local knowledge in the studies resulted in many lessons not being documented and therefore not being used in the development of technical recommendations for the future management of the Kien Giang coastline.

While natural factors (adverse effects of climate change and sea level rise) have been widely reported as the main causes of coastal erosion, human activities initially were not recognised by local communities as significant contributors to coastal erosion and mangrove degradation. To manage erosion, a thorough understanding of the underlying causes of the erosion is needed, particularly when many sections of the Kien Giang coast continue to erode despite management interventions. Apart from the causes of coastal erosion reported by

Asian Development Bank (2011), and CDBRP (2012 a; 2012 b), it was crucial to investigate with communities possible causal links between erosion and the construction of coastal infrastructure and management interventions on the coast not reported in previous studies and government documents. In the investigation, local communities and governments were involved as co-investigators and local knowledge was collated, linked, and justified using the scientific understanding of coastal dynamics and the results of the previous studies in Kien Giang to allow for the investigation of the relationship between human activities and coastal erosion.

3.4. Investigating possible causal links between human activities and coastal erosion

3.4.1. Human uses of the Kien Giang coast

- Aquaculture in Kien Luong, An Bien and An Minh districts

In the 1980s, aquaculture development was promoted in Kien Giang Province. In Kien Luong, An Bien and An Minh districts, mangroves were heavily cleared during aquaculture pond construction. Ponds were manually and mechanically constructed by cutting mangroves, opening short deep channels along pond dykes and within ponds to extend farming areas. The mechanically constructed pond dykes were narrow with a maximum width of 3 metres and close to the open coast. Pond gates were manually constructed along natural rivers or man-made channels to allow for saline water intrusion into ponds. In areas where there were no natural rivers or man-made channels, gates were built through thin mangrove edges to allow the passage of saline water and wild larvae (Fig 8). Pond gates were opened during high tides to collect natural larvae of shrimp, fishes and crabs from the sea, and were closed during low tides. Ponds were constructed mainly on the seaward side of the sea dyke in Kien Luong and An Bien, while ponds were built perpendicular to the sea dyke in An Minh area.

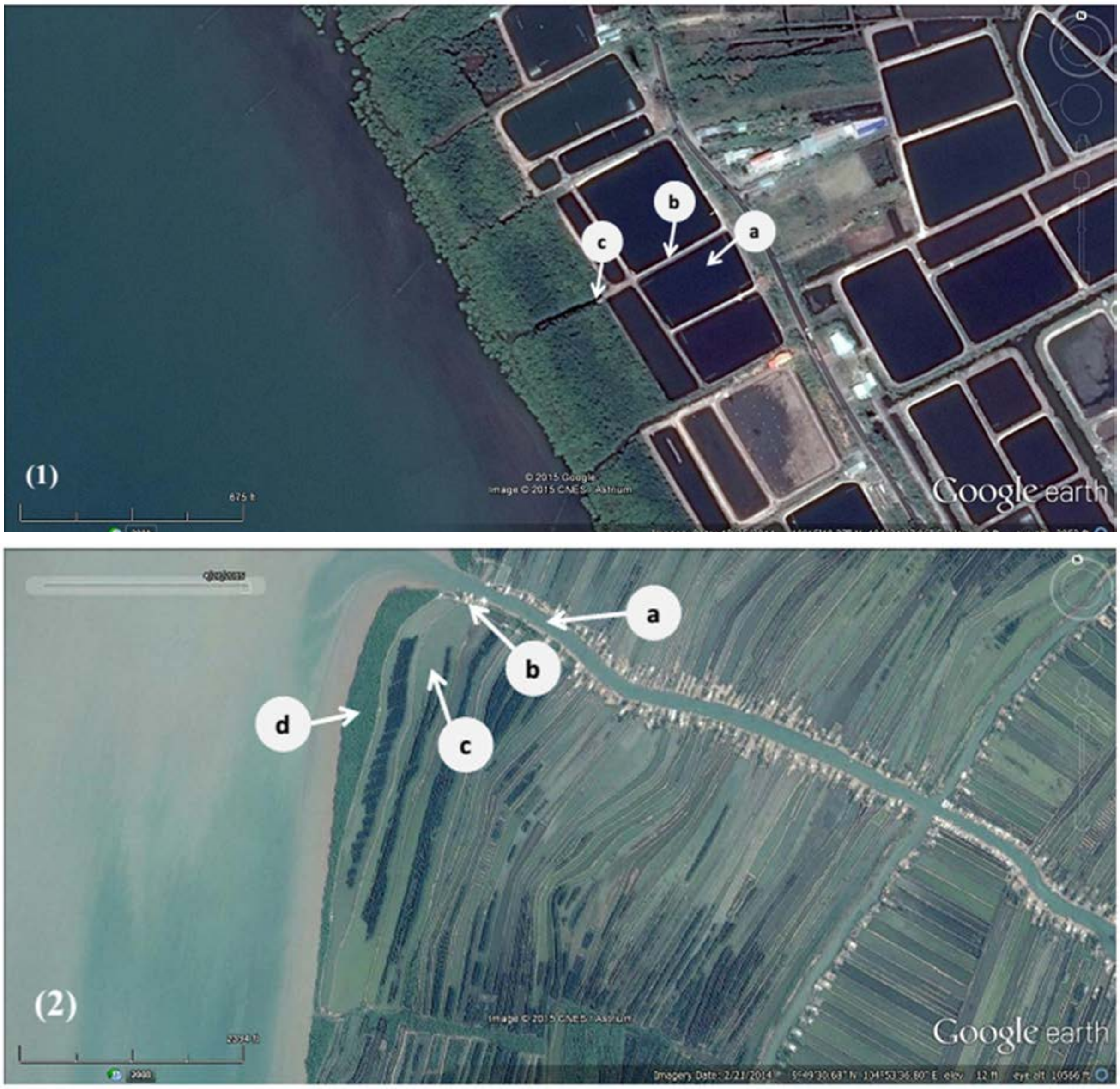


Fig 8: Two pond construction techniques have been repeatedly used over time in Kien Giang Province, (1) pond construction and operation in Kien Luong district, a) pond area, b) pond dyke, and c) a pond gate was opened across the mangrove edges towards the sea to allow saline water into ponds during high tides, and were closed during low tides. *Source:* "Kien Luong coast." 10^{0}15'48.27" N and 104^{0}34'37.06" **E. Google Earth.** 25 December 2014 [Accessed 25 December 2015].

(2) pond construction and operation in An Bien district, a) natural river, b) a gate was constructed adjacent to the river to supply water to ponds, c) coastal mangrove areas cleared to construct ponds for aquaculture, and d) mangrove edges. *Source:* "An Bien coast." 9^{0}49'30.68" N and 104^{0}53'36.80" **E. Google Earth.** 21 February 2014. [Accessed 3 April 2014].

In 1992, most of the Kien Giang coastline was legally protected with the establishment of coastal mangrove protection areas, including areas used for aquaculture. A management mechanism adopted by the Vietnamese government is to allocate mangroves to local community members who are dependent on mangrove resources, for mangrove protection and livelihood improvement (Vietnamese Prime Minister 2001). The allocation program was initially implemented by a policy of the Kien Giang Province in 2005 and revised in 2011. Households and individuals have been allocated mangrove areas in the secondary mangrove belt under contracts to provide for coastal protection and for producing income. Under a contract (valid up to 50 years) issued by the two Management Boards (contractors), households and individuals (contractees) have to protect 70% of allocated areas in return for the right to use 30% of the area for aquaculture, with a condition that the activities pose no threat to mangrove resources (Kien Giang PPC 2005; Kien Giang PPC 2011 a). However, the 2011 policy and contracts (Fig 9) did not provide any technical guidance on pond construction on the allocated mangrove areas. Consequently, contractees constructed ponds on their 30% permitted areas without adequate guidance from the relevant government agencies. In some areas, contractees selected areas comprising mature individual trees of *Rhizophora apiculata* because they wanted to harvest products from the cutting of *Rhizophora apiculata* during pond construction for commercial purposes as the first objective, with aquaculture being a secondary goal. In other cases, contractees ignored allocated area boundaries and constructed aquaculture ponds in areas with adequate water flow close to natural rivers, constructed channels or places with connections to the open sea because much less capital was needed for constructing pond gates and dykes.

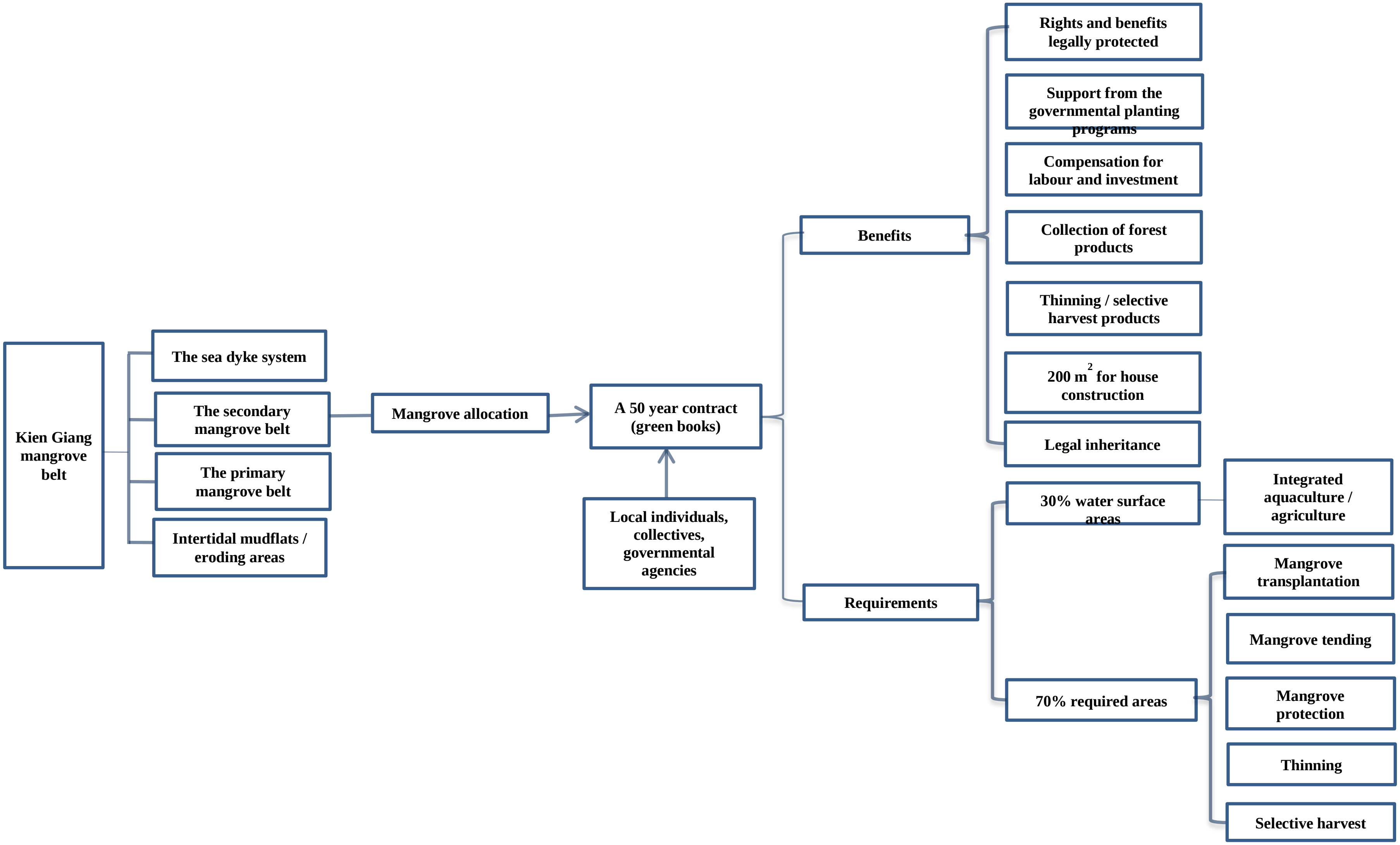


Fig 9: Summary of the allocation process, selection of contractees, and contractual requirements and benefits in relation to mangrove allocation for protection and livelihood improvement in accordance with the 2011 policy in Kien Giang, Vietnam.

- Agriculture on private lands in Hon Dat district

In Vam Ray, Hon Dat district, mangroves were cleared by early migrants for agriculture in the 1970s. In 1980, the Vietnamese Government's New Economic Program began with the resettlement of Vietnamese citizens from elsewhere to the coastal area behind the mangroves of Hon Dat district. Private agriculture areas were constructed by cutting mangroves, opening deep channels within ponds to store fresh water for irrigation, and leaving high elevation areas for growing winter melon, sweet potato, pumpkin and rice (Fig 10).

In 2005, in Hon Dat district, the 30% permitted areas were typically not used either for aquaculture or agriculture production. The reason for this was that the Hon Dat secondary mangrove belt was too narrow as a consequence of continued severe erosion to practice aquaculture and agriculture and that erosion had become more serious. The Hon Dat contractees used their allocated areas for harvesting products from thinning and selective harvests or for collecting naturally recruited marine species (fishes, crabs, shrimps, etc.) for additional income, and used land behind sea dykes for production, such as rice, fruit gardens, and fish farming.

- Sea dyke construction and uses

Earth sea dykes have been constructed in coastal areas rich in mangrove species. The sea dykes were manually and mechanically constructed by clearing mangroves and excavating sediment on both sides of the sea dykes. During various upgrades, sediments were directly taken from the surface of the sea dyke, especially in the Hon Dat area. The sea dyke construction and upgrades resulted in channels being dug on either side of the sea dyke. These deep channels are still found along the earth sea dykes (Fig 11).

While a small number of sluice gates were constructed further inland, most were constructed at the channel mouths in the coastal mangrove edges. The construction at the channel mouths was undertaken by closing channels, clearing mangroves and using sediment from the seaward side.

The surface of the sea dykes has been used by local fishers to grow crops for additional income. Crops included sugar canes, bananas, mustard greens, winter melons, pumpkins, water melons, and okra. Sections of the earth sea dyke in areas of Vam Ray, village of T5 and village of T6 of Hon Dat district were excavated to place water pipes across the dykes to pump saline water to ponds landward of the sea dyke.

- Local boating channels and mangrove cutting

In the 1970s, when mangroves still exhibited a diversity of many mangrove species, many natural small creeks were dredged and more deep channels were opened through the mangroves for boating and transportation of goods between the land and the sea. These small but deep channels and creeks are still to be found in many areas along the coastline (Fig 11).

Mangroves along the shoreline were cut for charcoal and firewood, or for constructing fish nets. As a consequence, mangroves became degraded or lost, and remnants were fragmented with *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Bruguiera gymnorrhiza* dominating.

In 1985, Vam Ray's agriculture land was extensively flooded. To save local agricultural production, the dyke was purposefully breached. A long channel was also opened across the mangrove belt in front of the sea dyke by the locals to discharge flood water into the sea, despite the opposition of the local authorities.

Storm Linda in 1997 caused significant mangrove destruction. Disastrous flash flood events in 2000, 2001 and 2002 caused local communities to cut through the earth sea dyke system and mangroves, to discharge flood water from Kien Luong, Hon Dat, An Bien and An Minh districts.

- Afforestation using a single mangrove species

In 1992, most of the Kien Giang coastline was legally protected with the establishment of coastal mangrove protection areas, including areas used for aquaculture. Local communities were encouraged to plant the propagules of *Rhizophora apiculata* and seeds of *Avicennia marina* along the shoreline, even within their ponds. The communities were provided with propagules and seeds, and were paid for costs of planting (at a density of one tree per square metre) and protecting trees for up to three years. As there were no specific guidelines on transplantation, mature trees of *Avicennia marina* were cut and replaced with propagules of *Rhizophora apiculata.* The communities grew the propagules of *Rhizophora apiculata* on the high elevation areas within ponds, on pond dykes, and even in pond channels because *Rhizophora apiculata* was easy to transplant. As a consequence, the whole Kien Giang coastline is now dominated by *Rhizophora apiculata*.

Between 2005 and 2011, contractees were paid an amount of USD 15 per hectare per year for protecting and afforesting mangroves on the required 70% of allocated areas. Contractees, who received allocated areas with less than 70% being covered by mangroves, were contractually required to transplant seedlings or propagules of *Rhizophora apiculata* to meet the requirement. However, contracts provided no technical guidance on planting methods. A majority of the contractees did not want to undertake the transplantation because it reduced economic viability, instead choosing to construct aquaculture ponds on the 70% protection areas, even though they knew that it was illegal. To date, only a few contractees, particularly those who did not depend on mangrove farming and agriculture production for income, have satisfied the contract requirements in relation to forested areas.

Contractees who satisfied the contractual requirements in relation to mangrove protection and afforestation are permitted to undertake thinning and selective harvests in their protected 70% areas to derive income. Mature trees of *Rhizophora apiculata* at ages between 5 and 6 years are permitted to be thinned and mature *Rhizophora apiculata* trees between the ages of 10 and 15 are permitted to be selectively harvested to a minimum density of 5,000 mature trees per hectare (evenly distributed). Income from thinning and selective harvests went to contractees, adding to the income derived from aquaculture. Contractees are required to undertake transplantation after selective harvests are completed. However, there has been limited success in transplantation because propagules of *Rhizophora apiculata* were not well protected from strong waves and contractees had no incentive to ensure the mangroves grew, resulting in low survival rates.

Fig 10: Typical agriculture production on private lands in Hon Dat district, a) the earth sea dyke, b) the deep channel on the sea ward side, c) crops planted on high elevation areas within ponds, and d) deep channels within ponds to store fresh water for irrigation. *Source:* “Hon Dat coast.” $10^0$12’26.64” N and $104^0$47’22.92” **E. Google Earth.** 31 December 2014. [Accessed 25 December 2015].

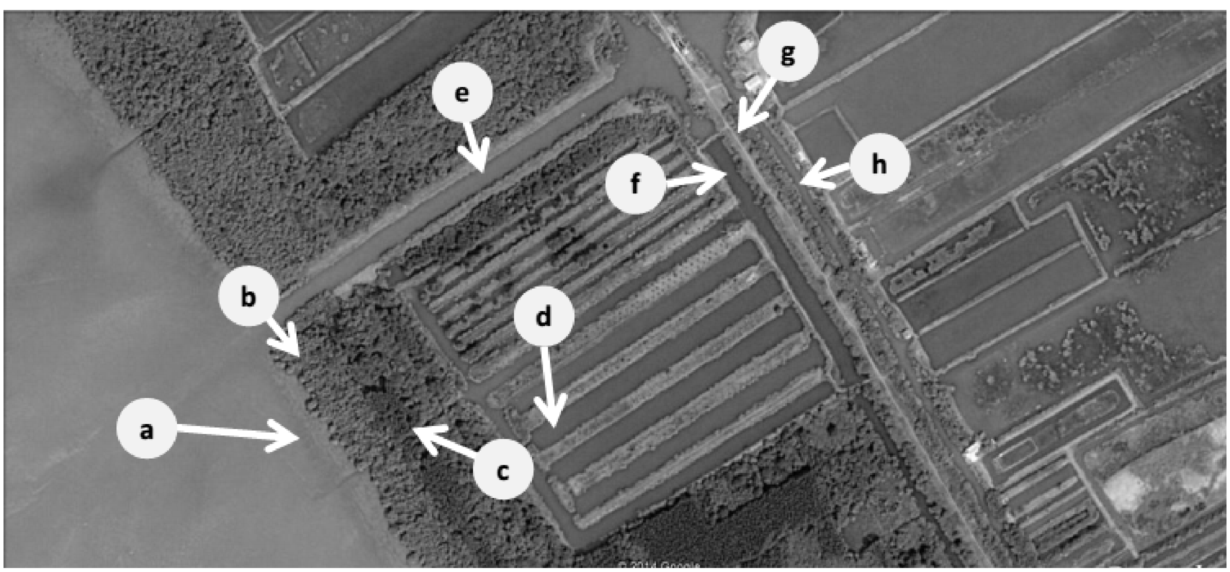


Fig 11: A typical mangrove belt in Kien Giang Province, a) intertidal mudflats, b) the primary mangrove belt, c) the secondary mangrove belt, d) seaward aquaculture ponds, e) a local boating channel, f) the channel on the sea ward side, g) the earth sea dyke and h) the channel on the landward side. The mangrove belts, intertidal mudflats and eroding coastal areas are managed by the management boards, while open sea water surface are under direct administration of the district people’s committees of Kien Luong, Hon Dat, An Bien, An Minh and the city people’s committee of Ha Tien. *Source:* “Hon Dat coast.” $10^0$10’22.95” N and $104^0$49’34.82” **E. Google Earth.** 3 April 2012. [Accessed 21 February 2014].

- Land uses and land use planning

Some local farmers living within the boundaries of the Hon Dat – Kien – Ha Coastal Mangrove Area Management were issued with land use right certificates (red books). In 2015, 8 households from Ta Sang village, Duong Hoa commune, Kien Luong district covering 11 hectares of the coastal area, and 22 households from Tho Son and Luynh Huynh communes, Hon Dat district covering 71 hectares were issued with red books. Farmers issued with land use right certificates are legally permitted to cultivate and / or farm aquaculture and agriculture on their land, normally resulting in mangrove clearance, aquaculture pond construction and construction of bunds for growing agricultural crops along the coast.

Residential areas, industrial zones, tourism facilities, and administrative areas were constructed with permission from the Kien Giang provincial people's committee. This construction disconnected coastal mangrove belts and created substantial gaps in the mangrove belts between Kien Luong district and Ha Tien town.

The open sea water areas located beyond the boundary of coastal mangrove belts are administratively managed by the district people's committees of Kien Luong, Hon Dat, An Bien, An Minh and the city people's committee of Ha Tien. The open sea area in An Bien and An Minh has been leased for farming bivalves and molluscs for many years. Kien Luong district established a 500 hectare pilot program for the same purpose. An application was lodged to the Hon Dat people's committee to lease the sea area for blood shell culture. Young blood shell is either purchased elsewhere or collected from intertidal mudflats in front of the mangrove belts. However, in some areas, the open sea administered area overlaps intertidal mudflats located beyond the primary coastal mangrove belt leading to conflicts of interest between the coastal mangrove contractors and open sea water lessees. Despite boundaries demarcated clearly in places, lessees expanded their farming areas illegally into mangrove belts by clearing naturally regenerated mangroves. Further, lessees used push nets to catch wild young blood shell on intertidal mudflats, where young trees of *Avicennia marina* regenerated naturally, resulting in the trees being killed.

- Coastal erosion processes

Between 2000 and 2008 strong waves during high tides propagated along the boating channels through fragmented mangroves and agriculture areas and caused erosion in the deep channels, leading to further loss of mangroves and the sea dykes being seriously breached in Vam Ray area, Hon Dat district. Agricultural products behind the sea dyke were badly damaged by saline intrusion and damage to the earth sea dyke. As a consequence, the whole area was isolated, resulting in the local people, especially school children, having to cross the sea dyke on foot in May 2009 (Fig 12).

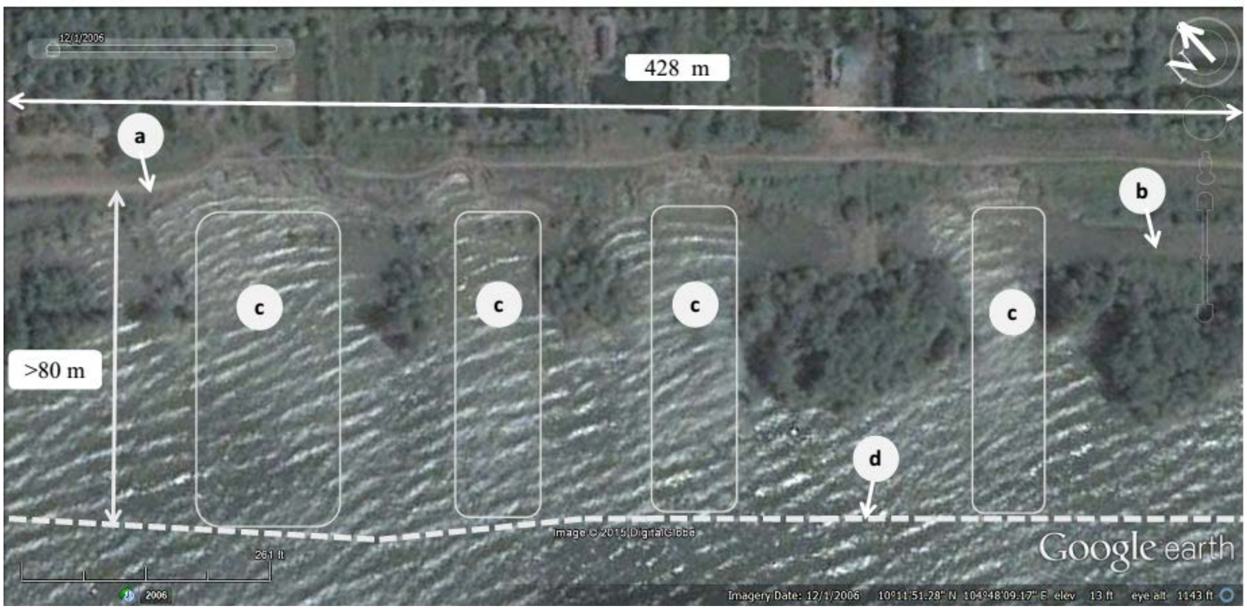


Fig 12: The Vam Ray severely eroding area in 2006, a) the breached earth sea dyke, b) the deep channel, c) the local boating channels, d) the mangrove edge in the 1980s. The presence of the deep channel on the seaward side, the boating channels and fragmented mangroves contributed significantly to the severe erosion. *Source*: "the Vam Ray coast." $10^0$11'51.28" N and $104^0$48'09.17" E. **Google Earth**. 1 December 2006. [Accessed 3 April 2012].

Strong waves together with high tides breached the thin pond gates and destroyed the thin and weak pond dykes, with waves propagating into the channels, causing serious coastal erosion in some areas along the coastlines of Tay Yen (An Bien district), Thuan Hoa, Dong Hung A, Van Khanh Dong, Van Khanh and Van Khanh Tay (An Minh district) between 2000 and 2008. Abandoned ponds and remnants of pond dykes can still be seen along the shoreline on low tides (Fig 13).

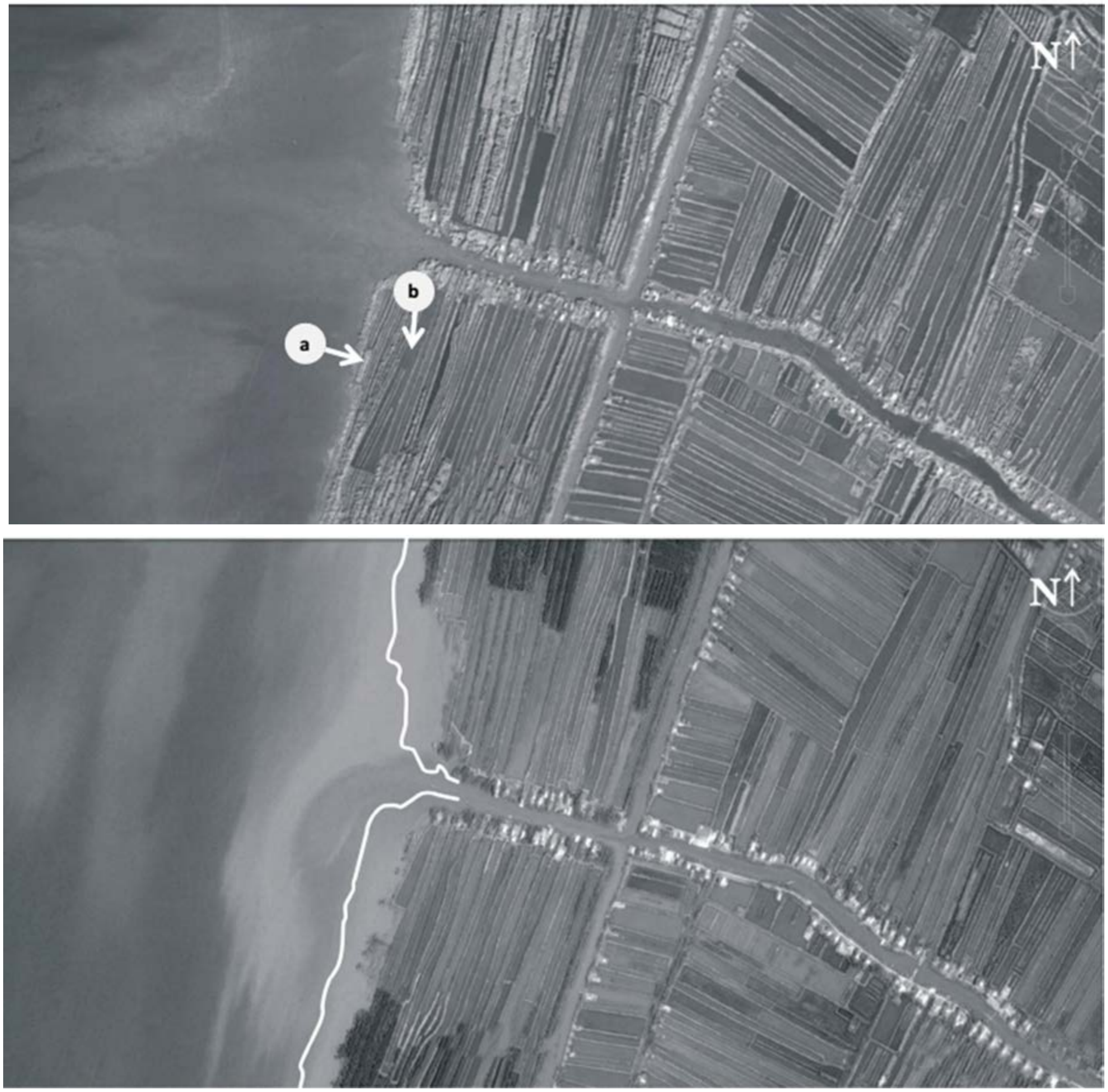


Fig 13: A coastal section of Thuan Hoa commune, An Bien district was actively eroded over time. In the top image in 2008, a) thin mangrove edge, b) pond area. *Source*: “the coast of Thuan Hoa.” $9^0$47’09.63” N and $104^0$52’54.54” E. **Google Earth.** 21 January 2008. [Accessed 31 January 2015]. In the bottom image, the white line represents the thin mangrove edge in 2008. Thin mangrove edges were lost and narrow and thin pond dykes were broken, resulting in ponds being abandoned. *Source*: “the coast of Thuan Hoa.” $9^0$47’09.63” N and $104^0$52’54.54” E. **Google Earth.** 21 February 2014. [Accessed 31 January 2015].

Burrows of brackish water fiddlers (*Uca minax*) occur at high density among the roots of *Rhizophora apiculata* in Vam Ray (Hon Dat district), Thuan Hoa, Tan Thanh (An Bien district) Dong Hung A, Van Khanh Dong, Van Khanh, Van Khanh Tay (An Minh district). Many mature trees of *Rhizophora apiculata* experienced sediment deficit around their roots.

Strong waves on high tides were observed to have penetrated into burrows, weakening the coastal soil structure and making it susceptible to collapse. Many mature trees of *Rhizophora apiculata,* which experienced sediment deficit around their roots, were observed to have been uprooted under the influence of strong waves on high tides or to die (Fig 14).

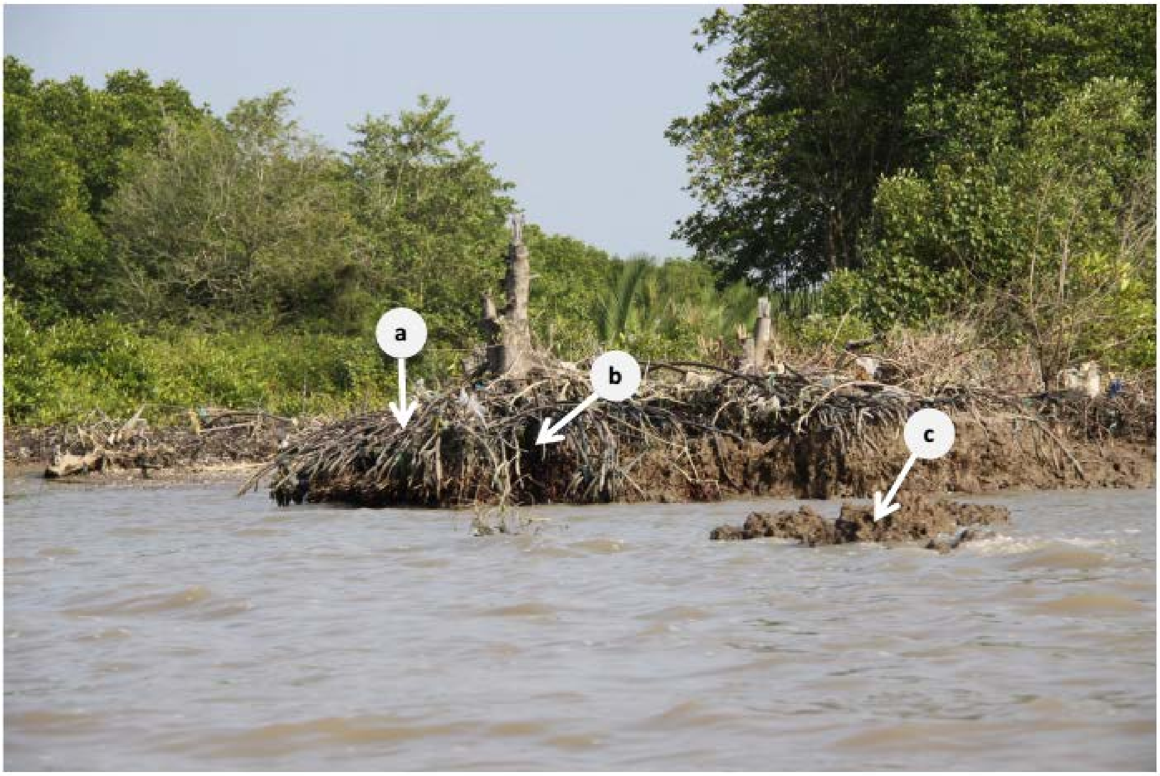


Fig 14: A location in Van Khanh Dong commune, An Minh district was badly eroded, a) a mature tree of *Rhizophora apiculata* experienced sediment deficit around the roots, causing the tree to die, b) a burrow enlarged over time, and c) a massive vertical collapse as a consequence of strong waves propagating into dense burrows with force. Huong Nguyen 2010. Photograph.

3.5. Local acknowledgement

At the start of this study, the communities of Kien Giang Province did not link their activities, and activities sanctioned by, or caused by, present or past government policies, with coastal erosion and mangrove degradation. By the end of the study, and through participation in the debriefing sessions, people in the communities and staff of government agencies were very aware of, and accepted that their practices, current and past management of the coast were significant contributors to coastal erosion (see Appendix 3). Currently, DARD is considering terminating the right to thin and selectively harvest in contracts. Termination of thinning and selective harvests would presumably cut income from these activities. To compensate for this cut, payment for annual mangrove protection and afforestation on the 70% required mangrove areas may be increased.

3.6. New knowledge regarding the relationship between human activities, management interventions on the Kien Giang coast and coastal erosion

3.6.1. Sea dyke construction and upgrades, and coastal erosion

There is clear evidence of poor sea dyke construction processes. Article 7 of *the 2006 Law on Dykes* clearly stipulates that the use of soil, rocks, sands and minerals and the construction of fish ponds are prohibited within the sea dyke protection corridor. Under Article 23 a and b, the sea dyke protection corridor is defined as at least 5 metres from the sea dyke toe on the landward side in urban areas and tourism destinations, and 25 metres in other areas, and 200 metres from the sea dyke toe on the seaward side of the dyke. The dyke upgrade in the 1980s using sediment excavated mechanically on both sides of the dyke and from the dyke surface, therefore violated Article 7, Article 23 a and b of *the 2006 Law on Dykes* (Vietnamese National Assembly 2006) and the Design Guideline on the Sea Dyke System and Sea Dyke Protection Works (MARD 2002 b). The sea dyke construction has jeopardised the structural integrity of the mangroves. As a consequence, the mangroves have become more vulnerable to erosion, especially during the rainy season. The findings are in accordance with those by Paez-Osuna (2001), Valiela et al. (2001), Han (2002), Bhandari & Nakamura (2004), Thampanya et al. (2006), Martin et al. (2005), and Ramesh et al. (2011).

From 2009 and up until 2020 the sea dykes in Kien Giang are to be raised and reinforced with cement and new sluice gates are to be constructed in response to climate change and sea level rise. If techniques for constructing sea dykes (using sediment from either side) and sluice gates (clearing mangroves and excavating sediment from the same location) remain unchanged, the erosion will continue and potentially worsen.

Proper application of *the 2006 Law on Dykes* is recommended for sea dyke construction agencies and local coastal communities to avoid the use of sediments from the sea dyke protection corridors

3.6.2. Sluice gate operation and density, and impacts on the shoreline

In Kien Luong and Hon Dat districts, silts and clay are deposited behind the sluice gates in the dry season, when they are closed. When sluice gates are opened in the wet season, flood water transports fine sediments into the nearshore, and they are then carried onshore by currents developed by the dominant north-east winds, and potentially deposited in the mangroves. Where mangroves have been removed, natural processes of sediment accumulation are disrupted and in the following dry season, south-west winds transport the silts out of the areas devoid of mangroves.

The density of sluice gates is another controversial issue. At present, 31 sluice gates have been constructed between Ha Tien and An Minh. No comprehensive studies have been undertaken to understand if there is a link between the operation and density of sluice gates and the impacts on the coastline. A further 64 new sluice gates are proposed (Kien Giang PPC 2011 b) and the impact on the coast is not known. Therefore, studies should be undertaken to understand negative impacts of sluice gates on sedimentation and current flows before more sluice gates are constructed

3.6.3. Aquaculture and coastal erosion

Othman (1994), Clark (1996), Masalu (2000), Primavera (2006) and Sohel & Ullah (2012) and CDBRP (2010 a; 2010 b) identified aquaculture as a likely cause of mangrove loss. It is clear from this study that pond construction techniques (mangrove areas cleared to construct aquaculture ponds, construction of narrow pond dykes and the opening of boating channels) significantly contributed to severe mangrove deforestation and coastal erosion. The Ben Tre coastline, on the eastern side of Mekong Delta of Vietnam was eroded by similar activities (Nguyen 2015 a; Nguyen 2015 b).

While mangrove areas continued to be allocated for both protection and mangrove based aquaculture under a provincial level decision, the same pond construction techniques continue to be used. If the techniques are not redesigned or improved, coastal erosion, as has occurred in Kien Luong, Hon Dat, An Bien and Minh districts, will occur elsewhere, especially under the influence of climate change, and sea level rise.

3.6.4. Afforestation using a single species and coastal erosion

As a result of the application of planting programs, since 1982, the Kien Giang coast has become dominated by *Rhizophora apiculata,* changing the previously mixed mangrove community, and weakening the resilience of the community and the coastal protection that mangroves provided. The dominance by *Rhizophora apiculata* significantly contributed to coastal erosion processes and mangrove degradation in Ben Tre province of Vietnam (Nguyen 2015 a; Nguyen 2015 b). In addition, Nguyen (2015 a) showed that Avicennia species developed their root systems in the mud, which led to resilience to strong wave events, while Rhizophora species spread their roots on the surface and were easily damaged.

3.6.5. Land uses and land use planning

The coastal mangrove areas were established as a strategic measure to control coastal erosion, reduce negative impacts of natural hazards and to promote sustainable coastal development. However, local farmers and local government agencies promoted coastal development (saline water aquaculture development, agriculture development residential areas and coastal industrial zone development) for socio-economic purposes in overlapping areas (Kien Giang PPC 2012). Land use right conflicts, management overlaps and uncoordinated land use planning resulted in coastal mangroves being degraded or deforested. Providing a balance between coastal natural resource management and the demand for socio-economic development is a major challenge. If a balance is not achieved in the future, the coastal mangroves will be further degraded and deforested.

3.6.6. The 2011 Kien Giang Mangrove Allocation Policy

The understanding of roles and responsibilities of the contractor and contractees with respect to coastal mangrove protection and aquaculture has been poor. Different understandings of the policy have resulted in inconsistent planning and management. As a consequence, contractees have been confused about the policy, resulting in aquaculture and mangrove protection being ineffectively and inefficiently practiced in almost all areas.

Improper technical guidance on the most effective ways to implement and use the permitted aquaculture areas led to gaps among established mangroves, thereby reducing the density and capacity of mangroves to protect from storm surges and sea level rise. Pond construction and aquaculture techniques (mangrove areas cleared to construct aquaculture ponds, construction of narrow pond dykes and the opening of boating channels) have caused even more mangrove degradation and coastal erosion, as described in Chapter 3.

Contracts have been poorly enforced. The 2011 policy stipulates that contractees, who failed to fulfil contractual requirements would be fined or deprived of their contracts. Despite this, only a small number of contractees satisfied the contractual requirements (CDBRP 2013). Transplantation using *Rhizophora apiculata* to achieve the 70% required forested areas was of limited success because no technical guidelines were made available to guide transplantation. Further to this, transplantation using a single species (rather than a more natural species assemblage) significantly contributed to mangrove degradation and erosion (Nguyen 2015 b). It is recommended that the lessons learned from previous inappropriate pond construction and single species planting need to be incorporated into future coastal management programs to avoid the same mistakes elsewhere in the Mekong Delta region and in other South and Southeast Asian countries. Detailed technical guidance needs to be given to regulate aquaculture operation, mangrove protection, and afforestation, and to configure mangrove allocated areas.

3.6.7. Thinning and selective harvests

The permitted thinning and selective harvests of *Rhizophora apiculata* seems to be contradictory to the objective of the 2011 policy that aimed to establish the coastal mangrove belt in response to climate change and sea level rise. The Kien Giang coastline is now dominated by *Rhizophora apiculata* species as a consequence of continued transplantation of a single species. Thinning reduced the density of coastal mangroves, weakening the adaptive capacity. Selective harvest of mature trees of *Rhizophora apiculata,* even controlled properly, undoubtedly reduced the capacity of coastal mangroves to protect sea dykes and properties inside the sea dykes in cases of storm surge and sea level rise (Nguyen 2015 a; Nguyen 2015 b). Uncontrolled selective harvests can create substantial gaps and disconnections in mangrove barriers, making the entire coastline vulnerable to coastal erosion and degradation. Permitted thinning and selective harvests should be reviewed.

3.6.8. Total allocation areas

There were three categories of mangrove allocations: a) less than 1 hectare; b) between 1 hectare and 3 hectares; and c) greater than 3 hectares. At present, the integrity of Kien Giang mangrove belts is compromised by hundreds of ponds of a range of sizes. Allocation and transfers of areas less than 1 hectare within current mangrove belts, if continued, would fragment continuous patches of mangroves into even smaller, isolated mangrove fragments. Smaller and isolated mangrove fragments are likely vulnerable to erosion under the influence of strong waves on high tides. Mangrove fragmentation will jeopardise the structural integrity of Kien Giang mangrove belts. Allocation of areas less than 1 hectare must be discontinued.

3.7. Conclusions

This chapter presented the integration of local and scientific knowledge in exploring the relationship between human activities and coastal erosion in Kien Giang, Vietnam. Use of published sources of information in collating, linking, justifying the activities which used local knowledge, through a two way communication process, has resulted in both a better understanding of the causes of coastal erosion and the awareness of the impact of community activities on the coast being improved.

At the beginning of the study, members of the local community only recognised external factors with coastal erosion, none of their own actions. While adverse effects of climate change and sea level rise have been widely recognised, human activities (poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels) have jeopardised the structural integrity of the mangroves and contributed to coastal erosion. The interaction of anthropogenic activities and physical processes are significant contributors to erosion. Improper technical guidance on the configuration of mangrove allocation, mangrove protection and afforestation methodologies, and permitted thinning and selective harvests led to the creation of substantial gaps and disconnections in the established mangroves, making the entire coastline vulnerable to coastal erosion. Knowledge gaps and necessary policy changes are also identified.

The next chapter describes the integration of local and scientific knowledge for effective management of an eroding mangrove dominated muddy coast in Vam Ray, Kien Giang, Vietnam.

CHAPTER 4[4]

INTEGRATION OF LOCAL AND SCIENTIFIC KNOWLEDGE FOR EFFECTIVE MANAGEMENT OF AN ERODING MANGROVE DOMINATED MUDDY COAST IN VAM RAY, KIEN GIANG, VIETNAM

This chapter uses two different sources of data and information considered: a) published reports by CDBRP (2011 a; 2011 b), DARD (2007 a; 2007 b; 2009 a), and work previously undertaken by the author while working as a technical staff for CBBRP between 2009 and 2012, a part of which was reported by Nguyen (2012) and was treated as a secondary source of this research, and b) the findings of this research between May 2013 and May 2016 obtained using the methodology and methods described in Chapter 2. Use of the two different sources of data and information aim to adequately and comprehensively illustrate how local knowledge was successfully integrated with scientific knowledge for developing ecologically based, cost-effective strategies for successfully controlling coastal erosion in Vam Ray of Kien Giang Province.

4.1. Introduction

Mangrove dominated muddy coasts can be eroded as a result of the negative impacts of over-exploitation for agriculture, aquaculture, industry, and settlements (Han 2002; Primavera 2006; Ramesh et al. 2011), by a deficit of sediments delivered to the coast from major rivers (Fan et al. 2004), and / or by adverse effects of natural factors including sea level rise and climate change (Bao & Healy 2002; Wang et al. 2002 b; Lee et al. 1994; Asian Development Bank 2010).

[4] This chapter has been written as three manuscripts, two of which have been published as at the time of thesis submission; 1) **Community Perspectives on an Internationally Funded Mangrove Restoration Project,** accepted and published by Journal of Ocean & Coastal Management in 2016 (119): 146 -154**;** 2) **Gradual Expansion of Mangrove Areas to Stabilise and Eroding Muddy Coast,** submitted to Ecological Engineering Journal in November 2015; and 3) **Mangrove Restoration: Establishment of a Mangrove Nursery on Acid Sulphate Soils**, accepted and published by Journal of Tropical Forest Science in 2016 (28-3): 275 – 284.

Two common strategies for managing eroding muddy coasts are engineering solutions and ecological engineering solutions. In engineering solutions, (shoreline and offshore) structures are used to reduce the wave energy reaching the shore through dissipation, refraction, or reflection of incoming waves (Nordstrom 2000; Weigel 2002; Dugan et al. 2011). Ecological engineering solutions involve transplantation of mangroves or a combination of mangrove planting and engineering solutions for reducing negative environmental impacts caused by built infrastructure or providing a more natural habitat for species other than people (Bergen et al. 2001; Winterwerp et al. 2005; Dafforn et al. 2015; Thampanya et al. 2006; Borsje et al. 2011).

Vam Ray was one of the most severely eroded locations in Kien Giang Province (CDBRP 2010 a; CDBRP 2010 b). The Vam Ray coast was eroded by 2005, but the situation became serious in 2009. Erosion and breaches of the earth sea dyke and consequent saline intrusion badly affected agricultural production in the period prior to 2008 in Vam Ray. Mangroves had been gradually destroyed. The remaining mangroves, dominated by *Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata, Avicennia marina,* and *Sonneratia alba*, were fragmented (CDBRP 2008 a) (Fig 15).

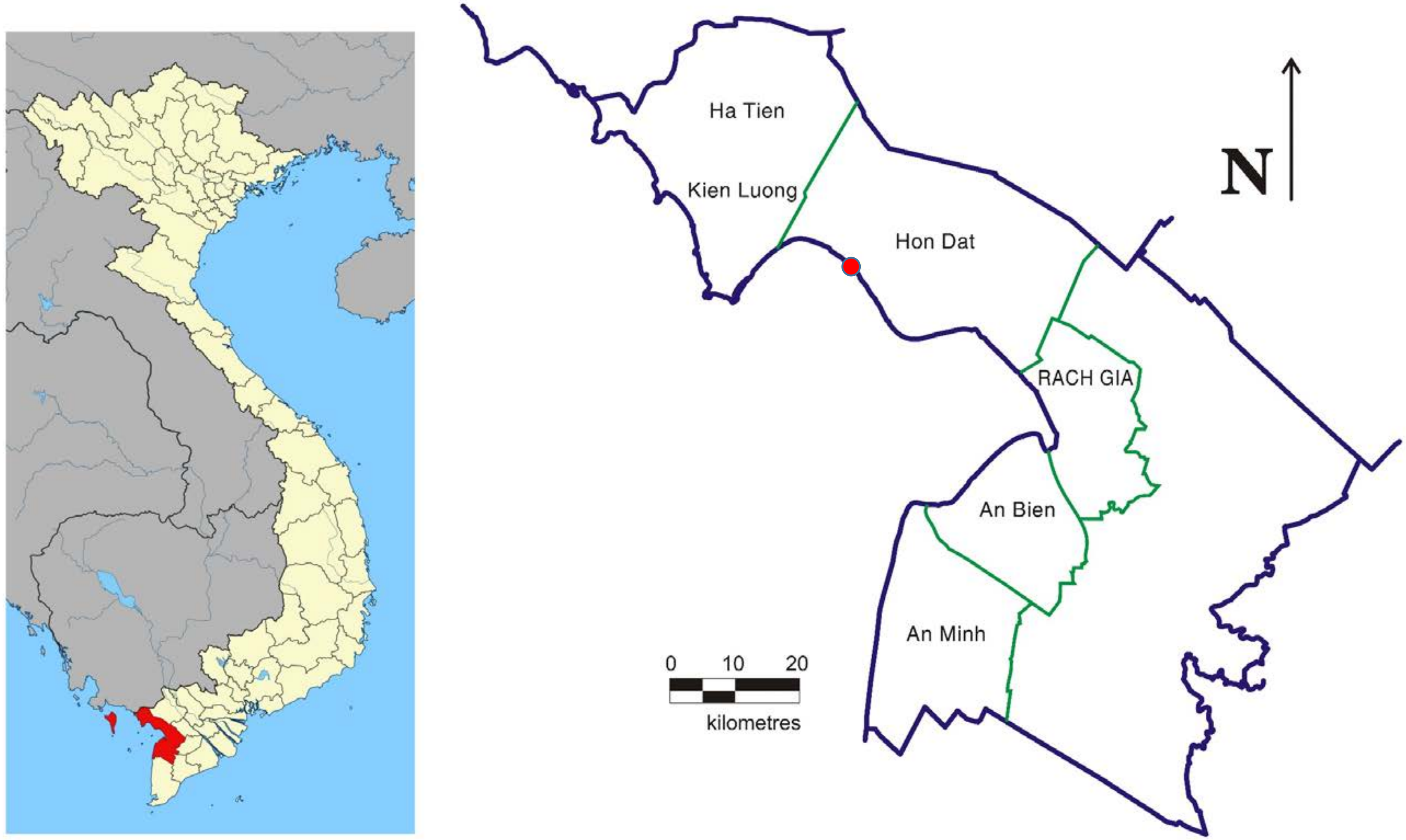


Fig 15: Vam Ray, the study site (red dot), Hon Dat, Kien Giang Province, Vietnam. The left map is Google map.

Ecological engineering methods were used by the Forestry Project Management Board under direct management of DARD on an actively eroding muddy coast (3.66 hectares) in the Vam Ray area, Binh Son commune, Hon Dat district, Kien Giang Province between 2006 and 2008. The project upgraded the earth sea dykes and transplanted a single mangrove species (*Avicennia marina*) supported by a long fence made of Eucalyptus poles (890 metres seaward of the earth sea dyke) (DARD 2007 a; DARD 2007 b). However, the Eucalyptus fences were not as effective as planned, the mangroves were uprooted by strong waves, and were weighed down and killed by marine debris (mainly plastic bags) floating onshore (DARD 2009 a). As a consequence, the program failed and no seedlings survived after two years (Nguyen 2012) (Fig 16).

Fig 16: Many seedlings died, either under the influence of strong waves or were weighed down by floating wet plastic bags. Huong Nguyen. 2009. Photograph.

4.2. Establishment of a partnership, local perspectives, and integration of local and scientific knowledge for developing solutions to coastal erosion

DARD recognised the limitation of its capacity in controlling coastal erosion, and the importance of mobilising potential sources for developing strategies for coastal erosion control in Kien Giang Province. In 2009, DARD suggested a partnership among the Vam Ray community, DARD, and CDBRP in search for strategies for controlling muddy coastal erosion in Vam Ray (DARD 2009 a). In this partnership, DARD was responsible for constructing the new sea dyke section in Vam Ray, CDBRP and the Vam Ray community used local knowledge, scientific understanding in relation to Vam Ray coast, and local resources for developing solutions to coastal erosion. CDBRP funded a pilot project, where I was involved as technical staff, to pursue this partnership in May 2009 (Nguyen 2012).

The Vam Ray people, having observed failures in the past, were certain that previous practices could not be emulated if the mangrove restoration was to be successful. The Vam Ray people could not afford new expensive technologies and were not sure if knowledge from outsiders could help solve problems (Nguyen 2012). Likewise, all relevant parties agreed to incorporate local knowledge, to build local capacity and to utilise as many local resources as possible, so that if the model were successful, it would be easy to replicate elsewhere (Nguyen 2012). The partnership facilitated a series of consultation events and participatory meetings organised with the relevant stakeholders, including DARD, the Management Board of Forestry Projects of DARD, CDBRP, and the Vam Ray community in 2009. As a result, current management of mangrove dominated muddy coasts and lessons learnt elsewhere in relation to coastal erosion control were shared among the relevant stakeholders for a broad understanding (Nguyen 2012). Apart from the shared understanding, lessons learnt of the previous failures (an inappropriate planting time, poor seedling quality and the Eucalyptus fences not providing appropriate protection) were collected and analysed and a thorough understanding of the physical characteristics and dynamics of the restoration area was gained (Nguyen 2012).

By taking account of established practices and by being given the opportunity to apply them to the local situation, the Vam Ray people were willing to work with project staff, and government staff through co-learning processes and made informed decisions to solve their own problems (Nguyen 2012). In order to assist the locals in solving their specific problems, local knowledge held by individuals, and local contexts were systematically collected and brought together with the relevant scientific knowledge into solutions for controlling coastal erosion (Nguyen 2012). The solutions were: a) production of high quality seedlings of mangroves on acid sulphate soils; b) upgrading traditional Melaleuca fences into sea mud accumulation fences; and c) gradually stabilising the eroding area using the upgraded Melaleuca fences that helped accumulate sea mud and promote natural regeneration. The results in relation to production of high quality seedlings of mangroves were obtained from this research. The upgrade of Melaleuca fences and gradual expansion of mangrove areas, was previously reported by Nguyen (2012), but is repeated for this chapter to provide further information regarding the integration process and relevant lessons learnt.

4.3. The new solutions and their testing process

4.3.1. Production of high quality seedlings of mangroves on acid sulphate soils

The technical guidelines on nursery construction, mangrove seedling propagation and tending were understood by the relevant stakeholders as a result of a series of consultation events, and participatory community meetings in 2009. Ideas for mangrove nursery construction were then developed further into detailed strategies for constructing an effective nursery, within a local context and with an understanding of the area’s dynamics. Because of the nursery’s location inland from the sea, a major challenge was to reasonably simulate natural environmental conditions, so that seedlings were not subject to stress when transplanted. The nursery construction strategies included construction of a nursery site near the restoration site to ensure easy logistics and to ensure local involvement (this being a strong desire of government agencies, the Management Board of Forestry Projects of DARD and CDBRP), the use of local mangrove seeds / propagules for propagation and local materials for construction, and to ensure seedlings were treated and grown as close to their future habitat as possible to ensure the highest chance of survival.

A nursery (15 metres x 35 metres) was constructed in June 2009 landward of the damaged earth sea dyke commencing in May 2009, on the property of Tong Van Anh. The nursery was unlike most others, being somewhat inland of the sea, and in an area of actual acid sulphate soils and acidic water during the wet season. It was believed by the residents that the soil would not support tree growth. The local residents suggested that a 50 centimetre layer of liquid sea mud put on the sediment surface would be sufficient to keep acidic water from coming to the surface. This was done before any seedlings were established in the nursery.

Materials used to construct the nursery were locally made and traded products. Melaleuca poles (*Melaleuca cajuputi*) and Eucalyptus poles are sustainably harvested from Kien Giang's production forests, while small gauge fishing nets and bamboo mats are locally made and are readily available (traded by the kilogram). Small gauge fishing nets were placed around the nursery to stop insects and domestic animals. Two thirds of the nursery area was covered with fishing nets to shade mangrove seedlings from the sun.

Mangrove seed and propagule collection commenced in June 2009. Seeds and propagules were collected from two areas of Kien Giang province, Rach Dung (Kien Luong) and Xeo Ro (An Bien), sharing the same mangrove species (*Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba,* and *Nypa fruticans)* with the Vam Ray area. At the recommendation of MARD (2002 a), seeds and propagules were collected in areas where mother trees were a minimum 13 years old.

June is not the time when all seeds and propagules of the five mangrove species along the Kien Giang coast are mature, resulting in difficulty in collecting sufficient stock. To overcome the difficulty, local laborers at seed collection sites were employed to collect and store mangrove seeds and propagules in shady areas before they were transported to the nursery site. Traditional 'long-tail' boats and trucks were employed to transport mangrove seeds to the nursery construction site. Mangrove seeds were covered with wet banana leaves or wet palm leaves or stored in wet bags. Mangrove seeds were transported from collection sites in early morning and arrived at the construction site around noon the same day.

Potting took place in June 2009. As standard pots were difficult to source, plastic shopping bags of different sizes, available locally, were used for potting the mangrove seeds and seedlings. Bags were holed before they were filled by hand with liquid sea mud, collected at low tide from the mud flats using buckets which were normally used by residents for storing rain water (Fig 17).

Fig 17: Liquid sea mud collected to fill plastic shopping bags. Thua Nguyen. 2009. Photograph.

After filling, the bags were transported to the nursery ground. Mangrove seeds of *Avicennia marina, Sonneratia alba* and *Nypa fruticans,* and propagules of *Rhizophora apiculata* and *Bruguiera cylindrica* were not propagated into filled bags until liquid sea mud dried out so that seeds and propagules could be firmly placed during propagation. Unlike many restoration projects, *Rhizophora apiculata* (3 per pot) and *Bruguiera cylindrica* (5 per plot) were potted with more than one individual in an attempt to increase survival rates during the transplantation. *Avicennia marina, Sonneratia alba* and *Nypa fruticans* were potted as single individuals (Fig 18).

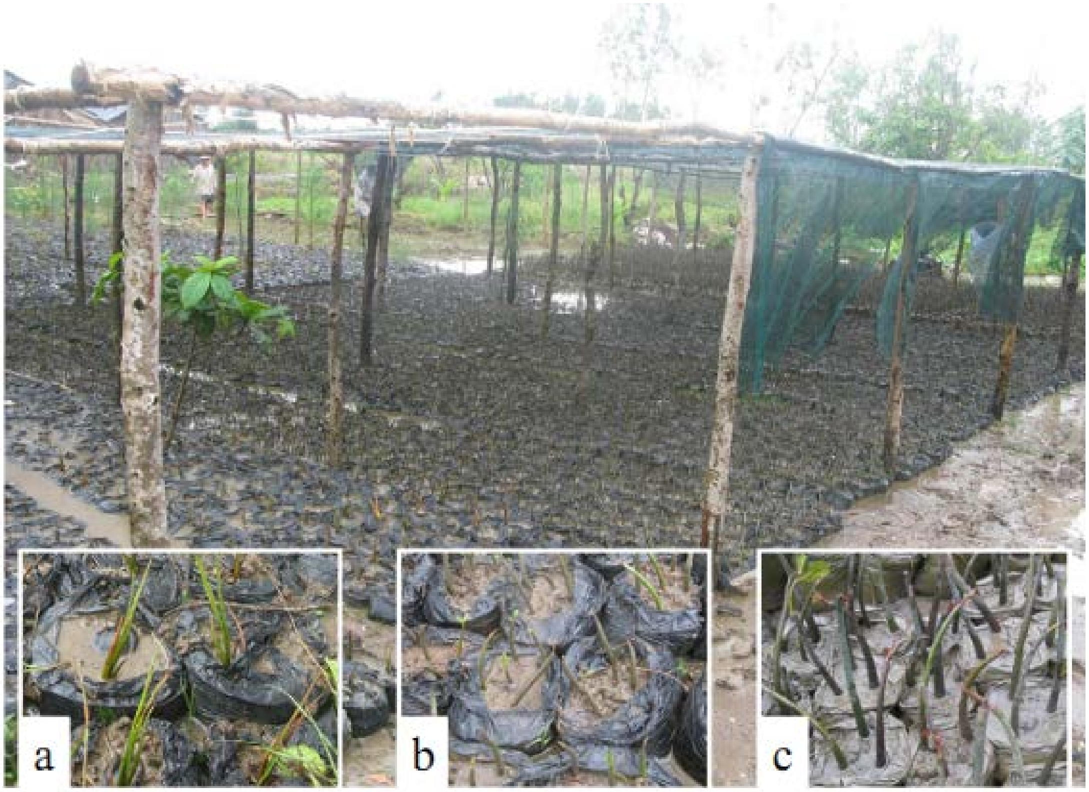


Fig 18: Propagation of mangrove seedlings a) *Nypa fruticans* propagated with single seed per pot, b) *Bruguiera cylindrica* with five propagules, c) *Rhizophora apiculata* with three propagules per pot, placed on a 50 centimetre thick sea mud, overlying acid sulphate soils.

The reasoning behind planting multiple propagules in one pot for *Rhizophora apiculata* and *Bruguiera cylindrica* was to enable the seedlings to support each other in a cluster, and therefore assist survival when exposed to strong waves. In addition, at transplantation time, clusters of these species were planted at high density to assist re-colonisation of the eroded area in the shortest possible time. Local knowledge indicated that *Nypa fruticans* were likely to grow well when exposed to full sun, while *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba* prefer less sun, so these species were positioned in sections of the nursery covered with fishing nets.

Mangrove seeds and propagules were irrigated twice a day (early morning and late afternoon) with saline water, which was pumped over the sea dyke. The owner of the land, where the nursery was located, was responsible for irrigating mangrove seeds and propagules in the nursery. There was no irrigation on wet days. Pesticides and fertilisers were not used. Weeds growing outside the pots were removed for the first two months. After the third month, it was thought to be unnecessary to eradicate weeds because the seedlings grew faster than weeds and by then the weeds could not compete for nutrition and the sun. Shopping bags used for potting that were cut from filled bags before being transplanted were safely disposed in areas close to transplanting site to avoid accumulation of wastes in the area.

4.3.2. Upgrade of traditional Melaleuca fences into sea mud accumulation fences

The key challenge to controlling coastal erosion was to stabilise fine sea mud. Melaleuca fences, traditionally used to prevent river bank erosion in Kien Giang Province (Fig 19 a), were redesigned to accumulate fine sea mud as the first step. The redesign was undertaken integrating local knowledge of traditional Melaleuca fences with scientific understanding in relation to sedimentation, and coastal dynamics in Kien Giang, Vietnam (Nguyen 2012). As a result, seven types of Melaleuca fences were constructed and tested for their effectiveness for different circumstances. Single line silt trap fences were tested in scattered mangrove areas for accumulating sea mud, and followed by lateral double line silt trap fences constructed out from the shore to build inter-tidal mudflats (Fig 19) (Nguyen 2012).

4.3.3. Gradually stabilising the eroding area using the upgraded Melaleuca fences

The next step was the transplantation of seedlings of local mangrove species and the fences to gradually expand mangrove areas for stabilising the actively eroding muddy coast. Gradual expansion included a two stage process. The first stage involved closing gaps between the established scattered mangrove patches by transplanting mangroves protected by fences, complementing the protection afforded by the scattered mangrove patches. In the second stage, treatments were established using fences for expanding the area, providing additional protection to the previous treatments (Nguyen 2012) (Fig 20).

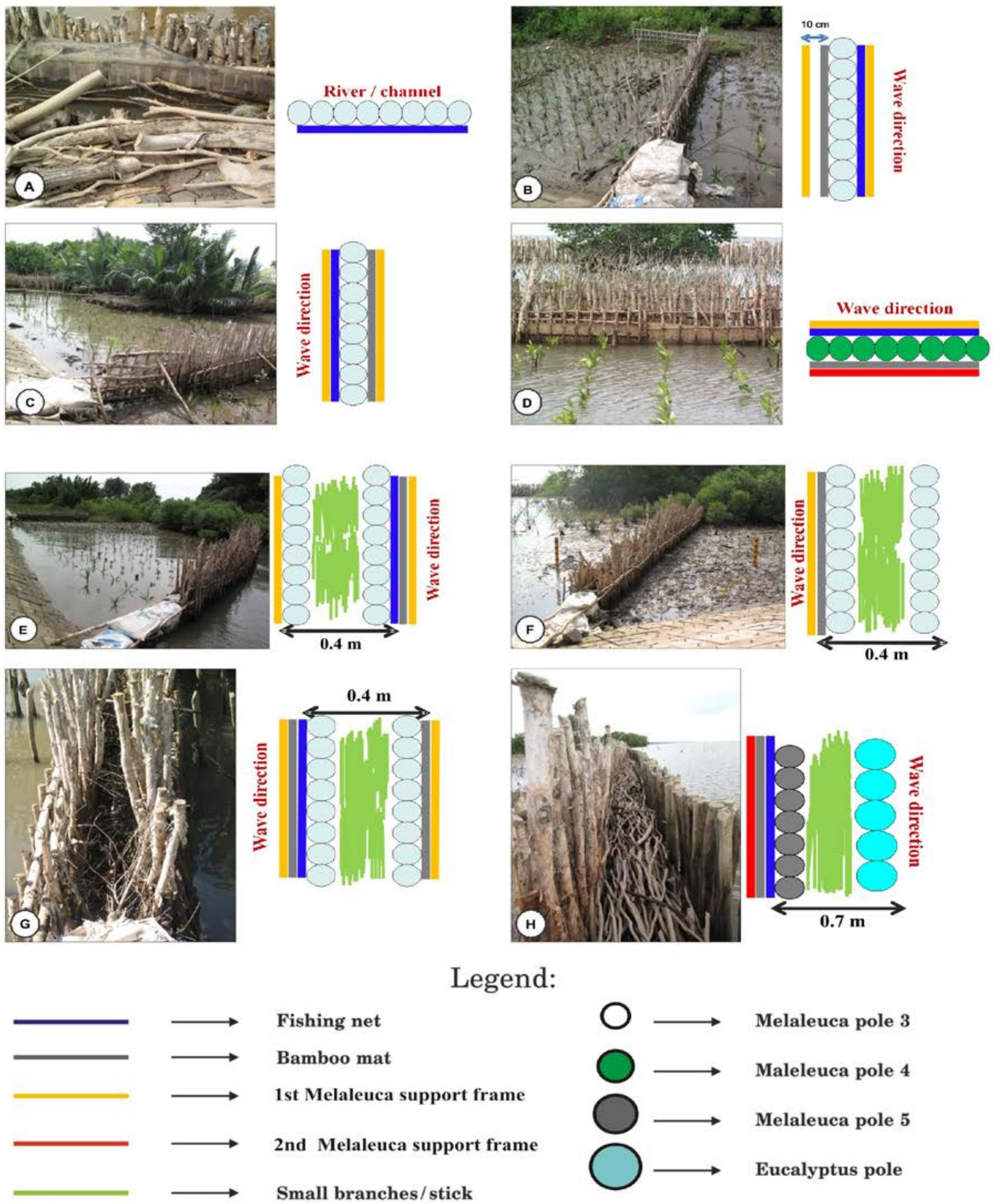


Fig 19: Fence designs, adapted from Nguyen (2012), a) Traditional Melaleuca fences, b) The lateral single line silt trap fence 1, c) The lateral single line silt trap fence 2, d) the single line silt trap fence, e) The lateral double line silt trap fence 1, f) The lateral double line silt trap fence 2, g) The lateral double line silt trap fence 3, and h) The double wave break fence.

Pole 3: 2.7 metres long, ranging between 3.0 centimetres and 5.4 centimetres in diameter at the top. Pole 4: 3.8 metres long, ranging between 3.5 centimetres and 5.4 centimetres in diameter at the top. Pole 5: 4.8 metres long, ranging between 3.5 centimetres and 5.4 centimetres in diameter at the top.

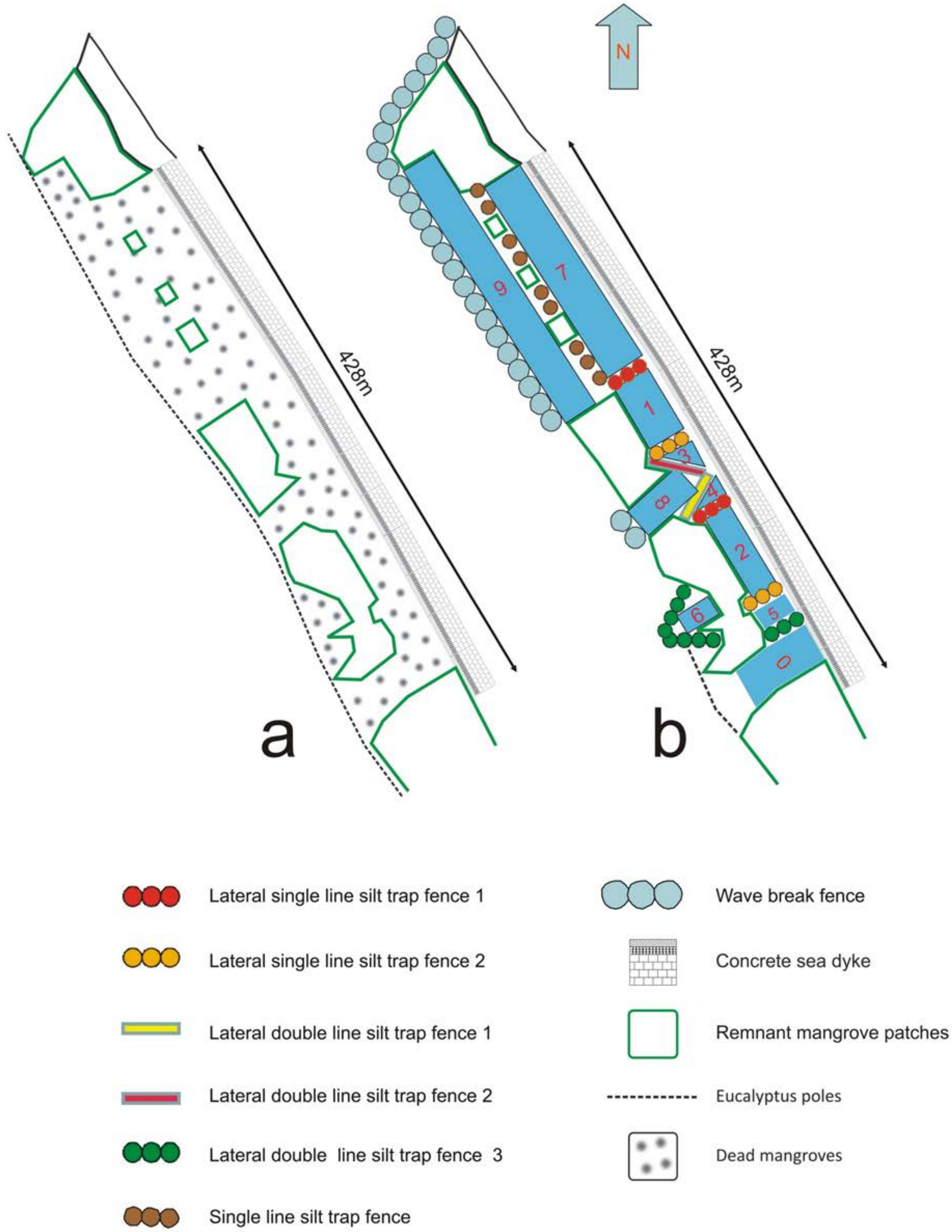


Fig 20: The gradual expansion method, adapted from Nguyen (2012); a) Vam Ray status in November 2008 and b) the expansion method employed in May 2011 with the numbers representing various treatments.

Seedlings of five local mangrove species (*Avicennia marina, Bruguiera cylindrica, Nypa fruticans, Rhizophera apiculata,* and *Sonneratia alba*) were potted and transplanted in four phases between September and October 2009. The transplantation was undertaken using Melaleuca frames for support (Fig 21). Seedlings were transplanted in the square grids of the supporting frame. Melaleuca planting support frames were not used in Treatments 8 and 9 (Nguyen 2012).

Fig 21: Melaleuca frames for supporting transplantation in Treatment 2. Huong Nguyen. 2009. Photograph.

4.4. Community acknowledgement of the effectiveness and application of the tested solutions

4.4.1. Effectiveness of production of high quality seedlings on acid sulphate soils

A total of 37,500 seeds (26,500 pots) were potted in June 2009. Of these, 36,000 seeds and propagules of the five species were purchased from contracted collectors and 1,500 seeds of *Avicennia marina* were collected by Vam Ray residents. Seeds and propagules propagated in the nursery had a 100% survival rate of seedlings with no disease damage. Seedlings were ready for transplantation in early September 2009 (Fig 22 and Table 2).

Fig 22: Three month seedlings of mangroves; a) Three month seedlings of *Rhizophora apiculata*, b) of *Bruguiera cylindrica*, c) *Nypa fruticans* and *d) Avicennia marina*.

Table 2: Number of seeds and propagules of five mangrove species potted and their height in June 2009.

Species	Seed/propagules	No. of seeds / propagules in each pot	No. of pots	Average height of seedlings after 3 months (centimetre)
Nypa fruticans	Seed	1	6,000	35
Rhizophora apiculata	Propagule	3	2,500	43
Bruguiera cylindrica	Propagule	5	1,500	32
Sonneratia alba	Seed	1	7,500	60
Avicennia marina	Seed	1	9,000	55

Transplantation took place in four phases: early September (*Nypa fruticans* and *Rhizophera apiculata*), late September (*Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata),* early October *(Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata)* and late October *(Bruguiera cylindrica, Avicennia marina, Nypa fruticans,* and *Sonneratia alba).*

In October 2009, DARD requested that 4,000 seedlings of *Avicennia marina* and 2,500 of *Sonneratia alba* be supplied to a planting program elsewhere in the Hon Dat area. It was reported at a later stage that the seedlings survived well.

The utilisation of local resources and plastic shopping bags kept costs of nursery construction to a minimum. The production cost for each seedling ready for transplantation (including labor, land rent, nursery construction, seed collection and seedling maintenance costs) and was approximately 2,770 VND (equivalent to USD 16 cents a mature seedling as at July 2009).

4.4.2. Effectiveness of upgraded traditional Melaleuca fences and gradual expansion of mangrove areas

Nguyen (2012) showed that seven Melaleuca silt trap fences were all effective in accumulating fine sea mud, protecting the seedlings, breaking the energy of waves, and stopping plastic bags entering the site from the sea. The results were increased sea mud levels, a high survival rate of planted mangroves and robust natural mangrove regeneration (observed in 2012 and 2013). Sediment became compacted and firm in the dry season. Firm sediment formation has indicated the potential effectiveness of the fences not only in stabilising the actively eroding muddy coast, but also in allowing for the coastline to build up over time (Nguyen 2012). The Vam Ray project has been widely recognised as a success in relation to sea mud accumulation, the survival rate of planted mangroves and encouraging natural regeneration (Kien Giang PPC 2009 b; CDBRP 2011; CDBRP 2012 a). These positive changes were confirmed by Fig 23.

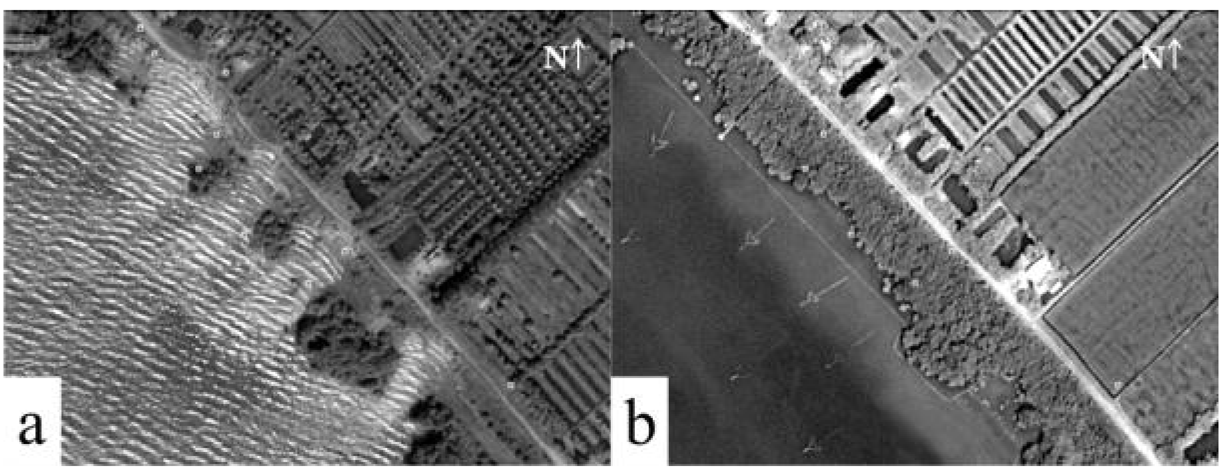


Fig 23: The Vam Ray coast changed over time with more mangroves established, a) September 2008. *Source*: "the coast of Hon Dat." $10^0$11'53" N and $104^0$48'11" **E. Google Earth.** 1 December 2006. [Accessed 24 September 2008], and b) February 2014. *Source*: "the coast of Hon Dat." $10^0$11'53" N and $104^0$48'11" **E. Google Earth.** 21 February 2014. [Accessed 24 February 2014].

4.5. New knowledge derived from the testing of new solutions

Community meetings in Vam Ray (Table 1 of Chapter 2) reported many lessons learnt from the project with respect to fence construction and transplantation, which they believed could assist in the replication of the project elsewhere.

4.5.1. Lesson learnt regarding production of high quality seedlings

The nursery used some unconventional techniques, and although largely trial and error, many procedures were based on extensive local knowledge of mangrove ecology and standard mangrove nursery techniques. Location selection, and nursery construction and maintenance methods (Clarke & Johns 2002; Thoi & Thinh 2011) were regarded by Vam Ray residents as impossible to implement for many reasons. By necessity, the Vam Ray nursery was established on acid sulphate soils, which have been shown to poorly support natural growth and restoration of young mangroves. The Vam Ray community used a 50 centimetre layer of liquid sea mud to protect seedlings from acidic water coming to the surface on rainy days. The placement of sea mud was shown to be a cost-effective and environmentally friendly solution to the problem of establishing a mangrove nursery on acid sulphate soils that may have application elsewhere.

The use of pumped irrigation sea water and the potting of more than one individual per pot were methods used in Vam Ray, but a technique not commonly used elsewhere. Despite the lack of pesticides and fertilisers, the success of the nursery was evidenced by a high survival rate and successful transplantation despite the adverse acid sulphate conditions, and was a source of considerable pride for the community. Establishing a base of sea mud and regular irrigation with pumped sea water proved successful to overcome some of the expected problems associated with its location. The fundamental goal of all processes was to keep stresses on seedlings to a minimum at all stages.

The use of local resources, particularly Melaleuca poles and plastic shopping bags was a priority in establishing the Vam Ray mangrove nursery. As Vam Ray is in a relatively remote rural area, the ability to call on local resources and locally traded materials contributed significantly to the effectiveness and efficiency of the mangrove nursery construction and maintenance, resulting in significantly reduced costs, and providing a model for replication elsewhere. In addition, utilisation of local resources helped create demand for the local resources, especially Melaleuca poles and Eucalyptus poles during the nursery construction, and reduced waste, resulting in improved local livelihoods in the region.

The following lessons learnt were drawn as a result of integration of local and scientific knowledge in producing high quality seedlings of mangroves in Vam Ray, Kien Giang:

a) A nursery established landward of the tidal limit is feasible. Covering the ground with liquid sea mud at the depth of minimum 50 centimetres was sufficient to avoid problems associated with acid sulphate soils;

b) The use of local products (Meleleuca poles and locally traded resources such as shopping bags and fishing nets) was important for nursery success, keeping costs to a minimum, avoiding unnecessary waste and improving local livelihoods;

c) The nursery construction and collection of mangrove seeds and propagules should be undertaken at the beginning of the wet season (early June each year), with mature seeds and propagules of similar mangrove species ecologically present in the area collected for propagation. Seeds and propagules should be collected from mother trees at an age of minimum 13 years to ensure propagule or seed maturity. It is important to purchase or collect seed and propagules additional to the number required in order to provide for poor quality seeds and propagules, and loss during transportation;

d) Where collection is at some distance from the nursery, seeds and propagules should be collected and stored in shady areas for one day only before being transported to the nursery site. They should be covered with wet banana leaves or wet palm leaves or stored in wet bags, whether being transported by boat of vehicle. Transportation should also be undertaken early in the morning or late in the afternoon to avoid seeds or propagules being exposed to the sun;

e) Bags filled with liquid sea mud should be dried before propagules are propagated in order to ensure that seeds and propagules could be firmly placed during the propagation. *Rhizophora apiculata* and *Bruguiera cylindrica* were propagated with more than one fruit per pot to form a cluster that is able to survive strong waves and to facilitate rapid re-colonisation clusters should be at high density. In this nursery, *Rhizophora apiculata* were potted with three and *Bruguiera cylindrica* with five individuals in a single pot. *Avicennia marina, Sonneratia alba* and *Nypa fruticans* were potted with a single seed propagated in a pot;

f) *Nypa fruticans* are best tended and raised in the sun to promote full growth, while *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba* do best in shaded areas;

g) Irrigation with saline water twice a day, in the early morning and in the late afternoon seemed to be sufficient and successful. Seedling bags, especially those containing *Nypa fruticans* should be moved regularly to avoid roots growing into the base soil.

h) Shopping bags used for potting that are removed at the time of transplantation should be safely disposed to avoid accumulation of plastic waste in the area.

4.5.2. Lessons learnt regarding fence construction

Despite the effectiveness of the seven Melaleuca fences, attention should be given to the following technical aspects during the construction process to improve their effectiveness and efficiency:

a) The best time for constructing fences is at the beginning of the rainy season and during high tides. Once constructed, the fences are able to accumulate sea mud (which is greatest in the rainy season). Sea mud accumulation is crucial to the survival rate of planted mangroves and assists the natural regeneration process. During high tides, fence materials could be easily transported by boat or drifted in water to the construction site (Nguyen 2012);

b) Iron wire and nails used in fence construction are easily corroded in marine environments. Corrosion of iron wire and nails caused damage to the fences, especially with fence supporting frames detaching in some locations, and caused difficulty in fence maintenance, especially when the fences had been almost covered by sea mud. Durable fence such as large sized braided fishing line should be budgeted for and used for fence construction (Nguyen 2012);

c) Ideally, gaps in the wave break fence should be occasionally filled, probably only once a year, at the end of the rainy season, with Melaleuca branches to a height of only 0.5 metre above the mud surface (Nguyen 2012). If used at all as filling in the wave break fence, rice straw must be well secured in used rice bags (Nguyen 2012);

d) The lateral double line silt trap fences and the lateral single line silt trap fences are most efficient in semi-closed water areas, surrounded by natural vegetation. The single line silt trap fence is effective in building up the shallow coastal areas close to the land, the sea dyke and remaining mangroves close to the shore. The wave break fence significantly assists in building inter-mudflats (Nguyen 2012);

e) Insufficient local involvement in the reporting phase in 2012 resulted in inadequate reporting of the fences, poor description and illustration of the lessons learnt, and poor recording of the integration of local and scientific knowledge for developing successful strategies for controlling coastal erosion. The resulting negative effects were misinterpretation of the pilot project interventions, and the construction of inappropriate fences elsewhere (Nguyen 2012);

f) Monitoring and good record keeping were matters of concern for the Vam Ray project. No written recording other than local memory of things has been made available, leading to unsystematic recording of the information. Unsystematic recording with respect to integration of local and scientific knowledge, production of high quality seedlings of mangrove, fence construction, and gradual expansion method was a substantial challenge for this research because the research occurred up to three years after the project interventions were completed (Nguyen 2012). Regular written monitoring and record keeping should be established and maintained in the village;

g) Despite a high level of sea mud accumulation during the project, hydrodynamic parameters including waves and water movements have not been measured. These measurements should be determined at the time of fence construction to determine the processes that cause the changes that have been reported (Nguyen 2012).

4.5.3. Lessons learnt with regard to gradual expansion of mangrove areas

Gradual expansion was a significant contributor to successful stabilisation of the Vam Ray eroding area (Nguyen 2012). To meet urgent demands for more feasible action plans and strategies that encourage mangrove transplanting to help address coastal erosion in Kien

Giang Province and on the Mekong Delta, gradual expansion methods should be encouraged because of the following advantages:

a) Gradual expansion enabled adjustments to the original plan to be made at later stages to provide the most effective solution to the erosion problem (Nguyen 2012);

b) In contrast to a short term planting project, in gradual expansion, using local labor and materials and harvesting products of *Nypa fruticans* over an extended period ensured proper care and monitoring of the newly established mangroves (Nguyen 2012);

c) Gradual expansion has a dual purpose: ecological purposes and alternative short term and long term local incomes. Once fully established, transplanted and naturally regenerated mangroves assist in accumulating sea mud, and stabilising the Vam Ray severely eroded coastal area in Vam Ray. Additionally, the Vam Ray local community benefits from harvesting commercially mature leaves of Nypa fruticans for extra income and for roofing local houses (Nguyen 2012);

d) Gradual expansion is likely to be applicable and sustainable locally. While gradual expansion and its maintenance require labor, best supplied locally, as opposed to a single large scale planting (commonly *Rhizophera apiculata* or *Avicennia marina*) that may use imported labor (Nguyen 2012). In Vietnam, there are many strategies and plans put in place to try to restore mangrove areas and eroding coastal areas, such as the Programme of Reinforcing and Upgrading the Sea Dyke System from Quang Ngai to Kien Giang provinces (Vietnamese Prime Minister 2009), the Program for Rehabilitation and Development of Mangrove Forests for the period 2008 to 2015 (MARD 2008 b). Where other transplanting programs have failed, gradual expansion methods, if implemented properly, are more likely to succeed and at the same time promote local community involvement and potentially improve local livelihoods (Nguyen 2012).

4.6. Conclusions

This chapter presented the details of the integration of local and scientific knowledge in managing successfully the Vam Ray eroding coast in Kien Giang, Vietnam. In this integration process, local knowledge was systematically collected and brought together with the relevant scientific knowledge into developing ecologically based, cost-effective strategies for controlling successfully coastal erosion in Vam Ray of Kien Giang Province. The two way communication established in this project was a significant contributor to a successful integration process.

The next chapter describes the development and elaboration of a practical framework for integrating local and scientific knowledge in managing mangrove dominated muddy coasts.

CHAPTER 5[5]

DEVELOPMENT OF A PRACTICAL FRAMEWORK FOR INTEGRATING LOCAL AND SCIENTIFIC KNOWLEDGE FOR MANAGING MANGROVE DOMINATED MUDDY COASTS

5.1. Introduction

Chapter 1 reviewed the theoretical context in relation to the integration of local and scientific knowledge in natural resource management, including the benefits and necessary requirements. The chapter also identified the challenges facing sustainable management of mangrove dominated muddy coasts, especially in Southeast Asia: limited success in muddy coast management, a low level of local involvement, and a minimum level of integration of local and scientific knowledge.

Chapters 3 and 4 applied research design and methodology developed in Chapter 2 for examining the integration of different knowledge systems for sustainably managing mangrove dominated muddy coasts in the practical context of Kien Giang Province, Vietnam.

This chapter develops a practical framework for integrating local and scientific knowledge in managing eroding mangrove dominated muddy coasts. The practical framework is developed using the results and conclusions from the previous chapters, especially Chapter 3 and 4. The practical framework, its benefits, and challenges are presented and discussed.

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[5] The chapter is written as two manuscripts: the first manuscript is a conference paper, entitled***: Integrated Local and Scientific Knowledge in Managing Eroding Muddy Coasts,*** which was presented in May 2015 in a **Regional Conference on Climate Change: Lessons Learnt and Management Issues,** organized by Tra Vinh University, Vietnam. The second manuscript "***Theoretical Framework for Integrating Local and Scientific Knowledge in Managing Muddy Coasts***" is scheduled to be submitted to ***Local Environment: The International Journal of Justice and Sustainability*** in August 2016.

5.2. The current integration of local and scientific knowledge in natural resource management

Local knowledge has been increasingly integrated with scientific knowledge in search for sustainable management of natural resources around the world. Integration is required when a single knowledge system failed to manage local issues sustainably (Mercer et al. 2009; Kniveton et al. 2014) or is not able to assist in adequately understanding local issues (Tengö et al. 2012). Integration has been undertaken using advanced technologies (computer programs, geographical information system) (Mackinson 2001; Shivakoti & Ruddle 2003; De Freitas & Tagliani 2009; Giordano & Liersch 2012; Tran et al. 2009), dialogue (Tengö et al. 2012; Terer et al. 2012), community based or co-management projects (Datta et al. 2012; Carlsson & Berkes 2005), frameworks (Raymond et al. 2010; Mercer et al. 2010), and processes (Hiwasaki et al. 2014; Failing et al. 2007). The process normally involves relevant scientific knowledge and local knowledge being introduced and analysed in a local context that includes context, culture, policies, and capacity available locally in a search of ways to theoretically understand the issues and put them into practice. The integrated knowledge as a result of the integration process, was considered as a new knowledge. This new knowledge was made available for local use. The integration process is summarised in Fig 24.

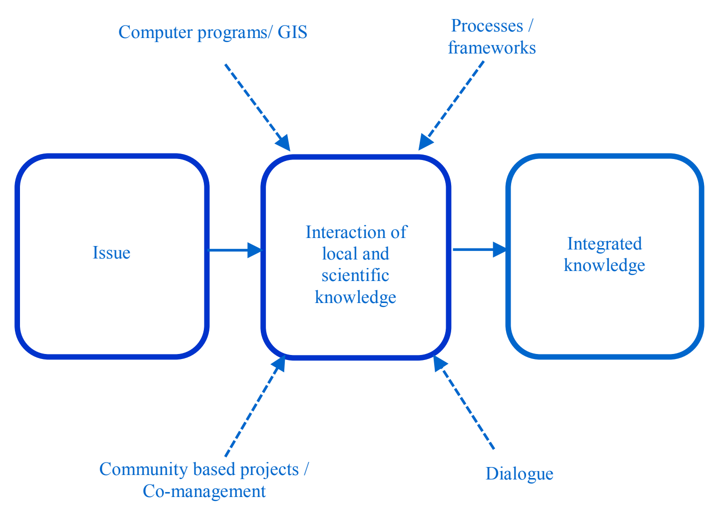

Fig 24: Illustration of some parameters associated with the integration of local and scientific knowledge and a summary of the current integration of scientific and local knowledge in natural resource management.

Products of integrated knowledge vary in form from case to case. They can be work plans, especially in development projects where external consultants collected information in relation to local issues from discussions or interviews with local communities (Anderson et al. 2012), or they can be management plans such as the management of artisanal fisheries in southern Brazil (De Freitas & Tagliani 2009); management of herring shoals (Mackinson 2001); sustainable management of isolated semi-arid papyrus swamps in Loboi, Kenya (Terer et al. 2012); management of soil salinity in the lower Amudarya river basin in Uzbekistan (Giordano & Liersch 2012). In some cases, they can be monitoring and evaluation programs of biodiversity, ecosystems and human wellbeing (Tengö et al. 2012; Borgström et al. 2015). They can be mechanisms that support and enhance learning and decision making in the context of dynamic social-ecological systems in governance (Tengö et al. 2014). However, many questions have arisen in relation to local perspectives on the products of integrated knowledge and the effectiveness of the use of the products of integrated knowledge creation (Mercer et al. 2009; Raymond et al. 2010). In some development projects, the use of the products of integrated knowledge caused local communities to remain powerless, frustrated with decisions, and dependent on the development projects because they depended entirely on assistance offered by outsiders in relation to problem solving and development of solutions (Anderson et al. 2012).

5.3. Development and elaboration of the practical framework using the results of the Kien Giang case

In contrast to the current integration process, this research showed that the integration process does not stop with the creation of integrated knowledge which may be used in the ways outlined above, but should undergo a longer process. The framework suggested has six stages (Fig 25). The entire process is undertaken using a two way communication process.

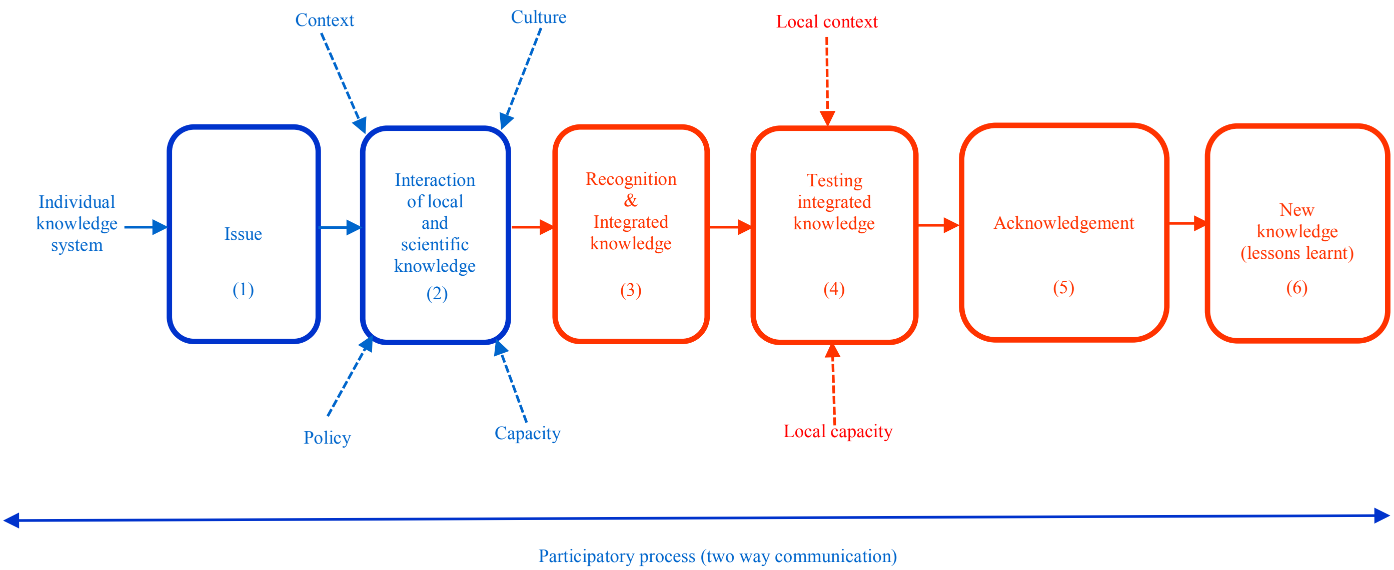

Fig 25: A practical framework for integrating local and scientific knowledge in sustainably managing mangrove dominated muddy coasts.

This research framework shares the first two stages of the generic framework presented in Fig 24. However, the framework developed from this research significantly differs from the third stage on. In addition to the creation of integrated knowledge, the third stage requires local recognition of the severity of the issues and the contribution of the individual knowledge systems to solving local issues. As described in Section 3.3 of Chapter 3, many sections of the Kien Giang coast continued to erode despite management interventions implemented by the relevant government agencies. Natural factors such as adverse effects of climate change and sea level rise were frequently believed to be significant contributors to coastal erosion at Kien Giang, with human activities not being considered important. A series of community meetings and semi-structured interviews led to an increased recognition among the Kien Giang communities and local authorities of the need to use different knowledge systems to more thoroughly understand the underlying causes of the erosion in order for effective erosion management strategies to be developed, resulting in what can be called a product of integrated knowledge (See Appendix 3).

Section 4.2 of Chapter 4 showed that the Vam Ray community recognised the severity of the coastal erosion and its negative impacts on their livelihoods. Their aquaculture ponds and agriculture production lands had been lost because of coastal erosion. As coastal erosion becomes more severe, the Vam Ray people recognise that it is highly likely that they will lose more areas in the future. However, early strategies implemented by the governments of all levels in Kien Giang Province have not been at all effective in controlling coastal erosion. The local communities believed that there would be more failures if the same strategies were repeated, and they were not sure if outsiders could help solve their problems.

During this study, the local communities have been keen to share their established knowledge of their local issues, because they had not been given opportunities to do so in the past. The partnership established in 2009 between the government, CDBRP and the Vam Ray community was the first real attempt in the Kien Giang context to give the people an opportunity to utilise their local knowledge alongside the scientific knowledge acquired from community meetings and photo voice in the local situation. The communities were actively involved in integrating local and scientific knowledge for developing solutions for successfully managing the Kien Giang coastline, with initial support provided by outsiders. This research has indicated the general success of the 2009 approach. Products of integrated knowledge as a result of the integration included production of high quality seedlings of mangroves, upgrade of traditional Melaleuca fences into sea mud accumulation fences, and gradual expansion of mangrove areas.

The fourth stage of the framework is the testing of products of integrated knowledge in a local context, where local context and capacity are provided. The products of integrated knowledge are tested for their effectiveness and applicability. In section 3.4 of Chapter 3, the Kien Giang communities were actively involved as co-investigators in using the product of integrated knowledge for investigating the underlying causes of coastal erosion in Kien Giang. The product of integrated knowledge was used for explaining, understanding effects of, or linking, justifying local knowledge activities through participatory action research methods (participatory community meetings, semi-structured interviews, field trips, photo voice, and debriefings).

In Section 4.3 of Chapter 4, the Vam Ray nursery construction was shown to have faced many challenges in relation to site selection, soil structure (acid sulphate soils not supporting growth and propagation of mangrove seedlings), and inadequate technical guidelines on mangrove propagation on acid sulphate soils. The main strategies that were developed to overcome these challenges included establishment of a 50 centimetre layer of sea mud on the nursery ground to inhibit the negative effects of acid sulphate soils, potting using sea mud, multiple propagules potted in one pot, daily irrigation using sea water, and re-use of shopping bags for exclusion of waste and for economical purposes. These strategies were developed using local knowledge regarding characteristics of acid sulphate soils, daily observations of natural growth and regeneration of mangrove species, transplantation and protection of other species from coastal erosion, and daily use of sea water for aquaculture (fish and crabs). After three months, the Vam Ray nursery produced approximately 26,500 pots (37,500 high quality seedlings of five local mangrove species on acid sulphate soils). High quality seedlings greatly contributed to a high level of transplantation success.

Traditional Melaleuca fences were upgraded into two types of silt trap fences: single line Melaleuca silt trap fences (three types) and double line Melaleuca silt trap fences (four types). Single line Melaleuca silt trap fences were first tested in scattered mangrove areas for accumulating sea mud, and followed by lateral double line silt trap fences constructed out from the shore to build inter-tidal mudflats. Seven Melaleuca silt traps fences were established together with four transplantations of mangrove seedlings and natural protection provided by scattered mangrove patches that constructed nine treatments. The establishment was gradually undertaken over time to enable adjustments to original plans to provide best solutions to the problem. Significantly, these strategies were not common at that time. Again, the upgrade of Melaleuca fences was undertaken using local knowledge in relation to sedimentation, sea mud collection, and protection of other species from storms and coastal erosion.

The fifth stage of the framework relates to local acknowledgement of effectiveness and applicability in relation to testing products of integrated knowledge in the local context. In particular, this stage is significantly important because local acknowledgement (by communities, management authorities and those responsible for policy) of the effectiveness and applicability of the integrated knowledge tested in a local context can lead to improved local awareness of the issues. Section 3.5 of Chapter 3 revealed that human activities such as poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels have jeopardised the structural integrity of the mangroves and contributed to coastal erosion. Further to this, the interaction of anthropogenic activities and physical processes are significant contributors to erosion. The results were in contrast to the previous local understanding that human activities and the interaction of their activities and physical processes were not significant contributors to coastal erosion. Therefore, by the end of the study, the Kien Giang communities and government were fully aware of why the coast was severely eroded and the possible danger of coastal erosion in the future.

In Section 4.5 4, the Vam Ray project was acknowledged to be a success in relation to sea mud accumulation, the survival rate of transplanted mangroves and high levels of natural regeneration. This success was confirmed by the donor and the local government and was particularly a source of pride for the Vam Ray community.

The sixth stage of the framework is the development of the new knowledge. The new knowledge is the understanding gained and lessons learnt during the testing of products of the integrated knowledge systems in a local context rather than products of integrated knowledge systems themselves. As shown in Chapter 3, the new knowledge is the proper understanding of negative impacts of human activities on the coast, such as improper technical guidance on the configuration of mangrove allocation, mangrove protection and afforestation methodologies, and permitted thinning and selective harvests. In addition, necessary policy changes are also identified for amendment.

Chapter 4 concluded that the new knowledge goes far beyond the nursery establishment, production of high quality mangrove seedlings, upgrade of Melaleuca fences and gradual expansion of mangrove areas. The new knowledge gained during this research is that to ensure high survival rates, a nursery should be created as a condition as close to their future transplantation areas to ensure high survival rates and to keep stressors to mangrove seedlings at a minimum level. The creation should be undertaken using sea mud to establish a protection of seedlings from negative impacts by acid sulphate soils and for potting, multiple propagules potted in one pot, irrigation using sea water in addition to re-use of plastic bags for exclusion of waste and economical purpose. In other words, lessons learnt during the nursery operation also constitute the new knowledge.

Likewise, the new knowledge established is not the Melaleuca silt trap fences themselves. The fence design process, the effectiveness of each fence type in accumulating sea mud, protecting seedlings, and stabilising actively eroded muddy coast, and lessons learnt related to fence construction and maintenance contribute to the development of new knowledge. New knowledge is also gained by understanding the misinterpretation of the fence designs applied elsewhere leading to poor results, due to insufficient local involvement in the reporting stage of the Vam Ray project in 2012, and most importantly the need for adequate local involvement in reporting, and monitoring and recording keeping. Similarly, the gradual expansion method is not new knowledge. Lessons learnt during the construction and their potential application are the new knowledge that can be replicated elsewhere in the future.

In summary, the framework developed from the Kien Giang case emphasises four significant elements in addition to the current generally adopted process of integration:

i. Recognition (part of the third stage),
ii. Testing,
iii. Acknowledgement,
iv. New knowledge development.

In relation to recognition, people recognise the importance of each type of knowledge and they begin to be interested in the different knowledge systems. In addition to the fact that different knowledge systems are locally analysed, integrated adequately and properly in stage 2 (interaction process or situational analysis), testing of products of integrated knowledge in a local context is an important step because the products are tested locally for effectiveness and applicability.

Local acknowledgement of effectiveness and applicability in relation to testing products of integrated knowledge in the local context is an important step because as soon as people acknowledge that the products of integrated knowledge are effective and applicable together with the new knowledge established, they are more likely to apply them. As a result of recognition, testing, and acknowledgement, the local communities and governments 'own' the new knowledge through thoroughly inclusive processes, because they are involved as co-researchers in co-constructing a new knowledge. Local ownership of the new knowledge is possibly one of the highest levels of participation in reference to the seven types of participation developed by Pretty (1995) (Chapter 1). In accordance with Stojanovic et al. (2004), a high level of participation could facilitate a high level of integration of different knowledge systems. Therefore, local ownership developed in this framework assists in overcoming the challenge as indicated in Chapter 1 in relation to a low level of integration of local and scientific knowledge. Further to this, local ownership, and local acknowledgement of effectiveness and applicability are likely to contribute to the sustainability of project activities at the local level. A high level of participation, ownership, and sustainability are also the ultimate objective that development projects are seeking (Anderson et al. 2012).

The use of local resources and locally traded materials in the Vam Ray project not only helped substantially reduce the costs of mangrove dominated muddy coastal management and protection, but also provided encouragement for replication of the framework elsewhere in Kien Giang Province and in the Mekong Delta region.

This research showed that application of the Kien Giang practical framework promoted the development of tools that were used for stabilising the eroding muddy coast at Vam Ray, Kien Giang. For example, activities included the production of cost effective and ecologically sound seedlings of five local mangroves, successful transplantation of mangrove seedlings, the Melaleuca fence design and construction, and gradual expansion of mangrove areas. The eroding coast at Vam Ray was successfully stabilised after three years, as confirmed by the government (Kien Giang PPC 2009 b), and by CDBRP (CDBRP 2011; CDBRP 2012 a). In addition, the practical framework applied at Kien Giang significantly assisted in understanding the negative effects of human activities and management interventions on the Kien Giang coast, which had not been understood thoroughly using a single scientific knowledge system. Therefore, use of the practical framework in developing strategies for managing muddy coasts assisted in overcoming the challenges and limitations of the current management strategies for mangrove dominated muddy coasts.

5.3.1. Challenges

Three significant challenges to the practical framework developed at Kien Giang are recognised. The first challenge is the reporting system of the current coastal management and planning framework, controlled by the local governments. Only activities highly likely to be effectively and easily implemented are normally prioritised for reporting purposes, leaving limited opportunities for new ideas to be tested under current management practices. It is widely acknowledged among the staff working for the Management Boards in Kien Giang

Province, that it is risky to test something new in the current management planning environment. For example, despite having evidence that alternatives are more effective, transplantation of seedlings of a single mangrove species on mudflats is prioritised because it is easy to implement and can be quickly reported.

Communication difficulty is the second challenge. Local residents are not inclined to communicate their opinions in local interviews or local community meetings, especially those attended by government representatives or authorities. As a procedure, they need to seek approval and / or permission from the local authorities before they are engaged in any communication, especially with foreign visitors. Further, they do not want to freely express their ideas or to share their knowledge and experience in community meetings organised by the government authorities because they know that their voices are not likely to be acknowledged. Therefore, people's opinions rarely come out in local interviews or local community meetings attended by government representatives. In addition, people involuntarily follow what they are told, although they are often certain of failure or waste in implementing activities planned by the government. A good example in this regard is the repeated transplantation of mangroves using a single species on mudflats. Transplantation using a single species is rarely effective and can significantly contribute to mangrove degradation and coastal erosion (Nguyen 2015 a; Nguyen 2015 b; and as described in Chapters 3, 4, and 6). One-way communication and reporting, along with limitations on the ability to provide opinions, has been a significant constraint to the integration of different knowledge systems.

Another challenge is that although local recognition, the third stage in the framework, is a crucial element of the entire integration framework in relation to timing and progress, it takes time for local governments and local communities to recognise the nature of local issues and their consequence. Chapter 3 and Chapter 4 provide two good examples in this regard. In Chapter 3, the Kien Giang communities initially denied any links between their frequent activities and coastal erosion, although their livelihoods were affected negatively by coastal erosion. The Forestry Project Management Board of DARD, whose main responsibility is to effectively and efficiently manage forestry projects in Kien Giang Province, was not initially willing to accept the failure of controlling coastal erosion in Vam Ray, and to cooperate with CDBRP and the Vam Ray community for improved effectiveness and efficiency (Chapter

4). Initial denial and unwillingness to cooperate in some circumstances can cause confrontation, slowing down progress, or even terminating activities on the ground.

One of the key solutions developed in this research to overcome the initial denial and unwillingness was a trust building process through cooperation and mutual respect. As the first stage, I sought verbal and nonverbal consent from the provincial departments of Kien Giang and Brebes Regency agencies for my research in the areas through letters of introduction, self-introduction and explanation of the current status and purpose of the research during a series of meetings held in the areas. During the self-introduction and explanation process, I emphasised that problems they were facing were their own problems, not mine. My research was to be implemented by working side by side with the local communities and government agencies to understand problems and possibly to develop solutions that aimed to improve the local situation. Working alongside local communities and government agencies not only assisted undertaking the research, but also assisted local government agencies in fulfilling their responsibilities and local communities in protecting and / or improving local livelihoods. It was clear that I would derive no other benefit (for example financial) than successful completion of my research. Secondly, I maintained a mutual respect despite various differences in relation to ideology, methodologies, culture, and administration. I did not interfere with their administration and decisions, but was willing to accept what was offered, to work toward achieving the shared goal: Improved management of mangrove dominated muddy coasts. In return, the communities and government agencies respected my views, my advice and recommendations. I spent as much of my field trip time in the local communities as I could, gradually learning the local language, sharing Vietnamese cooking, or joining local and social events such as annual parades for celebrating the local New Year, and community transplantation programs. In summary, working together, eating together and staying together significantly contributed to mutual respect and trust building process.

5.4. Conclusions

This chapter presented and elaborated on the development of a practical framework for integrating local and scientific knowledge based on the mangrove dominated muddy coasts in Kien Giang Province. The development was based on the results and conclusions from the previous chapters, especially Chapter 3 and 4. The six stage practical framework promotes a high level of integration of local and scientific knowledge, local ownership, and sustainability that are the ultimate objectives that development projects are seeking, and assists in overcoming the challenges facing the current management strategies for sustainably managing mangrove dominated muddy coasts as identified in the literature.

The next chapter applies the practical framework to understanding the effectiveness and efficiency of the current strategies for managing mangrove dominated muddy coasts in Brebes Regency, Indonesia.

CHAPTER 6[6]

APPLYING THE PRACTICAL FRAMEWORK FOR UNDERSTANDING THE EFFECTIVENESS AND EFFICIENCY OF THE CURRENT STRATEGIES FOR MANAGING MANGROVE DOMINATED MUDDY COASTS IN BREBES REGENCY, INDONESIA

The environment of Brebes Regency, Indonesia, is in many ways similar to Kien Giang Province, Vietnam. This chapter presents the results of applying the practical framework developed in Kien Giang Province for understanding the efficiency and effectiveness of the current strategies for managing mangrove dominated muddy coasts in Brebes Regency, Indonesia.

6.1. The Brebes issue

Mackay (2012) reported that by 2010 there had been significant erosion along over two-thirds of the Brebes coast, with many abandoned aquaculture ponds. By 2012, an area of approximately 129 hectares had been transplanted with propagules and seedlings of *Rhizophora mucronata* across the Brebes coast (Mackay 2012). Propagules and seedlings of *Rhizophora mucronata* were transplanted in straight lines (spaced 2 metres apart), with support provided by bamboo sticks as a common strategy for coastal erosion control in Brebes Regency. Fences were constructed offshore of the coasts of Sawojajar and Kaliwlingi in August 2011 using triangular bamboo units (1.5 metres x 1.5 metres x 1.5 metres), with a distance of 0.5 metre between units to provide further protection for the propagules and seedlings. The construction of the bamboo fences was funded and implemented by the Brebes Regency Forestry Protection Department. The bamboo fence in Sawojajar was 150 metres in

[6] The chapter was also presented as part of a technical report: **Mangrove Restoration for Climate Change Adaptation and Mitigation in Brebes, Indonesia: Lessons learnt and Strategic Recommendations.** This report was submitted and accepted by BAPPEDA in December 2014. This chapter is also being written as a manuscript: **Addressing Lessons Learnt in Controlling Eroding Muddy Coasts in Brebes Regency, Indonesia.** This manuscript is scheduled to be submitted to the *Journal of Coastal Research* in September 2016.

length and in Kaliwlingi, 900 metres. The communities decided to transplant *Rhizophora mucronata* because this species was a local species and easy to transplant. The transplantation programs were funded either by the local government agencies, private companies or aid agencies. On field visits in Brebes Regency in August 2013, it was clear that *Rhizophora mucronata* has provided a low level of protection against strong waves and that the Brebes coast dominant with *Rhizophora mucronata,* continuously transplanted for decades, remains increasingly vulnerable to coastal erosion.

A pilot project, developed by the Indonesian Rainforest Foundation in cooperation with Planète Urgence, aimed to increase coastal resilience, and to improve and diversify local livelihoods in Brebes Regency (Indonesian Rainforest Foundation 2012). This pilot project was funded at USD 30,000 in 2012 by the Australian Embassy to Indonesia (the funding agency), and was implemented between early 2012 and November 2013. The project implementation was undertaken through a memorandum of understanding signed by representatives of local villages and the Indonesian Rainforest Foundation. In this project, transplantation of *Rhizophora mucronata* in straight lines was undertaken over an area of 13 hectares on the Brebes coast.

Between August and September 2013, propagules were seen dead and seedlings uprooted on many sections of the coasts. Coastal erosion was still occurring with many stands of *Rhizophora mucronata* being uprooted by strong waves on high tides. Triangular bamboo fences at both locations were broken and replaced every year. Despite these setbacks, transplantation continued through to early November 2013.

6.2. The integration process – the second stage

Although much on the ground work had been done in relation to mangrove restoration, there had been no formal integration of scientific and local knowledge systems. To develop an understanding from which the application of the model could be tested, general scientific understanding from the literature and the integrated knowledge and lessons learnt in relation to management of coastal erosion in Vam Ray, Kien Giang, Vietnam were shared with the Brebes communities during participatory meetings, field visits, and semi-structured interviews. Key relevant lessons included: a) the significant changes in coastal ecosystems and coastal erosion caused by afforestation using a single species (Nguyen 2015 a; Nguyen 2015); b), transplantation using a variety of mangrove species facilitating natural regeneration and growth (Mackay & Manuri 2013); c) adverse consequences of poor habitat selection, improper transplanting techniques, and lack of monitoring (Ranasinghe 2012; Gilman & Ellision 2007; Schmitt 2012); and d) promotion of natural regeneration and growth of local mangrove species for establishing mangrove belts (Kamali & Hashim 2011; Lewis 2005; Lewis 2009).

The practical framework developed in Kien Giang was introduced to the Brebes communities during field visits in September 2013.

6.3. Local recognition – the third stage

6.3.1. Local recognition

In 2011, Brebes Regency was selected as a pilot green belt on the North Coast of Central Java, launched by the Environment Minister, Gusti Muhammad Hatta (Burhani 2011). Under the North Coast Central Java Green Belt program, mangrove restoration was promoted along the coastal communities in Brebes Regency to reduce negative impacts of climate change, sea level rise and coastal erosion.

During the field visits, local communities and Brebes Regency agencies (BAPPEDA, the Environmental Department, the Marine Affairs and Fisheries Department, and the Forestry Department) became fully aware that implementation of the Brebes Regency pilot mangrove green belt required an assessment of the current situation and problems identified, including an assessment of the current strategies used for managing eroding muddy coasts for effectiveness and efficiency. It was important to draw lessons from current mangrove restoration projects, and to link the findings from these projects to the future identification, design, analysis and development of mangrove restoration in Brebes Regency, Indonesia. The Brebes Regency agencies and local communities agreed to be involved as co-investigators.

6.3.2. A product of different knowledge systems

The scientific knowledge of, and lessons learnt elsewhere in relation to, mangrove restoration were used as a product of different knowledge systems, and subsequently used to collate, link, and justify the Brebes erosion strategy for understanding its effectiveness and efficiency.

6.4. Using a product of different knowledge systems for understanding the effectiveness and efficiency of the current Brebes strategies for managing coastal erosion - the fourth stage

6.4.1. Production of mangrove seedlings

Mangrove nursery operation was poor in Brebes. There were a substantial number of discarded propagules around many nurseries. The reason given for the high number of discarded propagules was that propagules were young or damaged during transportation.

Poly bags were potted using locally sourced compost and dried clay soils, and then placed neatly in trenches dug on the nursery ground before propagules were propagated in the potting bags. The poly bags were small in size (5 centimetres x 15 centimetres) and short in length, approximately one third in the length of a seedling. Potting bags were not rotated regularly during the period of 6 months, leading to seedlings growing their roots into the underlying sediment. Roots had to be cut for transplantation, stressing and killing many seedlings. In Pulogading, all propagules in one nursery were stressed or died due to permanent inundation by fresh water (Fig 26).

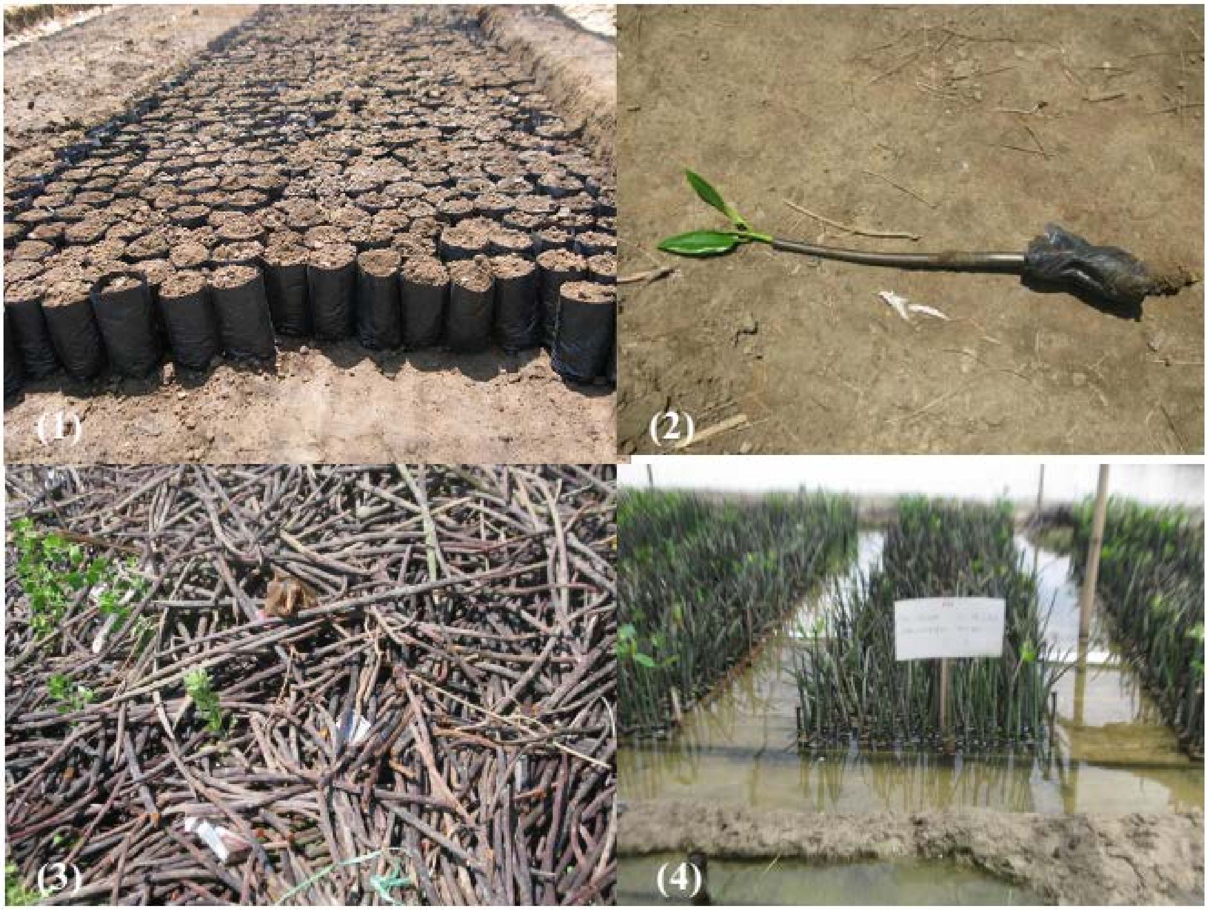

Fig 26: Poor mangrove nursery practice in Brebes Regency, (1) neat placement of short and small sized potted bags in the trenches dug on the nursery ground caused difficulty in rotating seedlings; (2) a three month seedling developing its roots into the underlying sediment through poly bags, 3) Propagules discarded around a nursery in Sawojajar, (4) seedlings were inundated permanently with freshwater in a nursery in Pulogading.

6.4.2. Mangrove transplantation

Propagules and seedlings of *Rhizophora mucronata* were transplanted on high tides. During the transplantation, propagules and seedlings were pushed hard into mud. Initial survival of transplanted mangroves was very poor. In accretion areas, propagules of *Rhizophora mucronata* died because they were pushed hard into the firm surface during the transplantation, resulting in their roots being severely damaged. Severely damaged roots caused propagules to die. In severely eroding areas, seedlings of *Rhizophora mucronata* were seen uprooted or dead. Short and small sized potting bags were not pushed deeply enough into the mud. In some circumstances, dried compost and clay soils broke away from the propagule completely when bags were torn before transplantation, leading to transplantation of bare rooted seedlings. Shallow and bare rooted transplanted seedlings were not able to stand strong waves on high tides themselves. When not well protected, especially by the offshore constructed triangular bamboo fences in Sawojajar and Kaliwlingi villages, they were subject to being uprooted. The majority of seedlings died because they were found to have been transplanted with potting bags still attached or their roots were cut carelessly before being transplanted.

Fully grown trees of *Rhizophora mucronata* died on many sections of the Brebes coast due to insufficient sediment around their roots causing them to be susceptible to being uprooted under the influence of strong waves on high tides. However, new propagules were transplanted in exactly the same areas where fully grown trees of *Rhizophora mucronata* were uprooted. The question was raised as to why the local communities kept transplanting the same species in the same area where this species provided a low level of protection and trees clearly were not surviving. They responded that they were instructed by the relevant Brebes agencies (the Environment Department, the Forest Protection Department) to transplant propagules on any mudflats or open areas to establish mangrove areas (Fig 27).

In addition, transplanting of seedlings / propagules of *Rhizophora mucronata* in straight lines, with protection provided by bamboo sticks did not prove efficient for wave energy dissipation. Waves easily propagated in many coastal areas along the Brebes coasts which were transplanted with seedlings and propagules of *Rhizophora mucronata.*

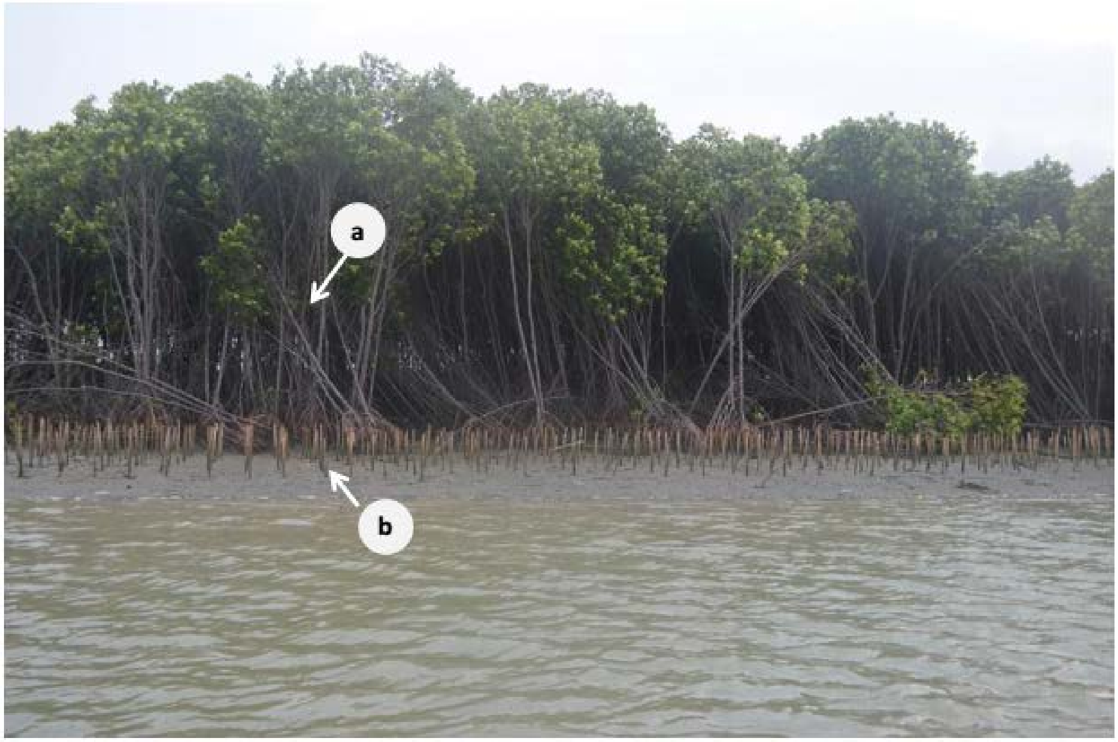

Fig 27: Transplantation in Pulogading, a) Mature trees of *Rhizophora mucronata* provided poor protection against strong waves on high tides, b) propagules continued to be transplanted in straight lines with protection provided by bamboo sticks in the same location.

6.4.3. Monitoring and evaluation

The government agencies purchased six month old mangrove seedlings of *Rhizophora mucronata* from local mangrove nursery operators for transplantation. However, seedlings were not checked for quality during purchase. Local members were contracted for transplanting seedlings and propagules of *Rhizophora mucronata*. Monitoring and evaluation was not undertaken until the transplantation was completed, and was undertaken for payment and reporting purposes only. There was no ongoing monitoring and evaluation made available locally for tracking successes and failures.

6.4.4. Natural regeneration and growth of other mangrove species

Propagules were transplanted among naturally regenerated trees of *Avicennia* species in Randusanga kulon, Limbangan, and Karang dempel. *Avicennia* species were observed to have grown more healthily than transplanted *Rhizophora mucronata* in areas of Limbangan and Kaliwlingi. Naturally grown *Avicennia marina* showed a better survival than transplanted *Rhizophora mucronata* in eroding areas of Sawojajar and Karang dempel under the influence of strong waves on high tides (Fig 28). However, the use of seeds or seedlings of *Avicennia marina* for transplantation, and even promotion of natural regeneration and growth *Avicennia marina* was rare in the Regency.

6.4.5. Coastal protection measures

The triangular bamboo wave break fences were not as functional as expected. They were broken and replaced every year. Their annual replacement was a considerable investment for the Brebes agencies. The fences were not built with features that assisted in dissipating the energy of incoming strong waves and / or trapping sediment. Strong waves were observed going through the fences easily. In addition, the fences were constructed offshore, too far in distance to protect seedlings and the coast (Fig 29).

Two types of bamboo fences were effective in protecting active ponds in Randusanga kulon, a fence made of bamboo mat and bamboo stems, and a fence made with fishing nets and bamboo stems. The average width of the above two bamboo fences is approximately 1 metre. Seeds of *Avicennia marina* have been grown within the bamboo fences (Fig 30).

A granite rock wall was established to dissipate the energy of strong waves in Randusanga kulon. The rock wall has been reported to be successful in wave energy dissipation and protection of mangroves inside it (Fig 31).

Fig 28: Natural regeneration of *Avicennia* species among *Rhizophora mucronata* transplanted in Sawajajar and Karang dempel, a) one year old trees of *Rhizophora mucronata,* b) propagules of *Rhizophora mucronata* transplanted in straight lines, and c) *Avicennia* species found naturally regenerated grew faster than transplanted *Rhizophora mucronata*.

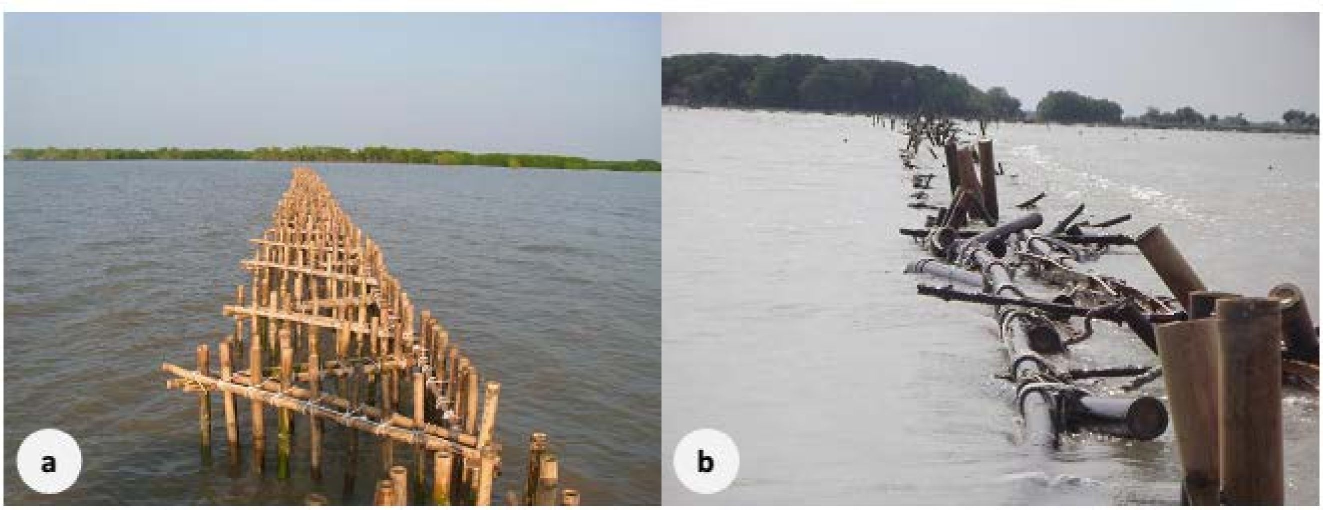

Fig 29: Triangular bamboo fences were constructed offshore in Sawojajar to protect seedlings from strong waves, a) new fences constructed 2011, and b) the fences were broken after construction in the same year.

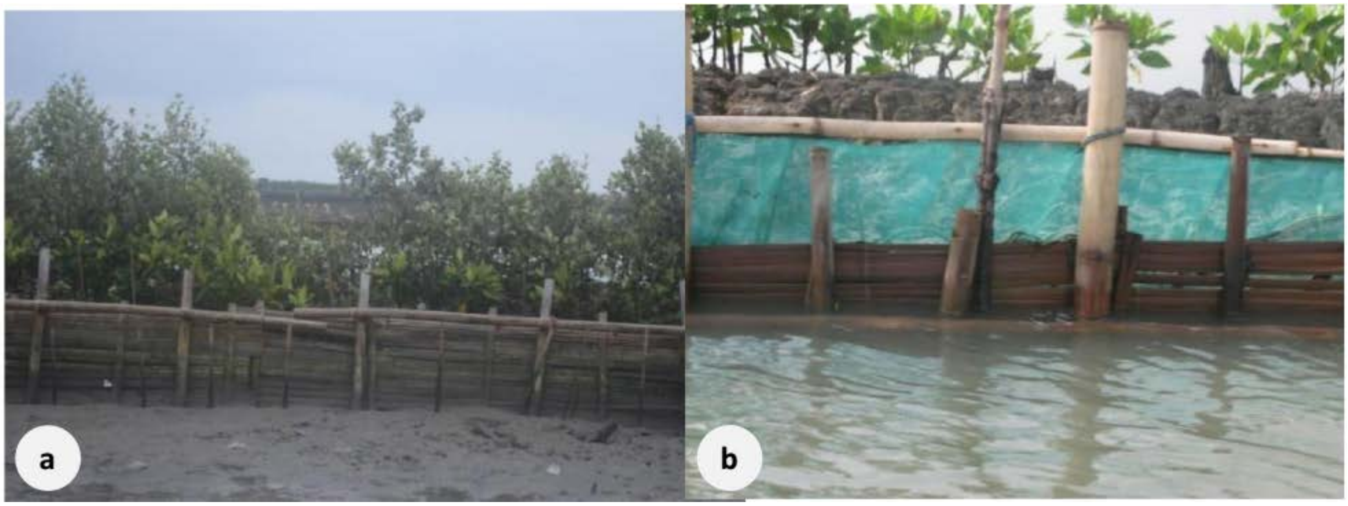

Fig 30: The two types of bamboo fences protecting pond dykes in Randusanga kulon, a) one type of fence is made of bamboo mat and bamboo stems, and b) the other is constructed with fishing nets and bamboo stems new bamboo fence. Coastal mangroves were planted behind the fences.

Fig 31: A rock wall was constructed to dissipate the energy of strong waves in Randusanga kulon.

6.5. Acknowledgement - the fifth stage

By the end of the research, the representatives of the Brebes communities and agencies acknowledged the lessons learnt and commitment made to improve by signing the minutes of community meetings, which detailed the findings, and lessons learnt in relation to the Brebes mangrove restoration. During the debriefings, the Brebes communities and agencies acknowledged that current mangrove nursery operation was not effective and efficient in producing mangrove seedlings in relation to costs and expenditure. The large number of discarded propagules caused a significant economic loss for the Brebes government agencies and the local communities. Sourcing of propagules, poly bags, fertilisers, and compost for potting increased nursery operation costs. Instead, shopping bags and sea mud was recommended to be used for potting to reduce capital investment and waste in the communities.

The Brebes communities were not initially aware of consequences of mangrove restoration using a single species. During debriefings in late November 2013 and December 2014, the communities recognised the adverse impacts of their current mangrove restoration practice on the coast and agreed to make corrections to avoid the same mistakes in the future. They agreed that it would be more effective and efficient to promote the natural regeneration and growth of other mangrove species rather than continuing with Rhizophera transplantation. Also during the debriefings, the Brebes Regency Forestry Protection Department admitted that offshore bamboo wave break fences were only a temporary measure, while still searching for more effective solutions.

The Forestry Department in Brebes said that the reason for inadequate monitoring and evaluation was that these activities were not budgeted. Inadequate monitoring and evaluation caused difficulty in evaluating effectiveness and efficiency of mangrove afforestation in Brebes. As a consequence, the same mistakes were repeated. Repeated low survival rates and mistakes caused substantial economic loss for local communities and the local government agencies (see Appendix 3).

6.6. The new knowledge - the sixth stage

During the debriefings, lessons learnt from the mangrove afforestation projects undertaken on the Brebes coast were agreed as follows:

6.6.1. Production of mangrove seedlings

It is not always necessary to construct nurseries to produce seedlings of mangroves. However, when production of mangrove seedlings is needed to suit local circumstances and needs, the following lessons should be taken into consideration to ensure effectiveness and efficiency:

a) Nurseries should be constructed as close as possible to transplantation sites and to sea water ways, for irrigation purposes;

b) Sea mud and large sized shopping bags should be used for potting;

c) Seeds and propagules of various local mangrove species should be collected and potted for producing seedlings;

d) Multiple propagules should be potted in one pot to establish a strong foundation;

e) Bags should be regularly rotated to prevent roots growing through bags into the base ground of nurseries;

f) Seeds and propagules should be tended in nurseries for a maximum period of 3 months.

6.6.2. Mangrove restoration

Based on the lessons learnt from Kien Giang and from Brebes, to achieve successful mangrove restoration in Brebes, the following matters should be taken into consideration:

a) To date, nothing has been done in relation to mangrove restoration in abandoned ponds and active ponds. Current transplanted mangrove areas have not been well protected. Abandoned and active ponds should be configured in a way that assists in establishing the mangrove green belt along the Brebes coast, together with protection of the current transplantation areas;

b) Bamboo fences should be upgraded with local resources such as coconut trunks using the lessons learnt from Vam Ray, Kien Giang, Vietnam to remove stressors to abandoned ponds and eroding areas, to protect current transplantation areas, and to promote natural regeneration and growth of other mangrove species. A rock wall is an effective choice if the Brebes agencies afford its construction and maintenance in eroding coastal areas;

c) In severely eroded areas, where mangroves must be transplanted to rapidly establish a mangrove green belt that provides adequate protection to local properties and increases coastal resilience, reduces coastal degradation, and avoids coastal erosion, local mangrove species should be prioritised for transplantation, especially to avoid the introduction of exotic species to the areas.

d) Transplantation in straight lines and utilisation of bamboo sticks to support seedlings or propagules was not effective. It would be better to mimic nature by mixing seedlings, seeds or propagules of various local mangrove species at high density in clusters to ensure high survival rates and to rapidly establish mangrove areas in severely eroded areas. Roots of seedlings and propagules should be protected during transplantation to avoid low survival rates.

6.6.3. Monitoring and evaluation of mangrove afforestation

Community based monitoring and evaluation programs should be established and chaired by the head of each community. In these programs, the issues related to mangrove transplantation need to be regularly monitored and evaluated to ensure effectiveness and efficiency, and to avoid the same mistakes.

6.7. Conclusions

This chapter applied the practical framework for understanding the effectiveness and efficiency of the current Brebes coastal erosion strategies. Inefficient and ineffective nursery operation, the wrong choice of mangrove species, improper transplantation techniques, and poor coastal protection measures contributed to limited success in coastal erosion control. Inadequate monitoring and evaluation meant that few lessons were learnt and the same mistakes continued to be made.

This research greatly assisted the communities in properly understanding the effectiveness and efficiency of the current Brebes coastal protection strategies, drawing on new knowledge in relation to mangrove restoration, production of mangrove seedlings, and coastal protection measures. Understanding based on the lessons learnt has led to a commitment to change practices by the communities and agencies, including improvement to the operation of mangrove nurseries, and the development of strategic plans for establishment of a mangrove green belt along the Brebes coast, including monitoring and evaluation.

The next chapter uses a part of the practical framework for future development of sustainable management for mangrove dominated muddy coasts in Kien Giang, Vietnam, and Brebes Regency, Indonesia.

CHAPTER 7[7]

SUSTAINABLE MANAGEMENT OF THE MANGROVE DOMINATED MUDDY COASTS IN KIEN GIANG, VIETNAM AND BREBES REGENCY, INDONESIA

This chapter applies the first three stages of the practical framework to the development of sustainable management strategies for mangrove dominated muddy coasts in Kien Giang, Vietnam, and Brebes Regency, Indonesia. Because the suggested practices have not been implemented, it is not possible at this stage to fully implement the model. This chapter contains two sections: Section 1: Sustainable management of the mangrove dominated muddy coasts in Kien Giang, Vietnam through a 30 (use) /70 (protection) of mangrove areas on allocated mangrove areas and a 70 (use) /30 (protection) configuration on private agriculture lands or planned coastal development areas, and Section 2: Sustainable management of the mangrove dominated muddy coasts in Brebes Regency, Indonesia through strategic establishment of a mangrove green belt for adaptation to climate change and livelihood protection.

As discussed in Chapters 3 and 4, the 30/70 policy that applies to allocated mangrove areas, aims to protect and use mangrove areas for coastal protection and income generation in Kien Giang. However, this policy has not achieved its goals because there were no specific technical guidelines, especially on the configuration of mangrove allocations, mangrove protection and transplantation. Land uses and land use planning practiced on private coastal areas caused many problems for the Kien Giang coastal mangrove belts. As a consequence, the entire coastline has been made vulnerable to coastal erosion and mangrove loss. During community meetings, the Kien Giang government agencies and communities have been made fully aware of the consequences of having no specific guidelines on the 30/70 ratio implementation and the risk from sea level rise and coastal erosion. The local communities were actively discussing ways of configuring allocated mangrove areas

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[7] This chapter is being written as two manuscripts: **Configuration of Mangrove Allocation Areas for Mangrove and Livelihood Protection in Kien Giang, Vietnam;** and **Strategic Solutions for Establishing a Mangrove Green Belt for Adaptation to Climate Change and Livelihood Protection in Brebes, Indonesia.** The first manuscript is scheduled to be submitted to the Journal of Ocean and Coastal Management in August 2016; the second to the Journal of Coastal Management in September 2016.

that could assist in balancing demands for their income generation activities (aquaculture activities) with contractual requirements for mangrove protection. The research assisted in building on their capacity and creating co-learning process and they made decisions to solve their own problems. The configuration to be discussed in this chapter was agreed by the Kien Giang communities (see Appendix 3).

As for the Brebes case (Chapter 6), the current strategies for coastal erosion issued by the relevant government agencies have had limited success due to insufficient technical guidelines on production of mangrove seedlings, transplantation and coastal protection. The local communities experienced loss of aquaculture ponds and mangrove areas due to coastal erosion. The strategic establishment plan discussed in this chapter has been a result of a series of community meetings, field visits and debriefings, with reference to lessons learnt elsewhere including the Kien Giang case.

The configuration plan in Kien Giang and the strategic establishment plan in Brebes are not final products. They need to be tested in the local circumstances of Kien Giang and Brebes for effectiveness and efficiency (new knowledge development) for future application and policy changes. Both locations have shown their support and commitment to the plans (see Appendix 3). However, it takes time to provide support and commitment due to administrative procedures and other contractual requirements.

7.1. SUSTAINABLE MANAGEMENT OF THE MANGROVE DOMINATED MUDDY COASTS IN KIEN GIANG, VIETNAM THROUGH THE CONFIGRATION OF MANGROVE AREAS (ALLOCATED MANGROVE AREAS AND PRIVATE AGRICULTURE LANDS OR PLANNED COASTAL DEVELOPMENT AREAS)

7.1.1. The issue – the first stage

Chapter 3 described human activities (poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels) and human activities integrated with physical processes as causal mechanisms significantly contributing to coastal erosion in Kien Giang Province.

In addition, the current policies for mangrove dominated muddy coasts issued and implemented by governments at all levels in Kien Giang Province have not been effective in mitigating negative effects of coastal erosion and protecting local livelihoods. Improper technical guidance on the configuration of mangrove allocations, and mangrove protection and transplantation methodologies were recognised as major contributors to the failure to establish a continuous mangrove belt. At present, design, planning, and construction of the sea dyke system in Kien Giang is the responsibility of MARD, the technical line manager of DARD. Procedurally, after the completion of the design and construction of the sea dyke system in Kien Giang, MARD assigns DARD budgets and responsibilities for protecting and maintaining the sea dyke system. Chapter 3 indicated that the construction of the sea dyke system in Kien Giang Province has jeopardised the structural integrity of the mangroves and contributed to coastal erosion. In other words, DARD and Kien Giang PPC do not have any legal requirements and responsibility for designing, planning, and constructing the sea dyke system. Although acknowledging the negative impacts of the construction of the sea dyke system, DARD and Kien Giang PPC could not do anything within their legitimate rights and responsibilities except by providing technical recommendations that aim to minimise the impacts.

The field visits and analysis of land use maps and Google maps showed that apart from the actively eroding coastal areas, the remaining coastal mangrove areas along the Kien Giang coastline are in danger from coastal erosion to varying degrees (Fig 32). A small percentage of the coast has a reasonable width of coastal mangrove forest. The majority of the coastline, however, is dissected by ponds and protected by a thin line of coastal mangroves. Much of the shoreline comprises the seaward side of aquaculture ponds without any protection from coastal mangroves. Impacted coastal mangrove areas are located on accretion areas and have been allocated to people who intentionally ignored natural hazards and who have intensively farmed for years. Ponds are left exposed to the sea, without any protection from coastal mangroves because aquaculture has not brought any benefits to the areas since pond dykes were broken by coastal erosion.

Well protected mangrove areas are those areas which have not yet been allocated or have been allocated to those who have undertaken few aquaculture activities on the allocated areas. On coastal areas issued with land use right certificates, local communities are legally permitted to cultivate or farm aquaculture and agriculture on their land. Aquaculture pond construction and construction of bunds for growing agricultural crops along the coast require clearance of mangroves, causing the coastal areas to be vulnerable to coastal erosion. Many coastal sections located within the mangrove areas were planned for the construction of residential areas, industrial zones, tourism destinations, private lands, and administrative areas, with permission issued by the Kien Giang PPC.

The muddy coasts of Vietnam including Kien Giang were predicted to be negatively affected by climate change, sea level rise, and coastal erosion, as discussed in Chapter 2. These negative effects would cause substantial social and economic burdens for local governments, and significant economic loss to communities who depend on coastal resources for livelihoods (Kien Giang PPC 2012). The question is how to balance needs for coastal protection with demands for socio-economic development on muddy coasts in Kien Giang.

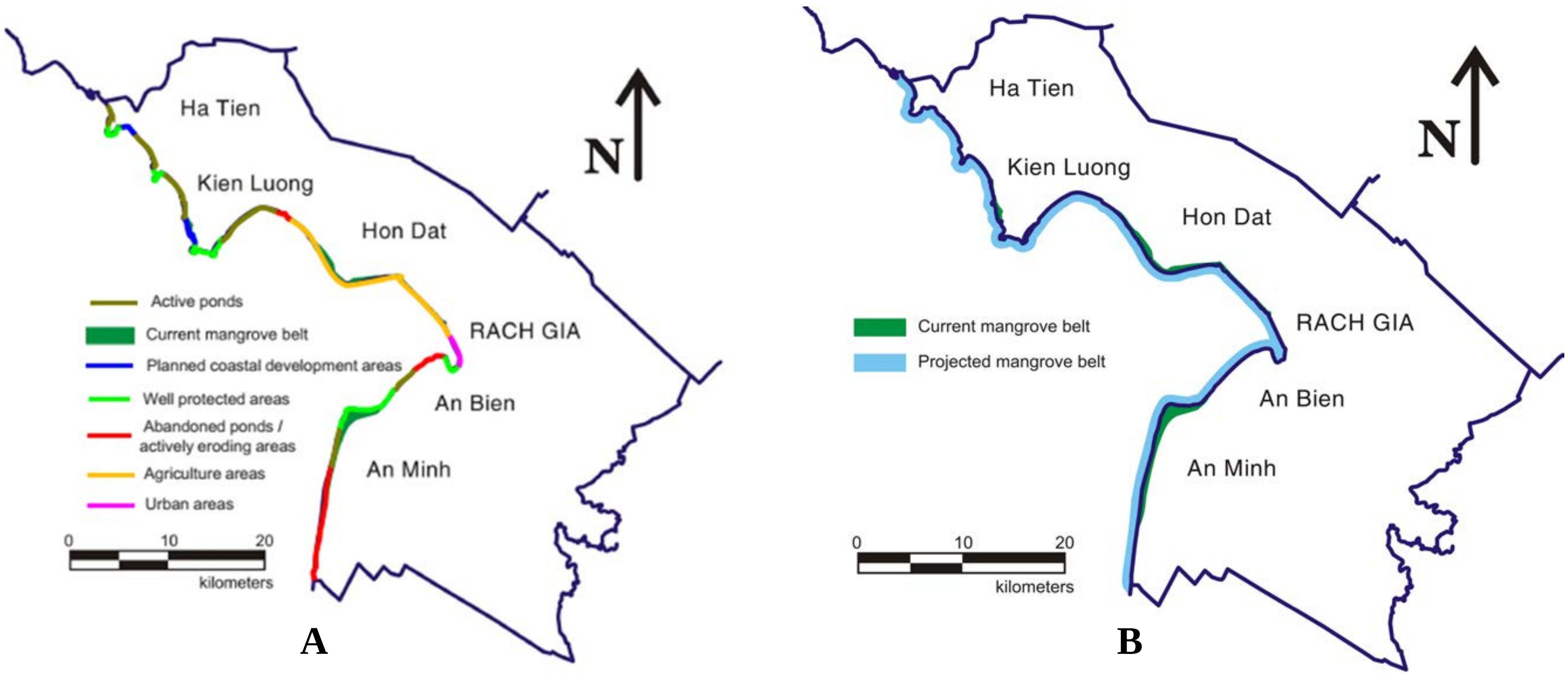

Fig 32: The projected mangrove belt in Kien Giang Province by 2020; a) the Kien Giang coastline in 2013 has planned coastal development areas, where coastal mangroves were cleared for constructing residential areas, abandoned ponds / actively eroding areas (remnants of pond dykes and pond gates found along the shoreline on low tides, loss of mangrove vegetation, sea dykes breached, mangroves were degraded or deforested, especially with *Rhizophora apiculata* being uprooted); active ponds (coastal areas dissected by ponds of all sizes and protected by a thin line of coastal mangroves, aquaculture ponds of all sizes exposed to the sea); and well protected areas (coastal mangrove areas are well protected by a width of coastal mangroves, areas not having been allocated, or areas having less aquaculture), agriculture areas, and urban areas (protected by sluice gates and sea dykes constructed along the shoreline); b) the mangrove belt to be established across the Kien Giang coastline by 2020.

7.1.2. The integration process – the second stage

The literature showed that mangroves are substantial livelihood resources for communities depending on mangrove resources (Walters et al. 2008). Mangroves provide adequate protection against coastal disasters (Das & Vincent 2009; McIvor et al. 2012), assist in dissipating wave energy (Quartel et al. 2007; Hashim & Catherine 2013), sequestering organic carbon (Comeaux et al. 2012; Bhatt & Kathiresan 2012), maintaining water quality (Wong et al. 1997; Wang et al. 2010), and adapting to sea level rise (McKee et al. 2007; McIvor et al. 2013).

Integrated mangrove aquaculture farming using mangrove functions in nutrient cycling has been popular throughout Southeast Asia (Primavera et al. 2007; Trino & Rodriguez 2002). Integrated mangrove aquaculture farming involves clearance of mangroves at certain percentages and construction of ponds among mangrove stands (Fan et al. 2013). In some circumstances, ponds are required to be constructed in degraded or fragmented areas, leaving remaining mangrove areas for protection. Integrated mangrove farming systems have caused loss of wetlands (Lee 1992), loss of mangroves (Valiela et al. 2001), changes in suspended sediments, nutrients and sediment processes in mangrove areas (Wolanski et al. 2000). Effective integrated mangrove farming requires a minimum ratio of 2 – 9 hectares of mangroves for 1 hectare of pond (Primavera et al. 2007). Integrated shrimp mangrove farming is most profitable if there is a minimum 30% mangrove coverage retained on a pond area (Binh 1997). Maintenance of mangrove quality and quantity and improvement of local livelihoods at the same time is an increased challenge to this farming system (Ha et al. 2012).

The Vietnamese government has instituted many laws and national strategic action plans that assist in establishing mangroves for adaptation to climate change, and using mangroves for livelihood improvement for local communities dependent entirely on mangroves (MARD 2008 b; Vietnamese National Assembly 2004; Vietnamese National Assembly 2006; Vietnamese National Assembly 2008; Vietnamese Prime Minister 2001; Vietnamese Prime Minister 2007 a; Vietnamese Prime Minister 2007 b; Vietnamese Prime Minister 2008 a; Vietnamese Prime Minister 2008 b; Vietnamese Prime Minister 2009; Vietnamese Prime Minister 2012). As a strategic solution put forward in 2009, a mangrove belt with a width of a minimum 500 metres was projected along the shore to mitigate adverse negative effects of climate change, sea level rise and coastal erosion. The mangrove belt helps protect the sea dyke systems, and local properties in adaptation to climate change, particularly sea level rise, and meet demands for socio-economic development (Vietnamese Prime Minister 2009; MARD 2008 b).

7.1.3. Local recognition – the third stage

7.1.3.1. Local recognition

During the debriefings in Kien Giang, local communities and the government agencies were well aware of the severity of the issues and importance of different knowledge systems in dealing with their local issues. The local communities and local government agencies showed their interest in improving the local situations. Mangrove belts will not, however, be established if current practices are not changed. The 2011 policy promotes coastal mangrove allocation for livelihood improvement and mangrove protection for adaptation to climate change, coastal erosion and sea level rise. This policy is due to be revised in late 2016, as is legally required.

Taking into consideration the issues discussed above, it is necessary to strengthen the protection of current mangrove areas in adaptation to climate change, sea level rise and coastal erosion towards establishing a continuous 500 metre wide mangrove belt along the Kien Giang coast. The strengthened mangroves will protect and improve local livelihoods (aquaculture and agriculture).

7.1.3.2. A product of integrated knowledge systems - Configuration of the Kien Giang mangrove areas (allocated mangrove areas and private agriculture lands or planned coastal development areas)

Protection of mangrove areas and livelihoods in Kien Giang is a shared responsibility for local communities and the Kien Giang PPC. Contractees recognised the problems that can result when there are no technical guidelines on pond configuration implementation available locally. The best use of resources to achieve the maximum possible immediate benefit is to use the current policy and develop and implement technical guidelines for the 30/70 policy for allocated mangrove areas.

During semi-structured interviews and field visits in Hon Dat district and Ha Tien town in December 2013 and March 2014, private coastal land owners saw their coastal areas at risk from sea level rise and coastal erosion. Private coastal land owners would like to maintain their production activities while still having their lands properly protected. Therefore, contractees and private land owners were actively involved in discussing ways of configuring coastal mangrove areas.

The configuration should be undertaken in two stages. The first step is to configure allocated mangrove areas (active ponds and abandoned ponds) at a ratio of 30 % (close to a sea dyke system for aquaculture activities) / 70 % (on the seaward side for mangrove protection). The configuration of allocated mangrove areas at the ratio of 30 /70 is entirely in accordance to the 2011 policy. The Kien Giang local communities showed their commitment to testing the configuration of allocated coastal areas at a ratio of 30 / 70, as shown in the minutes of the community meetings signed by a person nominated by the Kien Giang communities as meeting secretary.

The second step is appropriate configuration of private coastal areas (private agriculture lands or planned coastal development areas) at a ratio of 70 (close to a sea dyke system for agriculture activities or coastal development activities) / 30 (on the seaward side for voluntary mangrove protection). The configuration of private coastal areas need be undertaken on a voluntary basis. Although not ideal, 30 % is the maximum that private coastal land owners were willing to designate to establish voluntary mangrove protection areas. An increase from the proposed 30% protection may be possible once the benefits of a higher level of protection become obvious for private coastal areas.

Together with the primary mangrove belts, the configuration of allocated and private coastal areas, when configured adequately, will contribute to establishing a continuous mangrove belt along Kien Giang Province, as planned by the Vietnamese government and the government of Kien Giang province (Vietnamese Prime Minister 2009; DARD 2012).

The remaining framework stages (testing, acknowledgement and new knowledge development) are required extensions to this research at an appropriate time in the future after implementation.

i) Configuration of active ponds at a ratio of 30 / 70

Active ponds in Kien Luong, An Bien, and An Minh districts of Kien Giang Province should be configured at a ratio of 30 /70. The 30% aquaculture pond area should be located close to the sea dyke system and channels for aquaculture activities for livelihood incomes, while the 70% on the seaward side designated for promotion of natural regeneration or growth of other local mangrove species for protection (Fig 33).

a) <u>Proposed detailed configuration of active ponds protected by a thin line of mangroves:</u>

On the 30% permitted areas close to a sea dyke system for aquaculture activities:

- Good aquaculture practices based on lessons learnt in relation to aquaculture in An Bien, An Minh and Kien Luong districts should be developed for effectiveness and efficiency.
- Lessons learnt in relation to pond construction and operation should be taken into consideration for constructing new ponds on the 30% as described in the configuration.

On the 70% required mangrove areas on the seaward side for protection:

- The 70 % required mangrove areas should be ecologically restored using lateral double line silt trap fences in pond areas for promoting of natural regeneration and growth of mature seeds and propagules from current dispatches of mangrove areas.

b) <u>Proposed detailed configuration of active ponds exposed to the sea:</u>

On the 30% permitted areas close to a sea dyke system for aquaculture activities:

- Good aquaculture practices based on lessons learnt in relation to aquaculture in An Bien, An Minh and Kien Luong districts should be developed for effectiveness and efficiency.

- Lessons learnt in relation to pond construction and operation should be taken into consideration for constructing new ponds on the 30% as described in the configuration.

On the 70% required mangrove areas on the seaward side for protection:

- The 70 % required mangrove areas on the seaward side should be established using a series of single line silt trap Melaleuca fences that are built out from the shore, and transplantation of high quality seedlings of local mangrove areas at high density with protection to be provided by Melaleuca fences to promote rapid re-colonisation toward establishing continuous mangrove belt sections. High quality seedlings need to be produced using the lessons learnt regarding nursery construction and operation in Vam Ray area.
- Wooden board walks should be constructed for local transportation to avoid dredging natural small creeks or opening deeper channels through the mangroves.

c) The responsibilities of the Kien Giang agencies:

- Revising the 2011 policy incorporating the lessons learnt regarding the pond configuration on the allocated mangrove areas. Permitted thinning and selective harvests should be terminated and allocation of areas less than 1 hectare should be discontinued (Kien Giang PPC and DARD).
- Allocating funds that are used for implementing the configuration related activities, including increased payment for protecting and transplanting mangroves on the required 70% of allocated areas (Kien Giang PPC, DARD and the Management Boards).
- Undertaking participatory meetings to discuss technical issues in relation to the configuration and aquaculture farming systems (The Management Boards, District People's Committees, and Mangrove Protection and Management People Units).
- Establishing education and awareness programs on the establishment of a continuous mangrove belt along the Kien Giang coastline (the Management Boards, Mangrove Protection and Management People Units, District People's Committees).

d) <u>The responsibilities of contractees</u>

- Participating in testing the 30/70 configuration and aquaculture farming systems on their legally contracted areas.
- Establishing community based monitoring systems for issues related to the configuration, such as configuration of active ponds, ecological restoration of mangrove areas, and coastal dynamics.

ii. Configuration of abandoned ponds in actively eroding areas at a ratio of 30 / 70

The abandoned ponds in actively eroding areas located in Hon Dat, An Bien, and An Minh districts should be restored using ecologically appropriate mangrove regeneration methods for protection, with the 30%, close to a sea dyke system, not being used for aquaculture purposes until the 70% is established on the seaward side for mangrove protection (Fig 34).

a) <u>Proposed detailed configuration of abandoned ponds surrounded by current mangrove patches and mother trees:</u>

On the 30% permitted areas close a sea dyke system to be used for aquaculture activities:

- The remaining 30% close to the sea dyke system should not be used for aquaculture purposes until the 70% is established (other local mangroves regenerate or grow naturally).

On the 70% required mangrove areas on the seaward side for protection:

- The 70% required mangrove areas on the seaward side should be protected using the same strategic restoration activities that are recommended for protecting the 70% of active ponds, protected by a thin line of mangroves.
- Wooden board walks are constructed for local transportation.

b) Proposed detailed configuration of abandoned ponds devoid of mangroves:

On the 30% permitted areas close a sea dyke system to be used for aquaculture activities:

- The remaining 30% close to the sea dyke system should not be used for aquaculture purposes until the 70% is established (other local mangroves regenerate / grow naturally).

On the 70% required mangrove areas on the seaward side for protection:

- The 70% required mangrove areas on the seaward side should be protected using the same strategy that is recommended for protecting the 70% of active ponds exposed to the sea.
- Wooden board walks are constructed for local transportation.

c) The responsibilities of the Kien Giang agencies

- Revising the 2011 policy incorporating the lessons learnt regarding the pond configuration on the allocated mangrove areas. Permitted thinning and selective harvests should be terminated and allocation of areas less than 1 hectare should be discontinued (Kien Giang PPC and DARD).
- Allocating funds that are used for implementing the configuration related activities, including increased payment for protecting and transplanting mangroves on the required 70% of allocated areas (Kien Giang PPC, DARD and the Management Boards).
- Working with the local communities in developing alternative livelihood programs while waiting for the 70% of required mangrove areas to be established (The Management Boards, District People's Committees, and Mangrove Protection and Management People Units).
- Establishing education and awareness programs on the establishment of a continuous mangrove belt along the Kien Giang coastline (the Management Boards, Mangrove Protection and Management People Units, District People's Committees).

d) The responsibilities of contractees

- Engaging in restoring or transplanting mangroves that aim to establish continuous mangrove belt sections.
- Applying lessons learnt in relation to pond construction and operation for constructing new ponds on the 30% as described in the configuration, until the 70% is established.
- Establishing community based monitoring systems for issues related to the configuration such as configuration of active ponds, ecological restoration of mangrove areas, and coastal dynamics.

iii. Configuration of private agriculture lands or planned coastal development areas at a ratio of 70 / 30

Private agriculture lands and planned coastal development areas in Hon Dat and Kien Luong districts and in Ha Tien city, presently made vulnerable to coastal erosion, should be configured at a ratio of 70/30, with the 70% close to a sea dyke system being still used for agriculture or coastal development purposes, the 30% on the seaward side to be designated by private coastal land owners as voluntary mangrove protection areas toward establishing relatively thick mangrove belt sections in Hon Dat, Kien Luong districts and Ha Tien city (Fig 35).

a) Proposed detailed configuration of private agriculture lands:

On the 70% legally owned areas close to a sea dyke system for agriculture activities:

- The 70% close to the sea dyke system should be maintained for applying agriculture practices.

On the 30% voluntary mangrove areas on the seaward side for protection:

- The 30% voluntary mangrove areas should be established transplanting a variety of local mangrove species at high density to establish relatively thick mangrove belt sections.

- Wooden board walks should be constructed for local transportation of goods to avoid opening more deep channels through the mangroves.

b) Proposed detailed configuration of planned coastal development areas:

On the 70% legally owned areas close to a sea dyke system for coastal development activities:

- The 70% close to the sea dyke system should be maintained for coastal development purposes.

On the 30% voluntary mangrove areas on the seaward side for protection:

- The 30% voluntary mangrove areas should be established transplanting a variety of local mangrove species at high density to establish relatively thick mangrove belt sections.
- Wooden board walks should be constructed for local transportation to avoid opening deeper channels through the mangroves.

c) The responsibilities of the Kien Giang agencies:

- Undertaking participatory natural resource management and planning with relevant stakeholders, especially private coastal land owners in relation to the 70 / 30 configuration (The Management Boards, Mangrove Protection and Management People Units, District People's Committees).
- Supporting mangrove transplantation on the 30% required areas (The Management Boards, Mangrove Protection and Management People Units, District People's Committees).
- Supporting alternative livelihood programs, if local communities decide to transform their cultivation (The Management Boards, Mangrove Protection and Management People Units, District People's Committees).
- Undertaking the demarcation pillars to mark the boundaries of the protected coastal areas in Hon Dat and Kien Luong district (The Management Boards, Mangrove Protection and Management People Units, District People's Committees).

- Leasing inter-tidal areas inside and sea water surface areas outside the demarcation pillars in Hon Dat and Kien Luong districts for farming blood shells as economic incentives for those involving in the configuration process, especially in Hon Dat and Kien Luong districts (The Management Boards, Mangrove Protection and Management People Units, District People's Committees).
- Establishing education and awareness programs on the establishment of a continuous mangrove belt along the Kien Giang coastline (the Management Boards, Mangrove Protection and Management People Units, District People's Committees), encouraging the acceptance of a higher proportion allocated to protection.

d) <u>The responsibilities of private coastal land owners in Hon Dat and Kien Luong districts</u>

- Participating in testing the 70 / 30 configuration on their legal coastal areas.
- Engaging in restoring or transplanting mangroves that aim to protect livelihoods and to establish a continuous mangrove belt.
- Involving in establishing community based monitoring systems for issues related to the configuration such as configuration of private coastal lands, ecological restoration of mangrove areas, and coastal dynamics.

The central Rach Gia city was a landfill site, where intertidal mudflats and coastal mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba,* and *Nypa fruticans* were cleared approximately 30 years ago. The extent of reclamation was approximately 500 metres. The central Rach Gia City is highly populated (a total residential area of 3,024 hectares with a population of 229,755 in 2013[8], with restaurants, coffee shops, and houses protected by concrete sea dykes and sluice gates constructed along the shoreline. The open sea water in front of these structures is approximately 1 metre deep, which is not an ideal environment for transplantation of mangrove seedlings or for mangrove species to regenerate naturally at present. Therefore, it is unrealistic to configure these areas at present. Unallocated mangroves are recommended not to be allocated until lessons in relation to the configuration at a ratio of 30/70 of allocated and 70/30 of private mangrove areas (the new knowledge) are drawn.

[8] Source: Cantho online at http://www.baocantho.com.vn/?mod=detnews&catid=63&id=116571

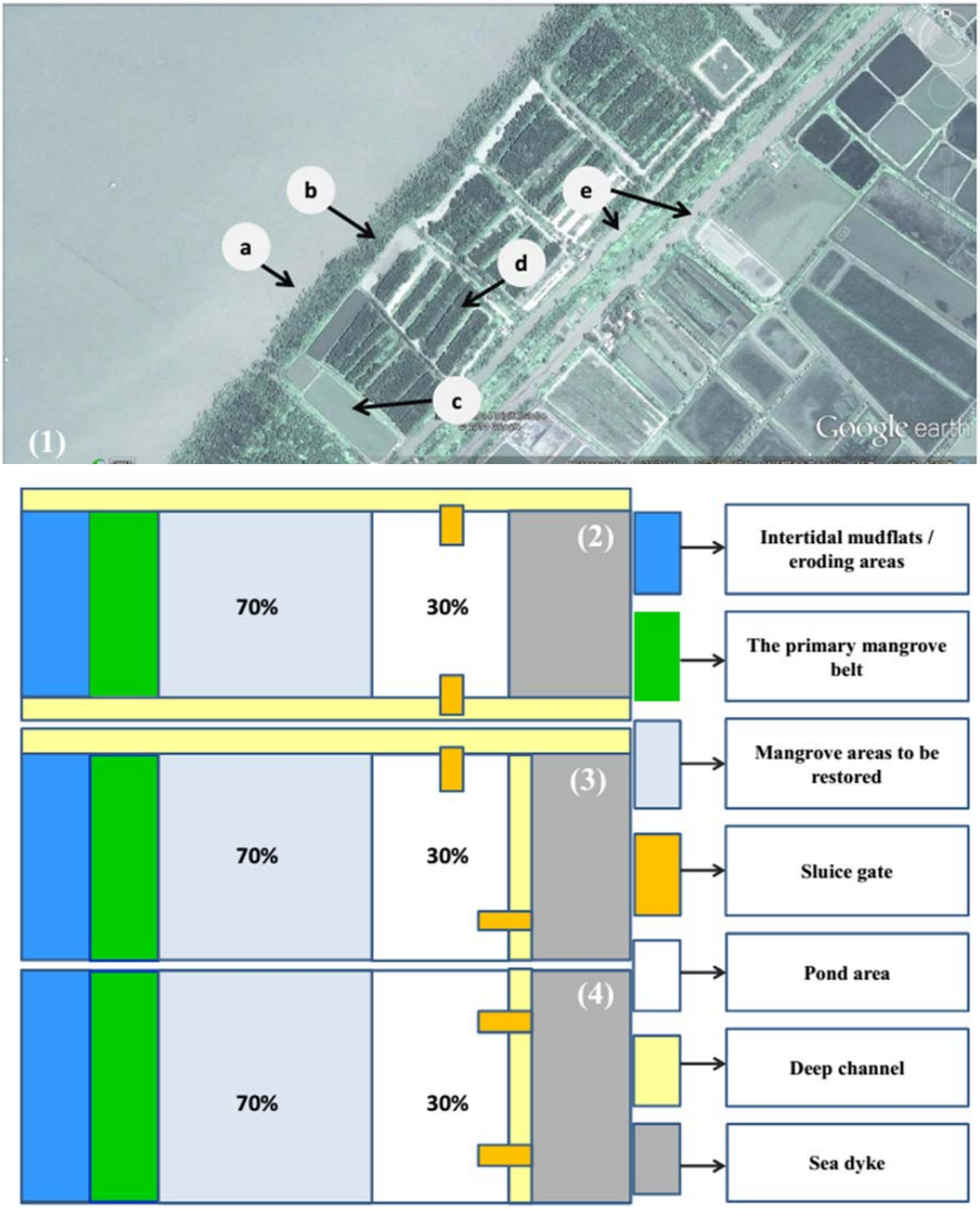

Fig 33: Configuration of active ponds. (1) indicates a typical active pond in An Minh, a) an intertidal mudflat area, b) a thin line of coastal mangroves, c) aquaculture pond area, d) *Rhizophora apiculata* grown on high eleVation areas within ponds, e) deep channels on either side of the sea dyke. *Source*: “An Minh coast.” 9^{0}52’49.88” N and 104^{0}58’58.67” **E. Google Earth**. 22 October 2011. [Accessed 3 April 2014]. (2), (3) and (4) indicate configuration of active ponds taking advantage of deep channels and rivers in a way that encourages water circulation to serve aquaculture purposes on the 30%, while together with the establishment of intertidal mudflats and the protection of the primary mangrove belt, the 70% are restored and protected to widen and improve the protection of mangrove belts along the shoreline.

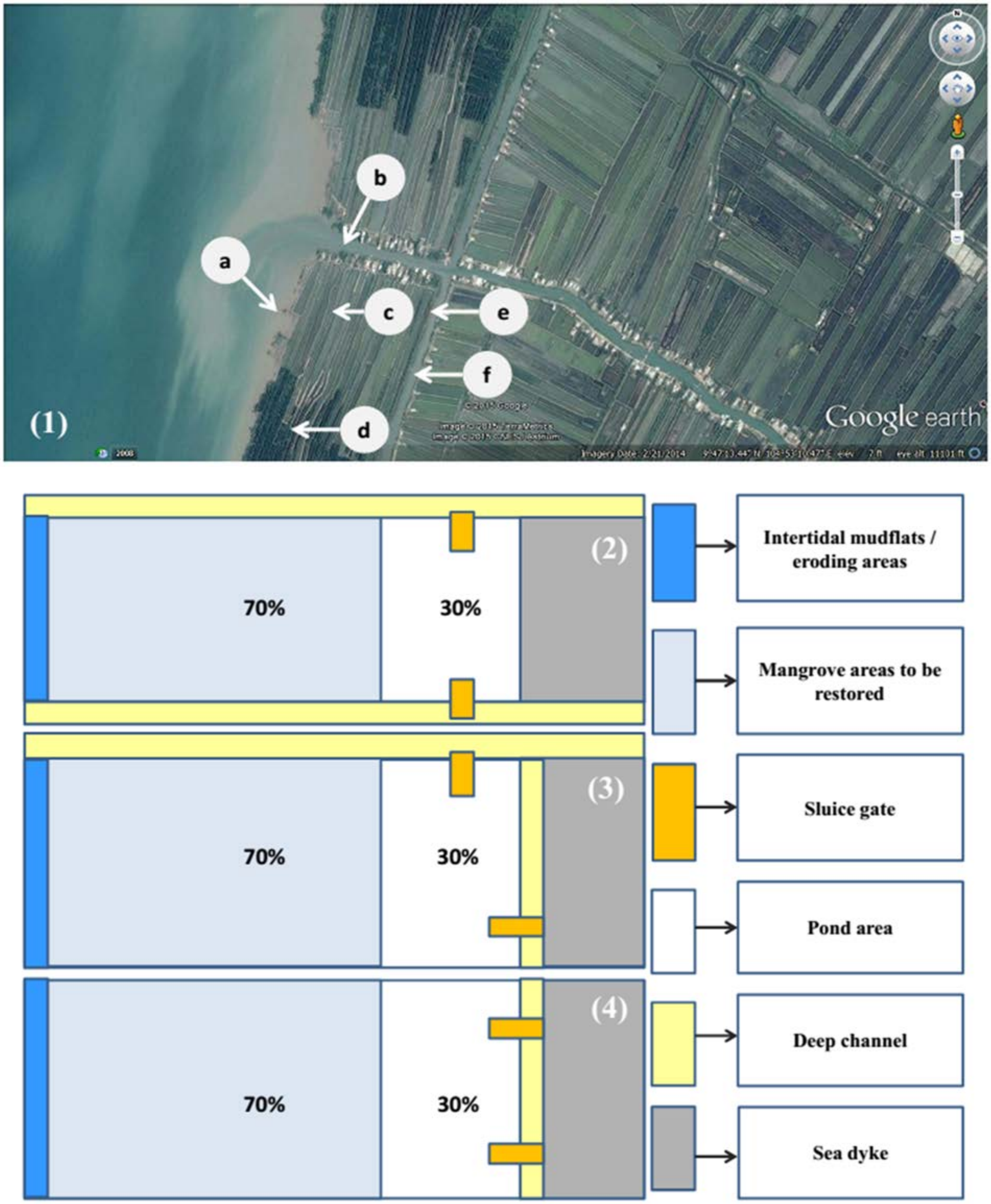

Fig 34: Configuration of abandoned ponds; (1) indicates a typical pond abandoned due to erosion in An Minh district, a) pond dykes were eroded, b) a natural river, c) aquaculture pond area, d) protected mangroves, e) the earth sea dyke, and f) the deep channel along the sea dyke. *Source*: “An Minh coast.” 9^{0}47’13.44” N and 104^{0}53’10.47” **E. Google Earth**. 21 February 2014. [Accessed 21 February 2014].
(2), (3), and (4) indicate configuration of abandoned ponds. The 70% is configured in a way that assists in protecting and connecting current fragmented mangroves and restoring ecologically abandoned ponds towards establishing a relative thick mangrove belt along the coastline. Aquaculture is not encouraged until a mangrove belt is fully established.

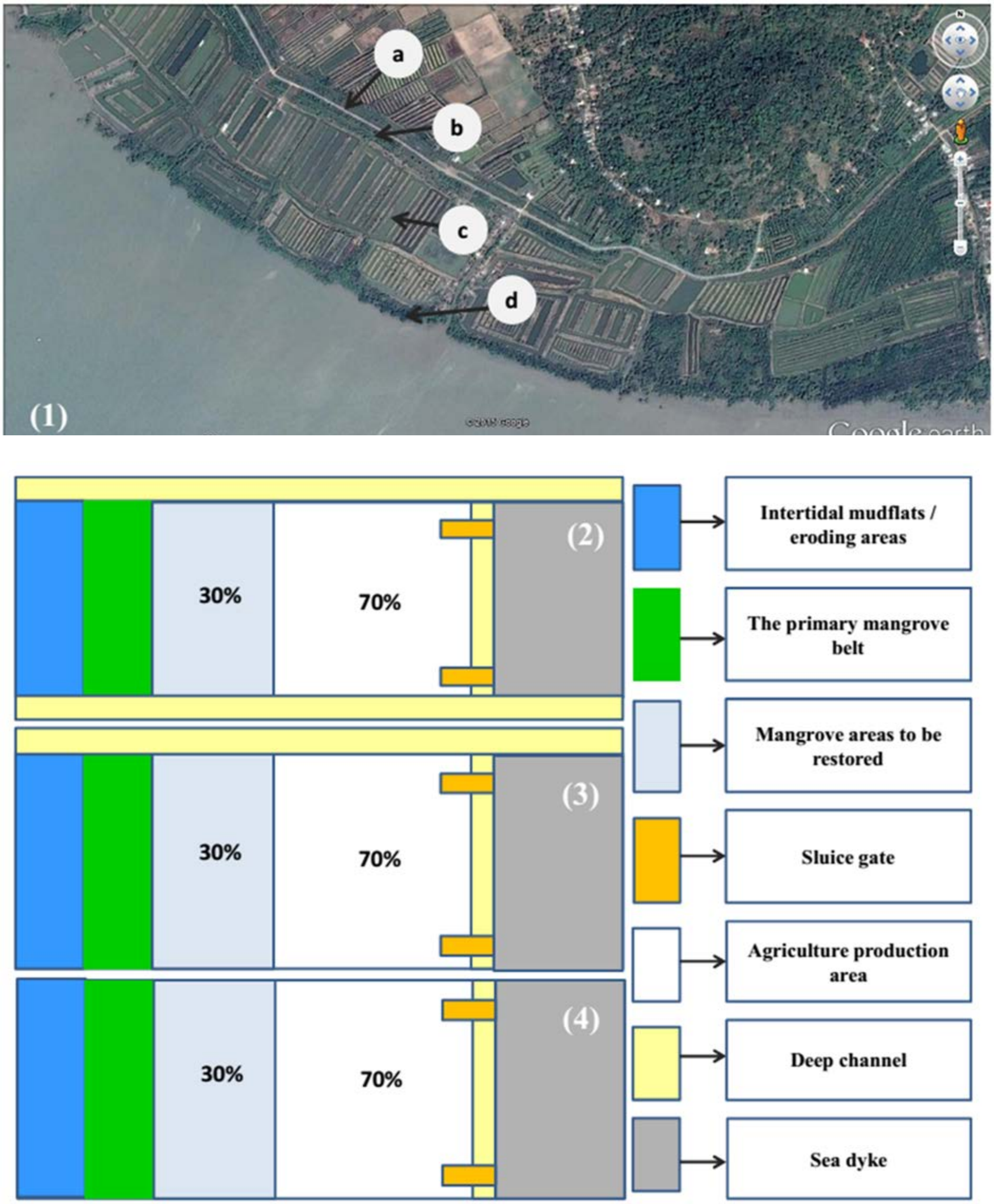

Fig 35: Configuration of private agriculture lands. (1) private agriculture lands currently protected by a thin line of mangroves in Hon Dat district, a) the earth sea dyke, b) the deep channel along the earth sea dyke, c) agriculture areas, d) a thin line of coastal mangroves. *Source*: "Hon Dat coast."$10^0$09'17.42" N and $104^0$50'08.76" **E. Google Earth**. 21 February 2014. [Accessed 3 April 2014],
(2), (3), and (4) (2), (3) and (4) indicate configuration of private agriculture lands taking advantage of deep channels and rivers in a way that encourages water circulation to serve aquaculture purposes on the 70%. The configuration is undertaken voluntarily as an action in participatory land use planning that assists in establishing a mangrove belt through mangrove restoration and protection, in return, protecting agriculture areas from being eroded or damaged by storm surge and strong waves.

7.2. SUSTAINABLE MANAGEMENT OF THE MANGROVE DOMINATED MUDDY COASTS IN BREBES REGENCY, INDONESIA THROUGH STRATEGIC ESTABLISHMENT OF A MANGROVE GREEN BELT FOR ADAPTATION TO CLIMATE CHANGE AND LIVELIHOOD PROTECTION

7.2.1. The issue – the first stage

Chapter 6 showed that the current strategy for mangrove reforestation has had limited success in preventing coastal erosion in Brebes. The Brebes coast is frequently affected by strong seasonal waves on high tides. These effects would be worsened under the influence of the projected climate change and sea level rise.

The coasts of Limbangan, Karang dampel, Kaliwlingi, Sawojajar are actively eroding. In contrast, mudflats are gradually expanding on the Pulogading coast. There are two rivers located at the ends of the Brebes Bay: Pemali River is located in the areas of Kaliwlingi and Randusanga kulon, and Cisangkung River is in Karang dempel and Limbangan. The areas of Sawojajar, Kaliwlingi, Limbangnan, and Kareng dempel were entirely cleared for aquaculture pond construction. Pemali River was completely closed by sedimentation, resulting in the flow being redirected to the sea through a small branch in Randusanga kulon. Cisangkung River has been gradually narrowed by sediment deposited along the river bank and river mouths (fig 37).

The Brebes coastal areas were unofficially leased in the 1970s to construct ponds for aquaculture purposes. Ponds were constructed for fish, crab, and shrimp farming. Pond construction was undertaken by clearing coastal mangroves, with narrow pond dykes and gates manually constructed. Propagules of *Rhizophora mucronata* were transplanted on the narrow pond dykes. Pond operation with propagules of *Rhizophora mucronata* transplanted on the narrow pond dykes was called an ‘integrated mangrove aquaculture farming system’.

In many coastal areas of Brebes Regency, coastal mangroves were dramatically degraded or totally cleared. Remaining mangrove areas have been seriously affected both by unplanned shrimp pond construction and the uncontrolled influx of people trying to earn a living from aquaculture (Mackay 2012).

7.2.2.The integration process – the second stage

Unlike Kien Giang Province, Vietnam, where policies regarding mangrove allocation for protection and livelihood improvement have been promulgated since 2005 and integrated mangrove aquaculture systems have become common practice, the relevant Brebes Regency agencies allocated coastal areas only for aquaculture purposes such as seaweed and milkfish farming. Configuration of allocated coastal areas for mangrove and livelihood protection was a new concept. As a new knowledge (discussed in Chapter 6), ecological restoration of abandoned ponds and actively eroding coastal areas and configuration of active ponds are necessary for the establishment of the Brebes pilot mangrove green belt program for promoting integrated aquaculture farming for livelihood improvements, and for adaptation to climate change and sea level rise. Therefore, it was crucial at this stage to assist local understanding by introducing scientific knowledge in relation to mangrove restoration using a variety of local mangrove species, integrated aquaculture farming systems, and configuration of mangrove areas for livelihood improvement and mangrove protection.

The literature showed that transplantation using various mangrove species has been proven to assist in creating greater ecological resilience (Blasco et al. 1996; Bhatt & Kathiresan 2012), improving morphological conditions of regeneration mangrove areas (Bhatt & Kathiresan 2012), facilitating the deposition of fine clay and silt particles onshore (Wolanski 1995; Young & Harvey 1996), promoting colonisation of newly deposited mudflats (Alongi 2008), and increasing soil surface elevation (Comeaux et al. 2012). Transplantation using various mangrove species has improved the ecological and socio-economic functions of mangrove habitats (McLeod & Salm 2006; Pandey & Pandey 2012; Mackay & Manuri 2013; Mahardi 2012).

In relation to integrated aquaculture farming systems, construction of drainage gates (Food and Agriculture Organization 1986), adequate understanding of important biological and biochemical processes in closed re-circulating and open seaweed culture (Troell et al. 2003), aquaculture integrated with herbivorous and omnivorous species (Primavera 2006), reduction of the concentration of dissolved inorganic matters and increase in the concentration of dissolved oxygen in aquaculture water bodies (Peng et al. 2009), farming of seaweed for bio-filtration to turn nutrient rich effluents into profitable resources (Neori et al. 2004), and integrated mangrove fishery farming systems (Selvam et al. 2012), could all assist in solving ecological degradation in aquaculture ponds, and maintain water quality (Wong et al. 1997; Peng et al. 2009; Wang et al. 2010). In addition, lessons learnt in relation to the configuration of allocated mangrove areas and mangrove restoration in Kien Giang were also shared in participatory community meetings in Brebes Regency.

Concrete steps have been taken to ensure sustainable coastal development for adaptation to climate change and sea level rise in Indonesia. At the national level, strategic efforts have been made to adapt to climate change that focus on economic growth (pro-growth), poverty alleviation (pro-poor), employment opportunities (pro-job) and environmental protection (pro-environment) (State Ministry of Environment 2007). A National Action Plan for Climate Change Adaptation was written in 2013 to provide direction and guidelines on sectoral and cross-sectoral climate change action plans through involving all relevant stakeholders including those from the governments, community organisations, public and private sectors (Ministry of National Development Planning of Indonesia 2013).

In Brebes Regency, regulations on long term spatial planning and coastal districts have been periodically established and approved. In the regulations, agriculture, aquaculture ponds and coastal mangrove areas have been formally zoned in an integrated way to ensure effective, efficient and sustainable coastal development (Mayor of Brebes 2004; Mayor of Brebes 2011).

7.2.3. Local recognition – the third stage

7.2.3.1. Local recognition

Common local understanding of the pilot mangrove green belt program was that the program primarily involved transplanting propagules of *Rhizophora mucronata* in landward abandoned ponds, and transplanting seedlings of *Rhizophora mucronata* supported by bamboo sticks on eroding coastal areas in Limbangan, Karang dampel, Kaliwlingi, and Sawojajar.

In consideration of the above issues, challenges, and the lessons learnt elsewhere, sustainable management of mangrove dominated muddy coasts in Brebes should be secured through strategic establishment of the mangrove green belt. Strategic establishment should address the current and future effects of mangrove degradation and coastal erosion, evaluate current needs and measures for coastal erosion and mangrove restoration in consideration of lessons learnt elsewhere, and highlight specific strategic recommendations to meet increased demands for sustainable coastal development in the future. The Brebes communities and agencies actively participated in discussing strategic establishment of a continuous mangrove belt in Brebes for adaptation to climate change and livelihood protection.

7.2.3.2. A product of different knowledge systems – A strategic establishment plan

The strategic establishment plan includes ecological restoration of abandoned ponds using gradual expansion of mangrove areas, the stabilisation of the two delta areas, and configuration of active ponds in Pulogading (Fig 36 and 37). Pulogading is an accreting area, where active ponds were permitted by local government agencies. The Brebes communities and agencies showed their commitment to being actively involved in strategic establishment of a continuous mangrove green belt in Brebes, as shown in the minutes of the community meetings signed by community representatives in Brebes. The application of the remaining stages of the practical framework is a necessary extension to the strategic establishment plan for Brebes Regency.

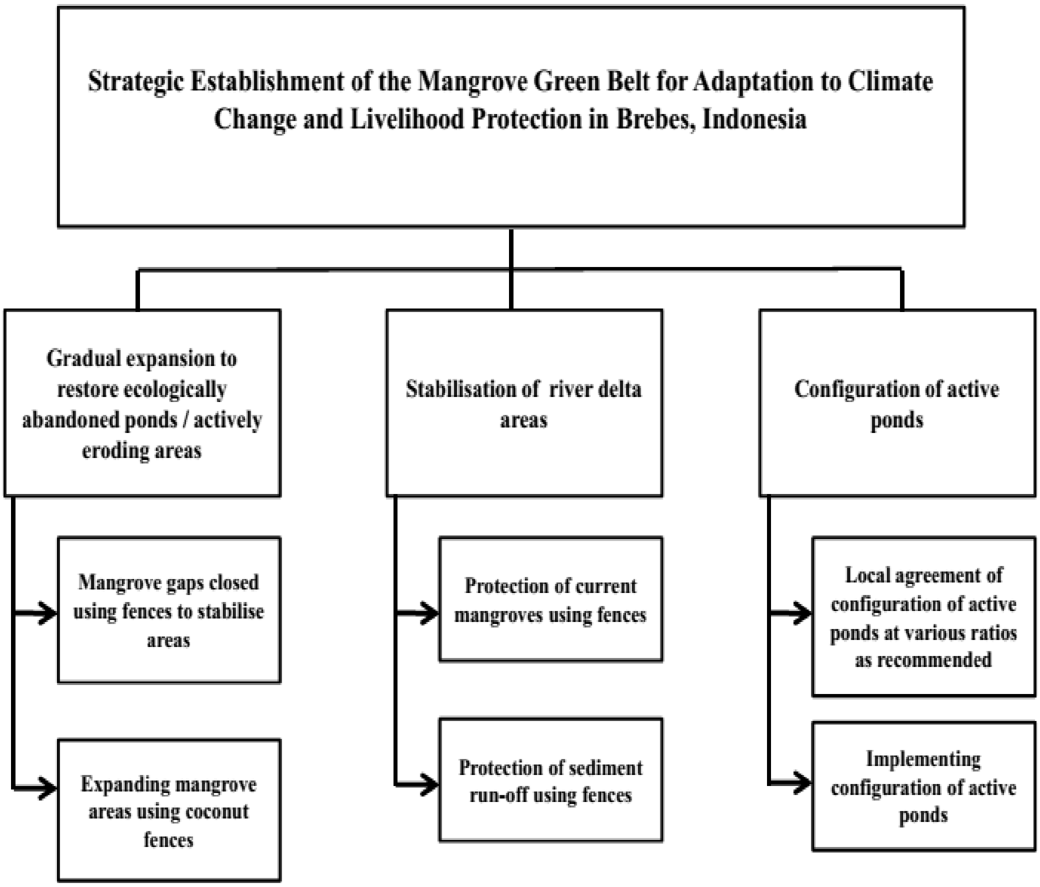

Fig 36: The components of strategic establishment of a mangrove belt in Brebes Regency, Indonesia

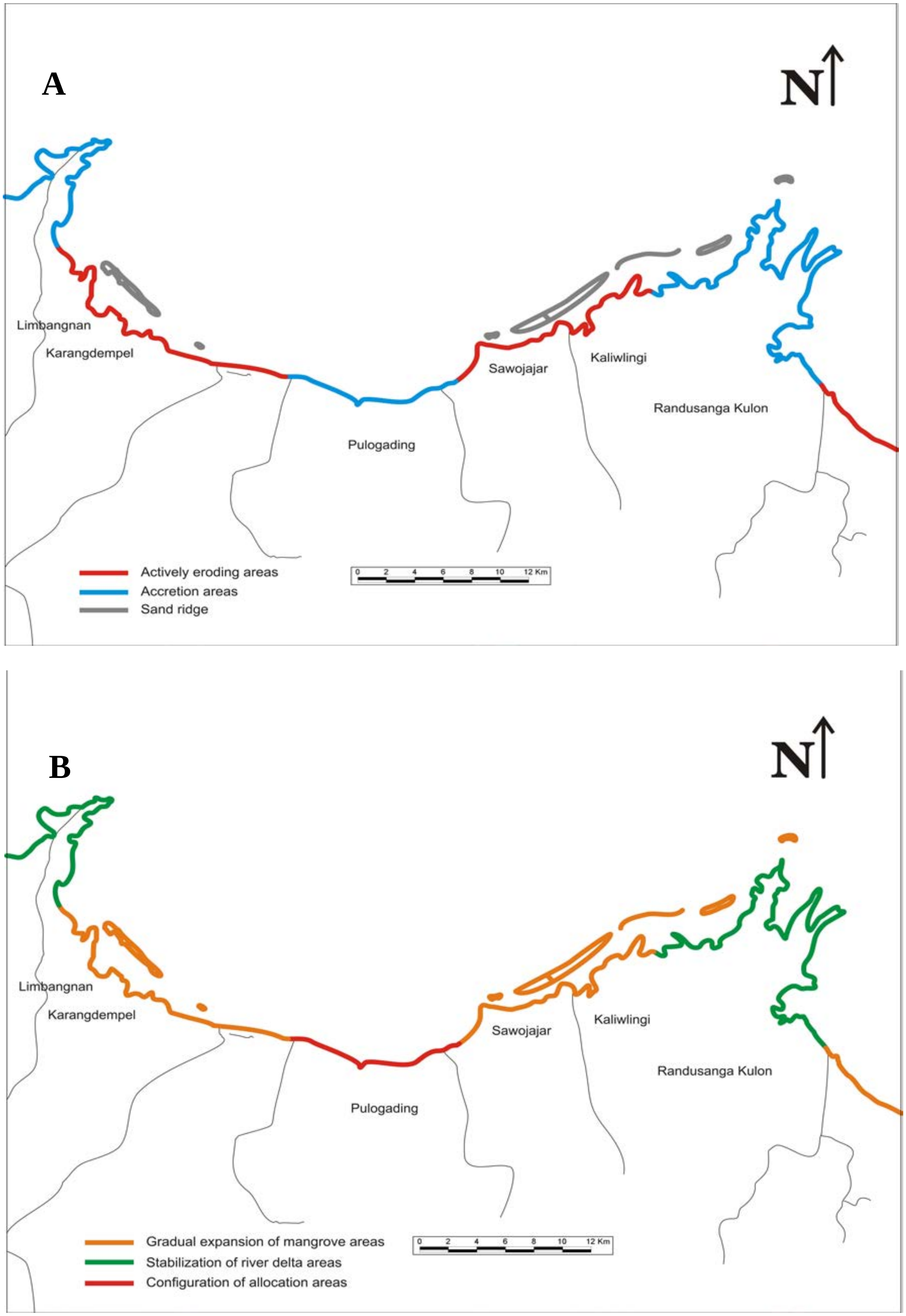

Fig 37: Overview of the strategic establishment of the mangrove green belt in Brebes Regency; a) the current Brebes coast in 2013; b) Strategic establishment plan of the mangrove green belt.

i. Ecological restoration of abandoned ponds in actively eroding areas

Ecological restoration of abandoned ponds in actively eroding areas should be undertaken using gradual expansion of mangrove areas for accumulating sea mud and promoting natural regeneration and growth of other local mangrove species. Ecological restoration should commence onshore. Abandoned ponds in actively eroding areas of Limbangan and Karang dempel should be protected using coconut trunk fences for sea mud accumulation and promotion of natural regeneration and growth. Coconut trunks, locally traded, were used in constructing a small section of fences that effectively protected active ponds in Pulogading. In Kaliwlingi and Sawojajar, transplanting high quality seedlings of local mangrove species to establish a continuous mangrove green belt is required on abandoned ponds in actively eroding areas after the floors of abandoned ponds in actively eroding areas are raised by sea mud accumulation using coconut trunk fences. Different strategies for establishing mangrove areas on abandoned ponds in actively eroding areas are recommended to achieve effectiveness and efficiency. Aquaculture farming should not be permitted until mangrove green belt sections are established. Proposed strategic interventions are described below:

a) <u>The first step: Closing gaps among abandoned ponds in actively eroding areas:</u>

- In abandoned ponds in actively eroding areas devoid of mangrove trees in Limbangan and Karang dempel, a series of single line coconut trunk fences (Fig 38) should be constructed onshore for accumulating sea mud. Sea mud accumulation would assist in gradually raising the floors of abandoned ponds, which are currently too deep for other mangrove species to regenerate or grow.
- Abandoned ponds in actively eroding areas having scattered mangrove trees in Limbangan and Karang dempel should be gradually closed using lateral coconut trunk fences (Fig 38) for accumulating sea mud to gradually raise the floors and for trapping seeds and propagules from mother trees for natural regeneration and growth.

- Gaps among clusters of transplanted *Rhizophora mucronata* in Limbangan and Karang dempel should be gradually closed using a series of single line coconut trunk fences for protecting transplanted mangroves and for stabilising the current transplantation areas.
- In abandoned ponds in actively eroding areas devoid of mangrove trees in Kaliwlingi and Sawojajar, high quality seedlings of a variety of local mangrove species, which need to be tended in nurseries using the Vam Ray lessons learnt should be transplanted in clusters in high density to rapidly establish many mangrove green belt sections, with protection provided by a series of single line coconut trunk and wave break fences (Fig 38) constructed onshore. The transplantation should not take place until floors of abandoned ponds and actively eroding areas are raised by sea mud accumulation using coconut trunk fences.
- Abandoned ponds in actively eroding areas with scattered mangrove trees in Kaliwlingi and Sawojajar should be gradually closed using transplantation of high quality seedlings of local mangrove species, which should be tended in nurseries using the Vam Ray lessons learnt with protection to be provided by lateral and wave break coconut trunk fences on abandoned ponds and actively eroding areas (Fig 38). The transplantation should not take place until floors of abandoned ponds and actively eroding areas are raised due to sea mud accumulation using coconut trunk fences.
- Gaps among clusters of transplanted *Rhizophora mucronata* in Kaliwlingi and Sawojajar should be gradually closed using a series of single line coconut trunk fences for protecting transplanted mangroves and transplantation of high quality seedlings of other local mangrove species for stabilising the current transplantation areas.

b) <u>The second step: Gradual expansion of mangrove areas:</u>

- As soon as the current transplantation areas are stabilised, and there is natural regeneration and growth of other local mangrove species, and a high survival rates of transplanted mangroves, a series of single line coconut trunk fences should be gradually built onshore to establish intertidal mudflats through sea mud accumulation.

c) <u>The responsibilities of the Brebes Regency agencies:</u>

- Analysing and evaluating historical shoreline changes in the communities using satellite images (the Forestry Protection Department, the Environment Protection).
- Working with the local communities in constructing coconut trunk fences that shall be tested for accumulating sea mud, and seeds and propagules of other local mangrove species floating onshore for natural regeneration and growth (the Forest Protection Department, the local councils, BAPPEDA).
- Developing community based monitoring and evaluation for survival rates of transplanted seedlings, construction of coconut trunk fences (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).
- Promoting local involvement in mangrove protection (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups)
- Allocating the Brebes funds that are used for fence construction and mangrove nursery construction and operation (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils).
- Working with the local communities in establishing education and awareness on the mangrove green belt program (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).
- Improving enforcement programs (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).

d) The responsibilities of the local communities:

- Involving in pilot construction of coconut trunk fences.
- Engaging in selecting local mangrove species for transplantation.
- Participating in pilot natural regeneration and growth projects.
- Engaging community based monitoring and evaluation programs.
- Participating in education and awareness of the mangrove green belt program.
- Strictly observing the law enforcement programs.

ii. Stabilisation of two river delta areas

Two river delta areas should be stabilised using lateral coconut trunk fences for protecting current mangroves and sediment runoff. Different strategies for stabilising the river delta areas are recommended to be most effective and efficient. Proposed strategic interventions are described below:

For Pemali river delta:

a) The first step: Protection of current mangrove areas:

- River delta areas where current mangrove patches and / or mother trees occur should be protected using lateral coconut trunk fences to be constructed among the mangrove areas. Construction of lateral coconut trunk fences (Fig 38) would assist in trapping floating seeds and propagules for promoting natural regeneration, protecting sediment from run-off.

b) The second step: Protection of sediment run-off:

- Delta areas devoid of mangrove areas and vulnerable to sediment run-off should be protected using a series of lateral coconut trunk fences (Fig 38). Construction of lateral coconut trunk fences also assists in trapping floating seeds and propagules for promoting natural regeneration.

For the Cisangkung River:

a) The first step: Protection of current mangrove areas

- Delta areas where current mangrove patches and / or mother trees occur should be closed using the transplantation of high quality seedlings of local mangrove species, which need to be tended in nurseries using the Vam Ray lessons learnt, with protection to be provided by lateral coconut trunk fences constructed among the mangrove areas.

b) The second step: Protection of sediment run-off

- Delta areas devoid of mangrove areas and vulnerable to sediment run-off should be closed using transplantation of high quality seedlings of a variety of local mangrove species in clusters in high density to rapidly establish mangrove green belt sections, with protection to be provided by a series of lateral coconut trunk fences constructed onshore.

c) The responsibilities of the Brebes Regency agencies:

- Analysing and evaluating historical shoreline changes in the communities using satellite images (the Forestry Protection Department, the Environment Protection).
- Working with the local communities in constructing coconut trunk fences that shall be tested for accumulating sea mud, and seeds / propagules of other local mangrove species floating onshore for natural regeneration / growth (the Forest Protection Department, the local councils).
- Developing community based monitoring and evaluation in relation to sea mud accumulation, levels of sediment run-off, natural regeneration / growth of other mangrove species, survival rates of transplanted mangrove species, and construction of coconut trunk fences (the Forest Protection Department, the Environment

Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).

- Promoting local involvement in mangrove protection (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).
- Allocating the Brebes funds that are used for fence construction and natural regeneration and growth, and mangrove nursery construction and operation (BAPPEDA).
- Establishing education and awareness on the mangrove green belt program (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).
- Improving enforcement programs (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).

d) <u>The responsibilities of the local communities:</u>

- Involving in pilot construction of coconut trunk fences.
- Engaging in selecting local mangrove species for transplantation.
- Participating in pilot natural regeneration or growth projects.
- Engaging community based monitoring and evaluation programs.
- Participating in education and awareness of the mangrove green belt program.
- Strictly observing the law enforcement programs.

iii. Configuration of active ponds in Pulogading at a ratio of 80 / 20

Active ponds should be configured on a voluntary basis at a ratio of 80 / 20. Mangrove area accounts for the 20% of total farming area on the seaward side to be voluntarily designated to construct continuous mangrove green belt sections for protection through natural regeneration or regrowth of local mangrove species, while the 80% should be designed for 'integrated mangrove aquaculture farming system' for income improvement or diversification on the landward side (Fig 39). Twenty percent is the minimum that the Pulogading community was willing to designate to voluntarily establish mangrove protection areas, and as shown in the minutes of the meetings with the Brebes communities in November 2013 and December 2014, but could increase once the benefits of designing areas for mangrove protection become obvious. Current models of aquaculture farming should remain unchanged. Proposed strategic interventions are recommended below:

a) Local agreement of configuration of active ponds at various ratios as recommended:

- Technical guidelines on configuration of active ponds at various ratios should be discussed and adopted by the Brebes community and agencies. The guidelines should take into consideration current land use planning and management, education and awareness, and the benefits to, and responsibilities of, relevant stakeholders.

b) The second step: Implementing configuration of active ponds:

On the 20 % of voluntary mangrove areas on the seaward side, single line and lateral coconut trunks fences should be constructed for trapping seeds and propagules floating onshore for natural regeneration and growth of local mangrove species. The maximum 80% on the landward side should be for 'integrated mangrove aquaculture farming'. A design of a pond dyke is recommended for better protecting ponds from strong waves (Fig 40).

c) The responsibilities of the Brebes Regency agencies:

- Preparing, discussing and signing agreements in relation to configuration of active ponds with the local communities in Pulogading (the Forest Protection

Department, the Environment Department, the Department of Marine and Fisheries Affairs, the Pulogading Council, the Mangrove Resource Rehabilitation and Conservation Group in Pulogading).

- Issuing new contracts to those who show their willingness to commit to the pond configuration process (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the Pulogading Council, the Mangrove Resource Rehabilitation and Conservation Group in Pulogading).
- Developing community based monitoring and evaluation regarding the natural regeneration or regrowth of other local mangrove species and construction of coconut trunk fences (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the Pulogading Council, the Mangrove Resource Rehabilitation and Conservation Group in Pulogading).
- Allocating the Brebes funds that are used for the configuration of active ponds (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs).
- Establishing education and awareness on the configuration of active ponds and the mangrove green belt program (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the local councils, the Mangrove Resource Rehabilitation and Conservation Groups).
- Improving enforcement programs (BAPPEDA, the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the Pulogading council, the Mangrove Resource Rehabilitation and Conservation Group in Pulogading).
- Supporting current or alternative livelihood programs, that is, blood shell farming (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs, the Pulogading Council, the Mangrove Resource Rehabilitation and Conservation Group in Pulogading).
- Organising technical training on alternative livelihood programs (the Forest Protection Department, the Environment Department, the Department of Marine and Fisheries Affairs).

d) The responsibilities of the Pulogading community:

- Involving in the configuration process.
- Participating in pilot natural regeneration or growth projects.
- Engaging community based monitoring and evaluation programs.
- Participating in education and awareness of the configuration process, alternative livelihood programs, and the mangrove green belt program.
- Strictly observing the law enforcement programs and allocation contracts signed.

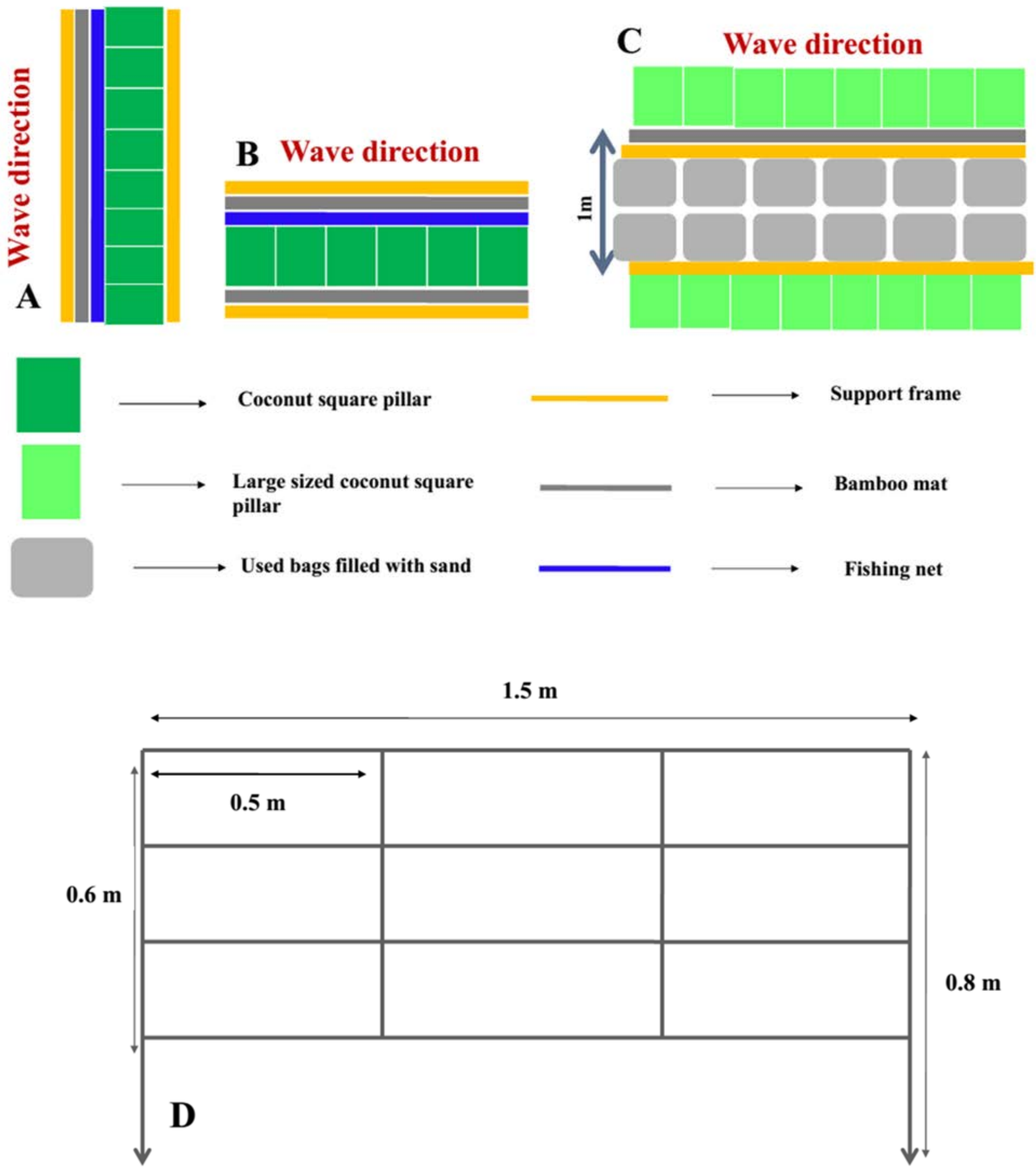

Fig 38: Design of coconut trunk fences, a) Lateral single line silt trap fence, b) single line silt trap fence, c) wave break fence, and d) a design of fence support frame.

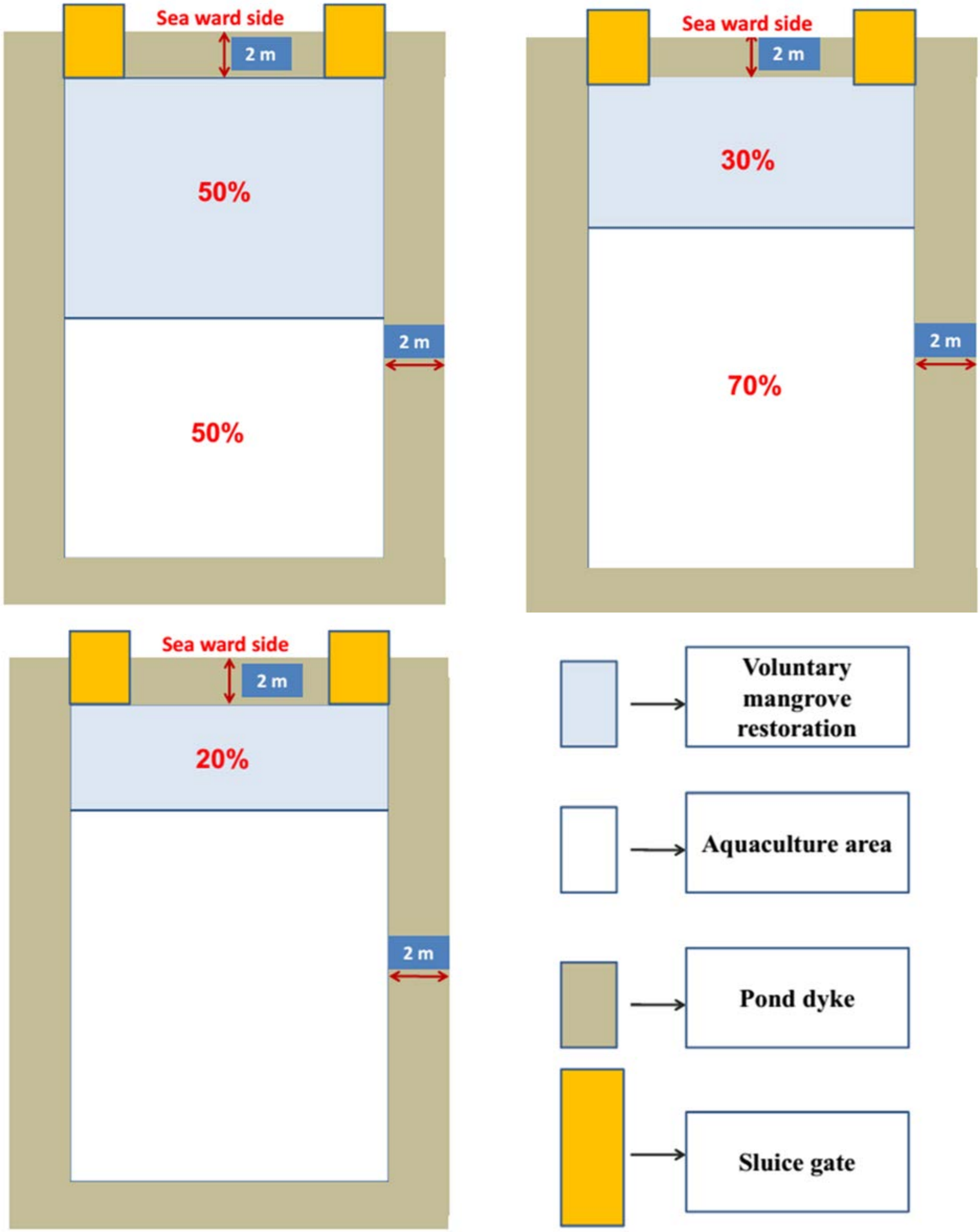

Fig 39: Configuration of active ponds at different ratios, depending on locations and agreements reached between the Brebes Regency agencies and the Pulogading community.

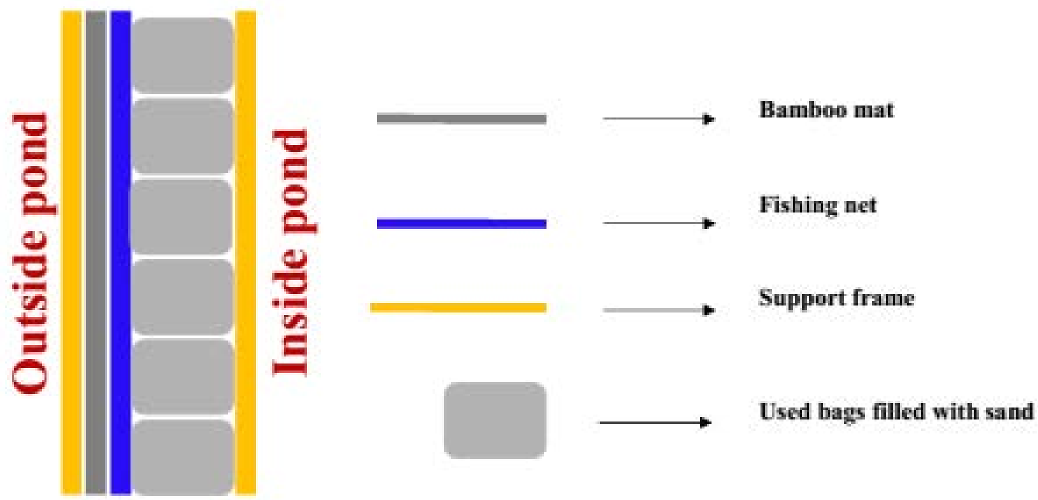

Fig 40: Design of pond dyke fence. Support frame is the same as that of Fig 38.

7.3. Conclusions

This chapter described the application of the first three stages of the practical framework for developing sustainable management plans for mangrove dominated muddy coasts in Kien Giang, Vietnam and Brebes Regency, Indonesia. The 30 (use) /70 (protection) configuration of mangrove areas for allocated mangrove areas and the 70 (maximum use) / 30 (minimum protection) for private coast lands in Kien Giang, and the strategic establishment plan in Brebes were products of integrated different knowledge systems that were agreed to be tested for establishing continuous mangrove belts for adaptation to climate change and livelihood protection. The remaining stages are required extensions after the plans have been implemented.

In Kien Giang, allocated mangrove areas are proposed to be configured at the ratio of 30 (close to a sea dyke system for aquaculture purposes) / 70 (on the seaward side with active and abandoned ponds being restored using ecologically appropriate mangrove regeneration methods), while private coastal lands at the ratio of 70 (close to a sea dyke system for agriculture or coastal development activities) / 30 (on the seaward side for voluntary mangrove protection areas). Although not ideal, 30 % is the maximum that private coastal land owners were willing to designate to establish voluntary mangrove protection areas.

In Brebes, strategic establishment plan includes ecological restoration of abandoned ponds using gradual expansion of mangrove areas, the stabilisation of two delta areas using lateral coconut trunk fences for protecting current mangroves and sediment runoff, and configuration of active ponds at a ratio of 80 (on the landward side for aquaculture activities) / 20 (on the seaward side to be designated for voluntary mangrove establishment). The twenty percent is the minimum that the Pulogading community was willing to designate to voluntarily establish mangrove protection areas.

The next chapter synthesises and concludes the findings of the research.

CHAPTER 8
CONCLUSIONS

The term scientific knowledge as used in this thesis means a combination of scientific understanding of coastal dynamics, the results of the previous studies, published sources of information, conventional practices, or management policies issued by government agencies. Local knowledge is built up over generations by those living near the site of interest. Local knowledge is often individually owned.

The literature showed that local knowledge and scientific knowledge, when integrated adequately and properly, produce enormous benefits for natural resource management in comparison to the different knowledge systems being applied independently. Both scientific knowledge and local knowledge systems have been used in mangrove dominated muddy coast management. Both approaches have advantages, but there have been many examples of limited success. The limited success is particularly noticeable when science based knowledge has been applied by outside agencies leading to a low level of local involvement, or where local communities proceed with projects without reference to science based technical guidelines. There have been many examples of projects, normally driven by government agencies and aid agencies, where ill-informed approaches have been adopted. The communities did not have the political power to object to the approaches even where their local knowledge indicated that the projects would fail. In these cases, the failure is the adequate integration of knowledge, and the application of lessons learnt previously from other projects. It is not simply a matter of communities acquiring the necessary knowledge to manage the projects successfully, and neither is it simply a matter of external agencies using local knowledge before implementing projects. In these cases, there was minimal integration of the different knowledge systems, informed by integration of knowledge systems, with adequate testing and learning from similar projects elsewhere.

The overall aim of this research was to identify mechanisms for integrating local and scientific knowledge for managing mangrove dominated muddy coasts in a sustainable way. The mechanisms identified address the adverse effects of climate change using mangrove restoration, and protect local livelihoods. The field research was undertaken in Kien Giang, Vietnam and Brebes Regency, Indonesia.

The research applied mixed methods (survey methods and participatory action research methods) to achieve the overall aim. The mixed method approach greatly contributes to developing a more complete picture of human activities and coastal management, thereby, achieving research goals in a timely manner. This research had two research questions, and four objectives.

8.1. Synthesis of the findings in relation to the research questions and objectives

8.1.1. Research objectives 1 and 3:

Research objective 1: Investigate the management of mangrove dominated muddy coasts in Kien Giang, Vietnam (Chapters 3 and 4);

Research objective 3: Test the practical framework for investigating management of mangrove dominated muddy coasts in Brebes, Indonesia (Chapter 6).

In Kien Giang, Vietnam, the current policies for mangrove dominated muddy coast management and their implementation have not achieved their goal (improved mangrove protection and livelihood improvement). Improper technical guidance on the configuration of mangrove allocations, mangrove protection and afforestation methodologies, and permitted thinning and selective harvests led to the creation of substantial gaps and disconnections in the established mangroves, making the entire coastline vulnerable to coastal erosion and degradation.

While natural factors (adverse effects of climate change and sea level rise) have been widely reported as the main causes of coastal erosion, human activities initially were not recognised by local communities as significant contributors to coastal erosion and mangrove degradation. Human activities such as poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses and construction of local boating channels, have jeopardised the structural integrity of the mangroves and contributed to coastal erosion. The interaction of anthropogenic activities and physical processes are significant contributors to erosion. During the course of this research, communities began to understand how their activities contribute to the erosion problem, and how they could participate and own the solutions.

The Vam Ray area, one of the most severely eroded mangrove dominated coasts on the Kien Giang, coast was successfully managed using ecologically based, cost-effective strategies (seven different types of Melaleuca fences, a method of gradual expansion with ten treatments gradually constructed over time and ecological mangrove restoration using five local mangrove species for transplantation). The strategies developed were a successful product of the integration of local knowledge, conventional practices and scientific understanding. The use of local labour, local resources and locally traded materials were the keys to making the project sustainable and promoting replication of the strategies at a regional level.

In contrast to the Vam Ray case, the strategy for managing mangrove dominated muddy coasts in Brebes Regency, Indonesia has had limited success in controlling coastal erosion. Inefficient nursery operation, the wrong choice of mangrove species, improper afforestation techniques, and poor coastal protection measures contributed to limited success in coastal erosion control. Inadequate monitoring and evaluation of the coastal protection program caused significant challenges for reflecting lessons learnt in relation to mangrove afforestation. Lessons from the mistakes were not learnt leading to failures being repeated and ineffective management of the eroding muddy coasts.

8.1.2. Research question 1 and the research objective 2:

Research question 1: How can local knowledge be integrated with scientific understanding in managing mangrove dominated muddy coasts sustainably? (Chapter 5).

Research objective 2: Develop a practical framework for integrating local and scientific knowledge in sustainable management of mangrove dominated muddy coasts (Chapter 5).

The practical framework for integrating local and scientific knowledge was developed using the results and conclusions from the research activities in Kien Giang, Vietnam. The framework consists of six stages: the issue (1st stage), the integration process (2nd stage) local recognition (3rd stage), testing (4th stage), acknowledgement (5th stage), and new knowledge (6th stage).

While the integrated knowledge was a new knowledge in the current integration framework and was made available for local use, the framework developed in this research showed that the development of new knowledge could not stop there, but needed a longer process for maximum benefit. Detailed consideration of the successes and failures in relation to application of the product of different knowledge systems in the local context provides new knowledge, adding to the product of the different knowledge systems. This finding and the development of a practical framework derived from the research in Kien Giang is a significant contribution of this research.

The integration framework developed in this research emphasises three additional important elements: 1) recognition, 2) testing, and 3) acknowledgement in the creation of new knowledge. While recognition and acknowledgement promote ownership of the knowledge by the local people and a high level of participation, testing of the product of integrated knowledge systems significantly contributes to the effectiveness and applicability. Furthermore, local ownership and local acknowledgement of effectiveness and applicability are likely to contribute to the sustainability of project activities at the local level. In other words, the six stage practical framework promotes a high level of integration of local and scientific knowledge, local ownership and sustainability that are the ultimate objectives that development projects are seeking. In addition, the framework assists in overcoming the challenges facing the current management strategies for managing mangrove dominated muddy coasts sustainably.

8.1.3. Research question 2 and research objective 4:

Research question 2: How can the integration of local and scientific knowledge improve management of mangrove dominated muddy coasts and develop local livelihoods? (Chapter 7).

Research objective 4: Develop plans for the sustainable management of mangrove dominated muddy coasts in Kien Giang, Vietnam, and Brebes Regency (Chapter 7).

Kien Giang sustainable muddy coast management should be undertaken using a more effective configuration of allocated mangrove areas, private agriculture lands and planned coastal development areas. Allocated mangroves should be configured at the ratio of 30 % (close to a sea dyke system for aquaculture activities) /70 % (on the seaward side for mangrove protection). The configuration of allocated mangrove areas at the ratio of 30 /70 is entirely in accordance to the 2011 policy, and therefore can be implemented quickly without requiring further political decisions.

Configuration of private agriculture lands or planned coastal development areas, currently vulnerable to coastal erosion, need to be undertaken on a voluntary basis, at a ratio of (at most) 70 % (close to a sea dyke system to be used for agriculture or coastal development activities / (at least) 30 % (on the seaward side for voluntary mangrove restoration). Thirty percent is the maximum that private land owners were willing to designate to voluntarily establish mangrove protection areas. If undertaken properly, together with the primary mangrove belt and inter-tidal mudflats and open sea water areas, which are fully protected in front of the secondary mangrove belt and private coastal areas, the configuration of allocated mangrove areas, private agriculture lands or planned coastal development areas on the secondary mangrove belt would significantly assist in establishing a continuous mangrove belt along the Kien Giang coastline. In return, the continuous mangrove belt would protect livelihoods from erosion and sea level rise, which is the ultimate objective of sustainable mangrove dominated muddy coast management in Kien Giang.

In Brebes Regency, Indonesia, the mangrove green belt should be established using restoration of abandoned ponds, stabilisation of the two delta areas, and configuration of active ponds on contracted mangrove areas at a ratio of (at most) 80 % (on the landward side for aquaculture activities) / (at least) 20 % (on the seaward side for voluntary mangrove establishment) / in Pulogading on a voluntary basis. The restoration of abandoned ponds using gradual expansion of mangroves and construction of coconut trunk fences aims to promote natural regeneration and growth of local mangrove species, to exclude negative effects of previous transplantation of a single species, and introduction of exotic mangrove species, and importantly, to reduce costs related to transplantation. The stabilisation of two delta areas using coconut trunk fences prevents sediment run-off and assists in establishing a continuous mangrove green belt. The configuration of active ponds at a ratio of 80 / 20 assists in protecting current livelihoods from erosion and in constructing a continuous mangrove green belt. The twenty percent is the minimum that the Pulogading community was willing to designate to voluntarily establish mangrove areas for protection.

These two plans are significant contributors to balancing needs for coastal protection with demands for socio-economic development, the ultimate objective of the current mangrove dominated muddy coast management policies in Kien Giang and Brebes. The configuration of ponds and other areas for both use and protection as described in Chapter 7 is expected to be a significant technical reference for Kien Giang to revise its current mangrove dominated muddy coast management policies which are due to be revised at the end of 2016, and for Brebes policies which are under review in 2016.

8.2. Limitations

In addition to the key challenges facing the application of the practical framework as discussed in Chapter 5, which are the current reporting system, communication channels, and initial denial of the severity of local issues and unwillingness to cooperate, a key limitation for this research was poor recording and documentation of previous restoration activities. Poor recording and documentation occurred when local community members tended to remember things rather than recording them systematically. Poor recording led to permanent loss of information and data, or caused significant difficulties in collecting information and data. The local Vam Ray recording system as discussed in Chapter 4 and the Brebes monitoring and evaluation as mentioned in Chapter 6 are good examples of this problem.

Poor recording and documentation of previous activities were also found in progress and technical reports prepared by governments of all types, and by consultants recruited by external agencies. These reports often attributed positive outcomes and events only to the governments and projects, and failed to describe negative outcomes or lessons that needed to be learnt to avoid the same failures in the future. This may have been to 'save face' or to try to ensure future funding. Poor recording and documentation of previous activities led to misinterpretation of results and the misconception that everything had been done satisfactorily.

The language barrier was a methodological limitation to the research in Brebes Regency, Indonesia. I am not fluent in Bahasha Indonesian and my local guide had limited English proficiency. Communication was often undertaken using hand drawings, Google Translate, or by hiring persons with adequate English skills for important community meeting events. The language barrier may have led to loss of important information and data during translation and field discussions, or insufficient gathering of data needed for thorough analysis of the results. In retrospect, some issues emerging later in the research, especially during the thesis writing process could have been better addressed if specific questions had been asked during the research implementation.

8.3. General conclusions

Despite the limitations as discussed above, the research successfully achieved the overall aims and objectives and reasonably answered the research questions. The complement of local and scientific knowledge during the integration process have assisted in investigating the management of mangrove dominated muddy coasts in Kien Giang, Vietnam and Brebes Regency, Indonesia. As a crucial result of the research, the six stage practical framework adds a new dimension to the literature in relation to integration of local and scientific knowledge in natural resource management. The framework also significantly contributes to overcoming the challenges that development projects are facing, including participation, ownership, and sustainability. The application of the practical framework contributes to developing sustainable management processes for the mangrove dominated muddy coasts in Kien Giang, Vietnam, Brebes Regency, Indonesia, and potentially elsewhere.

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APPENDIX 1: RESEARCH ETHICS APPROVAL

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APPENDIX 2: QUESTIONS USED IN CONVENIENCE AND PURPOSIVE SAMPLING, SEMI-STRUCTURED INTERVIEWS AND COMMUNITY MEETINGS

Convenience and purposive sampling methods, semi-structured interviews, and participatory community meetings were conducted to collect further relevant literature that were not made available and primary data. Before being interviewed or involved in discussions, interviewers were given a project information sheet for information. The information sheet and questions used in the research are included below.

INFORMATION SHEET

PROJECT TITLE: MANAGING ERODING MUDDY COASTS

You are invited to take part in a research project about **Integrating local and scientific knowledge to address muddy coastal erosion and local livelihoods in Kien Giang, Vietnam and Brebes Regency, Indonesia.** The study is being conducted by **Mr. Nguyen Tan Phong** and will contribute to the Degree of Doctor of Philosophy at James Cook University.

If you agree to be involved in the study, you will be invited to be interviewed / to participate in community workshops / participatory community meetings in the Brebes Regency, Indonesia. The interview, with your verbal consent should only take approximately 1 hour of your time. The interview will be conducted at a venue of your choice. Locations of community workshops / participatory community meetings shall be selected by community representatives or representatives of local government.

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice.

Your responses and contact details will be strictly confidential. The data from the study will be used in the following research publications. You will not be identified in any way in these publications.

1) Mangrove degradation and coastal erosion in Kien Giang, Vietnam: Causes and recommendations for strategic planning for sustainable muddy coastal development.
2) Mangrove degradation and coastal erosion in Brebes Regency, Indonesia: Causes and recommendations for strategic planning for sustainable coastal development.
3) Local and scientific knowledge used for successful ecological mangrove restoration in Hon Dat District, Kien Giang Province, Vietnam and the development of a methodology for replication; and
4) Traditional knowledge and local practices applied to establish a mangrove nursery on acid sulphate soils for mangrove restoration, Vam Ray area, Kien Giang, Vietnam.
5) Strategic planning for mangrove restoration and rehabilitation in Brebes Regency, Indonesia through the combination of traditional knowledge and scientific knowledge.
6) Improving local livelihoods using coastal mangrove protection: mangrove based economic development in Kien Giang, Vietnam; and in Brebes Regency, Indonesia.

If you have any questions about the study, please contact Mr. Nguyen Tan Phong, **the Principal Investigator and A/p Kevin E. Parnell, the Primary Supervisor.**

Principal Investigator:
Nguyen Tan Phong
School of Earth & Environmental Sciences
James Cook University
Email: phong.nguyen@my.cu.edu.au

Primary supervisor:
A/P Kevin E. Parnell
School of Earth & Environmental Sciences
James Cook University

Email: kevin.parnell@jcu.edu.au

If you have any concerns regarding the ethical conduct of the study, please contact:
Human Ethics, Research Office
James Cook University, Townsville, Qld, 4811
Phone: (07) 4781 5011 (ethics@jcu.edu.au)

QUESTIONS

I. Questions used in Kien Giang, Vietnam:

1) How did the area look like in the past?
2) When and how were sea dykes constructed?
3) When did aquaculture activities happen in the area?
4) When and how were aquaculture ponds constructed?
5) When and how did the transplantation using *R. apiculata* commence?
6) When and how did the transplantation using *A. marina* commence?
7) What are support from governments of all levels in relation to aquaculture and transplantation?
8) Which following activities, do you think, caused coastal erosion in the area? (you can choose as many activities as you think that caused coastal erosion and explain why).
    a) Climate change
    b) Sea level rise
    c) Flooding / inundation
    d) Changes in sedimentation
    e) Aquaculture techniques
    f) Agriculture techniques
    g) Mangrove cutting for timber use
    h) Sea dyke / sluice gate construction

II. Questions in relation to nursery construction and operation in Vam Ray:

9) When and how did the nursery constructed?
10) When did the collection of seeds and propagules start?
11) How and how long were seeds / propagules potted and tended?
12) What was the results?

III. <u>Questions in relation to mangrove restoration in Vam Ray:</u>

13) When and how was mangrove restoration started?

14) What was the results?

15) What was the lessons learnt in relation to mangrove restoration?

IV. <u>Questions used for semi-interviews with private coastal lands</u>

16) When and how did you own your private lands?

17) When and how did you start your agriculture activities / coastal development activities on your private lands?

18) What are your suggestions in relation to protection of your private lands?

19) What would you like the government agencies to assist in protecting your private lands?

V. <u>Questions used in Brebes Regency, Indonesia:</u>

20) How did the area look like in the past?

21) When did aquaculture activities happen in the area?

22) When and how were aquaculture ponds constructed?

23) When did coastal erosion occur?

24) What was measures taken by the governments and community to respond to coastal erosion?

25) What are support from governments of all levels in relation to aquaculture and transplantation?

APPENDIX 3: TRANSLATION OF THE MINUTES OF COMMUNITY MEETINGS

A series of participatory community meetings were held with local communities in Kien Giang, Vietnam and Brebes Regency, Indonesia. As an administrative procedure, letters of introduction by the provincial departments in Kien Giang, Vietnam and Brebes Regency, Indonesia were needed before any field work and interviews were conducted. The survey focused on two types of groups: focus groups and broader groups of farmers, women and youth. However, people involved in interviews remained anonymous. An informed consent form was developed and used in the surveys. Procedures included:

1) Self-introduction.
2) Explanation of the current status of the project and the purpose of the focus group.
3) Outline of topics that would be discussed.
4) Explanation of purposes of semi-structured interviews, community meetings, field trips.
5) Assurance of anonymity and a reminder to the participants of their right to decline.
6) Consent was assumed if they agreed to participate in the survey.

In Vietnam, the minutes of the participatory community meeting were written in Vietnamese and signed by a person nominated as meeting secretary by communities. In Brebes, the minutes of the participatory community meeting were written in Bahasa Indonesia and signed with stamped approval by community representatives. The original minutes are kept at James Cook University, Australia.

Attachment 1 mentioned in all the minutes of the meeting was lists of participants who were involved in community meetings. However, the list of attendees is not attached to the minutes as presented in the appendix because of confidentiality.

The Kien Giang minutes were translated into English by me in Australia. The Brebes minutes were translated into English using Google Translate, and with support from Mr. Mashadi, field coordinator of Indonesian Rainforest Foundation in Brebes Regency, Indonesia.

Minutes of the Meeting with Community Members of Vam Ray, Hon Dat district, Kien Giang Province

12 December 2013

I. The purpose of the meeting:

A meeting was held at 10:00 AM on 12 December 2013 at Ha Tien Town to understand sea dyke construction processes, agriculture activities and coastal erosion in Vam Ray, Hon Dat, Kien Giang.

II. Participants:

Local community members, who have been involved in the allocation program in Vam Ray, Hon Dat, Kien Giang (see attachment 1) were invited to the meeting.

III. Discussion points:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

Points discussed and agreed upon were summarised as follows:

a) Construction of national defence dykes

The sea dykes (national defence dykes) sections between Vam Ray Channel and 288 Channel were constructed using cranes in 1976. Construction was undertaken clearing mangrove trees. Sediment was excavated on either side with high density of *A. marina* and *S. alba*. Dykes were first used for national defence purposes, then for irrigation and prevention of saline water intrusion. Areas located 100 metres beyond sea dykes on the seaward side were rich in *A. marina* and *S. alba*. Channels were structured among mangrove areas for local boating and transportation. In 1999, national defence dykes were upgraded and used as rural roads.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as corns, bumpkins, okras, and bananas were grown on many surface sections of sea dikes for incomes and for domestic consumption. Sea dykes were cut on their surfaces to place water pipes which were used to pump saline water into ponds landward.

b) Agriculture and aquaculture activities

Between 1975 and 1976, local community members cleared mangroves for creating lands for rice paddies and crop growing. In 1997, rice paddies were inundated and local community members broke national defence dykes to discharge flood waters into the west sea.

In 1989, local community members constructed bunds which were used for growing crops and farming sea fishes. Crops were bumpkins, sweet potatoes, and rice. Fishes were *Lates calcarifer* and *Mugiliformes*. Larvae of *Lates calcarifer* and *Mugiliformes* were collected from the wild. Saline water was pumped into ponds for fish farming. Many households cleared *A. marina* located outside national defence dykes in the secondary mangrove belt for constructing ponds for fish farming. Ponds were mechanically constructed. Pond dykes were constructed using cranes, with a width of 1 and 3 metres. Mangroves beyond the coastal mangrove protected areas were fragmented with *A. marina* and *S. alba*.

In 1992, The Provincial People's Committee issued a policy that regulated transplantation and coastal mangrove protection. Local community members were asked to clear *A. marina* and to transplant *R. apiculata* between 1992 and 1994. Local community members were provided with propagules of *R. apiculata*, which were transplanted on their allocated lands. Local community members were provided with propagules, and were paid for transplantation and caring services. However, they were not provided with technical guidance in relation to transplantation and locations of transplantation. As a consequence, *R. apiculata* did not survive well, leading to a low level of forest coverage. Local community members applied aquaculture practices using construction of ponds and dredging channels.

Heavy cutting of mangroves fragmented mangrove belts. Between 2004 and 2005, coastal areas beyond sea dykes were allocated for coastal mangrove protection and management. Local community members were not allowed to harvest mangroves. They were permitted to collect fallen trees and dried branches for firewood.

The Kien Giang People's Committee issued the Policy No. 51 (in 2005) and Policy No. 25 (in 2011) to allocate mangroves to local community members for coastal mangrove protection and management. Local community members are required to protect and develop the 70% of required mangrove areas and are permitted to use the 30% allocated areas for aquaculture activities. When allocated, local community members were not provided with technical guidance in relation to aquaculture and uses of the 30% permitted areas and transplantation, while they are required to protect the 70% required mangrove areas. In addition, local community members were not fully aware of benefits and contractual requirements when involved in the program. Therefore, the 70% required mangrove areas were not guaranteed on allocated mangrove areas because *R. apiculata* transplanted previously did not survive. Local community members lost consecutive products because fishes, crabs and shrimps died.

At the policy No. 25 issued by the Kien Giang Provincial People's Committee, local community members were permitted to undertake selective harvests of fully grown trees of *R. apiculata.* Therefore, in 2012, Local community members cleared fully grown trees of *R. apiculata* on areas beyond sea dykes.

c) Causes of coastal erosion

Muddy coasts of Vam Ray were actively eroded due to human induced factors. In the primary mangrove belt and inter-mudflats, there were many natural rivers together with channels being constructed for local boating and transportation.

Strong waves on high tides propagated along natural rivers and man-made channels in the primary mangrove belt and inter-mudflats into deep channels in parallel with sea dykes causing serious erosion in mangrove areas and their surrounding areas. Therefore, the mangrove belts, originally fragmented and thin, became thinner over time. Repeated propagation led to mangrove areas being seriously eroded and further lost, especially during the time of strong waves in high tides.

d) Recommendations by local community members

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

Nguyen Phi Thong signed as the secretary of the meeting.

Minutes of Meetings with People Who Had Been directly Involved in Mangrove Restoration on Actively Eroding Area in Binh Son, Vam Ray, Hon Dat, Kien Giang From May to December 2009

15 December 2013

I. The purpose of the meeting:

A meeting was held in Ha Tien Town on 15 December 15 2013 to record the steps which had been undertaken and to evaluate mangrove restoration on an actively eroding area in Vam Ray, Hon Dat, Kien Giang, Vietnam. In this meeting, recommendations in relation to mangrove restoration in the future in Kien Giang province as well as elsewhere in Vietnam were also provided.

II. Participants:

People, who had been directly involved in mangrove restoration in Binh Son, Vam Ray, Hon Dat, Kien Giang from May to December 2013 (see attachment 1), were invited to the meeting.

III. Discussion points:

Mr. Nguyen Tan Phong introduced the contents and procedures of the meeting. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The meeting procedures were as follows:

1) Self introduction of Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

Many photographs and field notes between May 2009 and December 2013 are collected, collated and analysed to provide a complete picture of steps which were undertaken in mangrove restoration and status of restored mangroves in Binh Son, Hon Dat , Kien Giang.

Many issues in relation to mangrove restoration are discussed and status of restored mangroves in Binh Son, Hon Dat, Kien Giang (as in December 2013). Points discussed and agreed upon are summarised as follows:

a) Mangrove species and collection of seeds and propagules of mangrove species for mangrove restoration

Five mangrove species were selected for mangrove restoration in Binh Son, Vam Ray, Hon Dat, Kien Giang, Vietnam. These five mangrove species had occurred in Binh Son area before. Five local mangroves are:

1. *Avicennia marina*
2. *Rhizophora apiculata*
3. *Bruguiera cylindrica*
4. *Sonneratia alba*
5. *Nypa fruticans*

Seeds and propagules of these five mangrove species were collected in two locations: Rach Dung (Kien Luong district) and Xeo Ro (An Bien district). The reason for collecting the seeds and propagules in these two locations was that these two locations had similar mangrove species as Vam Ray.

b) Treatments

There were 10 treatments in total, including Treatment 0 (control treatment). The order of the treatments are marked on the design (see attachment 2).

c) Silt trap and wave break fences

There were 7 types of silt trap and wave break fences. They were (see attachment 3):

1) The lateral single line silt trap fence 1
2) The lateral single line silt trap fence 2
3) The lateral double line silt trap fence 1
4) The lateral double line silt trap fence 2
5) The lateral double line silt trap fence 3
6) The wave break fence.
7) The single line silt trap fence.

d) Time for and method of transplantation

Seeds and propagules of five mangrove species were collected and tended for a period between June and October 2009. Time for transplantation was follows:

❖ The 1^{st} transplantation: Early September 2009

- *N. fruticans* and *R. apiculata*

❖ The 2nd transplantation: Late September 2009

- *B. cylindrica, N. fruticans* and *R. apiculata*

❖ The 3rd transplantation: Early October 2009

- *B. cylindrica, N. fruticans* and *R. apiculata*

❖ The 4th transplantation: late October 2009

- *B. cylindrica, N. fruticans, A. marina, R. apiculata,* and *S. alba.*

Seedlings were transplanted in straight lines (0.30 cm apart) in treatments of 1, 2, 3 and 4. In treatments of 1, 2, 3 and 4, *N. fruticans* were transplanted close to the sea dyke foundation and *R. apiculata* right behind *N. fruticans* on the seaward side.

In particular, seedlings were transplanted in clusters in treatments of 5, 6, 7, 8 and 9. Transplantation was supported by a support frame made of Melaleuca poles (see the design on the attachment). Support Melaleuca frames were used in treatments of 1, 2, 3, 4 and 7.

e) Results up to August 2012

Sea mud accumulated and became firm in many treatments. Control Treatment has not accumulated sea mud and has not become firm. Despite not being recorded during the mangrove restoration, sea mud accumulation was measured using field notes prepared by some workers and photographs taken between December 2009 and May 2011.

There was a high survival rate, almost 100%. In addition, robust natural mangrove regeneration were recorded, mainly with *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica.* Other marine organisms such as crabs, oysters were recorded in 2012.

Treatment	Planted mangroves	Naturally regenerated mangroves
Treatment 1	*Rhizophora apiculata, Nypa fruticans*	*Rhizophora apiculata, Avicennia marina, Bruguiera cylindrica*
Treatment 2	*Rhizophora apiculata, Nypa fruticans*	*Rhizophora apiculata, Avicennia marina, Bruguiera cylindrica*
Treatment 3	*Bruguiera cylindrica, Rhizophora apiculata, Nypa fruticans*	*Avicennia marina, Bruguiera cylindrica*
Treatment 4	*Bruguiera cylindrica, Rhizophora apiculata, Nypa fruticans*	*Avicennia marina, Bruguiera cylindrica*
Treatment 5	*Bruguiera cylindrica, Rhizophora apiculata, Nypa fruticans*	*Avicennia marina, Bruguiera cylindrica*
Treatment 6	*Avicennia marina*	*Avicennia marina, Bruguiera cylindrica*
Treatment 7	*Bruguiera cylindrica, Avicennia marina, Nypa fruticans, and Sonneratia alba*	*Bruguiera cylindrica, Avicennia marina, Rhizophora apiculata*

Treatment 8	*Avicennia marina and Rhizophora apiculata*	*Avicennia marina, Bruguiera cylindrica*
Treatment 9	*Avicennia marina and Rhizophora apiculata*	*Avicennia marina*
Control area		*Avicennia marina*

f) Lessons learnt

In June 2010, rice straw was used as filling in the wave break fence. Rice straw was not tied tight and was easily washed onshore in strong waves. Many seedlings were covered with wet rice straw and died.

In March 2011, Melaleuca sticks and branches were used to fill gaps between the rows of the wave break fence. Over-abundance of Melaleuca sticks that were placed between the fence layers added pressure to the line of poles, damaging sections of Melaleuca poles of the wave break fence in Treatment 8. Sticks and branches were taken from the wave break fence since the damage.

Iron wire and nails were used to construct the fences. However, iron wire and nails were corroded quickly over time. Corrosion of iron wire and nails caused damage to some fence sections with bamboo mats detaching in some locations by strong waves on high tides. Detachment of bamboo mats and support frames reduced capacity for dissipating strong waves and accumulating sea mud as designed.

Some seedlings died. It was reported that some seedlings were planted with plastic bags or roots were carelessly cut before being transplanted.

Nguyen Quang Huy and Nguyen Van Tam signed as two secretaries of the meeting.

Minutes of the Meeting with the People who Had Been Directly Involved in Constructing and Operating a Nursery in Binh Son, Vam Ray, Hon Dat, Kien Giang From June to December 2009

16 December 2013

I. The purpose of the meeting:

A meeting was held in Rach Gia City on 16 December 2013 to record steps which had been undertaken for constructing and operating a nursery which produced mangrove seedlings for mangrove restoration on actively eroding area in Binh Son, Vam Ray, Hon Dat, Kien Giang, Vietnam. In this meeting, recommendations in relation to mangrove nursery construction and operation for mangrove restoration in the future in Kien Giang province as well as elsewhere in Vietnam were also provided.

II. Participants:

People, were directly involved in constructing a nursery which produced seedlings of mangroves for mangrove restoration on actively eroding area in Binh Son, Vam Ray, Hon Dat, Kien Giang from June to December 2013 (see attachment 1), were invited to the meeting.

III. Discussion points:

Mr. Nguyen Tan Phong introduced the contents and procedures of the meeting. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The meeting procedures are as follows:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent of participation.

Many photographs and field notes between May 2009 and December 2013 were collected, collated and analysed to provide a complete picture of steps which had been undertaken for constructing a nursery in Binh Son, Hon Dat , Kien Giang.

Many issues in relation to the nursery construction and operation were discussed. Points discussed and agreed upon were summarised as follows:

a) Mangrove species and collection of seeds and propagules of mangrove species for mangrove restoration

Five mangrove species were selected for mangrove restoration in Binh Son, Vam Ray, Hon Dat, Kien Giang, Vietnam. These five mangrove species had occurred in Binh Son area before. Five local mangroves are:

1. *Avicennia marina*
2. *Rhizophora apiculata*
3. *Bruguiera cylindrica*
4. *Sonneratia alba*
5. *Nypa fruticans*

Seeds and propagules of these five mangrove species were collected in two locations: Rach Dung (Kien Luong district) and Xeo Ro (An Bien district). The reason for collecting the seeds and propagules in these two locations was that these two locations had similar mangrove species as Vam Ray.

b) Transporting seeds and propagules

Seeds and propagules were transported using the traditional 'long-tail' boats and trucks. Local farmers in Rach Dung and Xeo Ro were employed to collect and store mangrove seeds and propagules in shady areas before being transported to the nursery site. The seeds and propagules were covered with wet banana or palm leaves or stored in wet plastic bags during transportation. The seeds and propagules were transported from collection sites early in the morning and arrived at the nursery site by noon the same day to minimise exposure to the sun.

c) Constructing a nursery on acid sulphate soils

A nursery (15 metres x 35 metres) was constructed on the property of Tong Van Anh. The Conservation and Development of Kien Giang Biosphere Reserve Project leased Mr. Tong's property for constructing a nursery at a cost of 25,000,000 VND per year.

The site was on acid sulphate soils with acidic water, especially in wet season. Residents believed the soils would not support tree growth. Thus, a 50 centimetre layer of liquid sea mud was laid on the surface prior to establishment of seedlings. The 50 centimetre layer assisted in preventing surfacing acidic water and supported the growth of seeds and propagules.

Materials used to construct the nursery were locally made products. The products included *Melaleuca* and *Eucalyptus* poles, locally made small gauge fishing nets, and bamboo mats. Two thirds of the nursery area was covered with fishing nets to shade mangrove seedlings from the sun at the first stage.

d) Potting

Liquid sea mud was collected at low tides. Plastic shopping bags of different sizes were used for potting the mangrove seeds and seedlings. Bags were holed and filled by hand with liquid sea mud collected at low tides and transported to the nursery ground. Propagation started when the liquid sea mud has dried up.

- *A. marina:* One individual seed per pot.
- *B. cylindrica:* Five individual propagules per pot.
- *R. apiculata:* Three individual propagules per pot.
- *S. alba* : One individual seed per pot.
- *N. fruticans:* One individual seed per pot.

e) Nursery operation – irrigation

Mangrove seeds and propagules, after being potted, were irrigated with saline water pumped over the sea dyke. Weeds growing around the pots were removed for the first two months. After the third month, it was not necessary to eradicate the weeds since the seedlings grew faster than the weeds, making it impossible for the weeds to compete for nutrition and sunlight.

f) Seedlings and survival rates

A total of 37,500 seeds (in 26,500 pots) were propagated in June 2009. 36,000 seeds and propagules of the five mangrove species were purchased from contracted collectors and 1,500 seeds of *A. marina* were collected by Vam Ray residents.

Species	Seed / propagule	No. of seeds / propagules in each pot	No. of pots	Average height of seedlings after 3 months (cm)
N. fruticans	seed	1	6.000	35
R. apiculata	Propagule	3	2.500	43
B. cylindrica	Propagule	5	1.500	32
S. alba	Seed	1	7.500	60
A. marina	Seed	1	9.000	55

Seeds and propagules were tended for three months in the nursery and were transplanted in four events as follows:

❖ The 1st transplantation: Early September 2009

- *N. fruticans* and *R. apiculata*

❖ The 2nd transplantation: Late September 2009

- *B. cylindrica*, *N. fruticans* and *R. apiculata*

❖ The 3rd transplantation: Early October 2009

- *B. cylindrica*, *N. fruticans* and *R. apiculata*

❖ The 4th transplantation: late October 2009

- *B. cylindrica*, *N. fruticans, A. marina*, *R. apiculata*, and *S. alba.*

The seedlings were reported by the Integrated Conservation and Development of Kien Giang Biosphere Reserve Project reported in 2011 and 2012 to have had 100% survival.

In October 2009, the Department of Agriculture & Rural Development of Kien Giang requested 4,000 seedlings of *A. marina* and 2,500 *S. alba* which were transplanted elsewhere in Kien Giang. As reported by the Department of Agriculture & Rural Development of Kien Giang, the seedlings grew well.

Tong Van Anh signed as the secretary of the meeting.

Minutes of the Meeting with Community Members of the Villages of T5 and T6, Hon Dat District, Kien Giang

1 March 2014

I. The purpose of the meeting:

A meeting was organised at 10:00 AM on 1 March 2014 at a local household in the village of T5 to understand sea dyke construction processes, aquaculture and status of coastal erosion in the villages of T 5 and T 6, Hon Dat district, Kien Giang.

II. Participants:

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in the villages of T5 and T6, were invited to the meeting (see attachment 1).

III. Discussion points:

Mr. Nguyen Tan Phong introduced himself, the contents and procedures of the meeting. The meeting procedures were as follows:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued participation assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, and coastal erosion in the villages of T5 and T6, Binh Giang, Hon Dat district, Kien Giang.

Points, which were discussed and agreed upon, were summarised as below:

a) Construction of sea dykes

Sea dykes (locally called national defence dykes) were constructed in 1997 using cranes to excavate sediments on either side of sea dykes. In locations close to the sea water, sediment was excavated on the landward side. Sea dykes were first used for national defence purposes, then for irrigation and prevention of saline intrusion. Areas located 200 metres beyond sea dykes on the seaward side were rich in mangrove species in the past. Channels were dug across rice field areas landward of sea dykes on the seaward side. Man-made channels were used for local transportation (using fishing boats and long tailed small boats).

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as corns, pumpkins were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Before 1997, people cleared naturally grown trees of *Avicennia marina* and *Rhizophora apiculata* for production of seasonal rice species trees (6 month rice species). Naturally grown mangrove trees located on the seaward side were manually and mechanically cleared for farming sea fishes, sea crabs, and sea shrimps. Local people opened short deep channels along pond dykes and cleared mangroves within ponds. More short channels were opened within ponds to extend farming areas of sea shrimps, sea crabs and sea fishes. Local people constructed underground pond gates to allow for saline water introduction into ponds for farming. Waste water was also pumped out of ponds through the same pond gates. In 2001, many farmers rushed into farming shrimps, barramundi fishes, and sea crabs. However, farmers lost their harvests due to heavily contaminated water.

In 1992, the Provincial Peoples' Committee issued a decision that shifted from promotion of aquaculture activities to coastal mangrove protection. Local community members were provided with propagules of *Rhizophora apiculata* which were transplanted on their contracted lands. Local community members were paid for transplanting and caring propagules. However, Local community members were not guided properly in relation to transplantation locations and methods. Local community members transplanted propagules in ponds, and on pond dykes. *Rhizophora apiculata* did not grow well and even died in many locations due to being transplanted in permanently inundated areas and / or other unknown factors.

The Provincial People's Committee issued two policies, namely Policy No. 51 in 2005 and Policy No. 25 in 2011. These two policies promote local involvement in transplantation and protection of mangrove species. Local community members are entitled to use the 30% of allocated mangrove areas for aquaculture activities in return for protecting the 70% required mangrove areas. However, many of allocated mangrove areas did not meet the 70% required mangrove areas due to high death rates of *Rhizophora apiculata* (only 30% of propagules of *Rhizophora apiculata* transplanted survived and the remaining 70% died). Local community members harvested fully grown trees of *Rhizophora apiculata* for making charcoal for extra money because farming of shrimps and fishes was not productive anymore. Some local community members did not use the 30% permitted mangrove areas for aquaculture activities because they owned lands elsewhere which were used for rice production.

Shrimps continued to die and local people in Hon Dat district believed that the water which ran from Rach Gia City was contaminated. Local community members cleaned ponds using lime to control pH levels before larvae of shrimps were released into ponds. Some local community members used the 30% permitted areas close to a sea dyke system (national defence dykes) for aquaculture activities, while the 70% was located on the seaward side for protecting mangroves. Local community members practised extensive farming of shrimps, crabs, and fishes, in which shrimps, crabs, and fishes were not fed regularly on the 30% permitted areas. Sea water in ponds and sea water sources were not treated properly, leading to water contamination that killed sea shrimps, sea crabs, and sea fishes. Water often became contaminated in the second year of operation.

c) Causes of coastal erosion

Muddy coasts of the villages T5 and T 6 were actively eroded in 2004, and the erosion became serious in 2009. Mangroves within ponds (naturally grown trees of *Avicennia marina)* were fragmented and degraded. Pond gates, which had been manually constructed became structurally weak. Strong waves during high tides broke weak pond dykes and propagated along the channels through fragmented and degraded mangroves into farming areas. Pond gates were easily broken by strong waves on high tides. Repeated propagation led to ponds being seriously eroded and mangroves within ponds being further lost, especially during the time of strong waves in high tides.

d) Recommendations by local community members

To balance protection of coastal mangrove areas with demands for socio-economic development, local community members discussed and made the following recommendations that assisted in control coastal erosion and improving aquaculture productivity. The recommendations were as below:

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

- Multi targeted aquaculture such as seaweed, fishes and crabs should be promoted. Detailed technical guidance on multi targeted aquaculture should be made locally for use. Models of integrated sea weed and fishes in Brebes, Indonesia should be studied for replication.

- Lessons learnt in relation to mangrove restoration on actively eroding areas in Vam Ray (seven types of fences constructed gradually over time, with transplantation of different mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica,* and *Nypa fruticans)* should be studied and replicated in the areas in response to coastal erosion in the areas.

- Transplantation of mangrove species to meet the 70% required mangrove areas should be resumed. A period of five years was needed for local community members to transplant and manage properly the 70% required mangrove areas to protect the lives and property of local community members in the event of a tsunami, sea level rise, and to meet contractual requirements. Detailed technical guidance on transplantation and production of seedlings should be made locally available.

- Transplantation beyond the 70% required mangrove areas should be continued to establish strong mangrove belts.

- Local authorities, local community members and the management board of coastal mangrove protected areas should manage cooperatively aquaculture activities in open sea surface areas beyond the protected mangrove areas to prevent any damage to transplantation to be caused by farming activities from these areas.

Nguyen Phi Thong signed as the Secretary of the meeting.

Minutes of the Meeting with Community Members of Van Khanh commune, An Minh District, Kien Giang

26 February 2014

I. The purpose of the meeting:

A meeting was held at 10:30 AM on 26 February 2014 at a local household in Van Khanh commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Van Khanh commune, An Minh district.

II. Participants:

Local community members, who have been involved in mangrove allocation for protection and development in Van Khanh commune, An Minh district, Kien Giang (see attachment 1), were invited to the meeting.

III. Discussion points:

Mr. Nguyen Tan Phong introduced himself, the contents and procedures of the meeting. The meeting procedures are as follows:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Van Khanh commune, An Minh, Kien Giang.

Points discussed and agree upon were summarised as below:

a) Construction of sea dykes

Areas where sea dykes were constructed were agriculture lands. In the 1980s, cranes were used to construct sea dykes on the seaward side. Sea dykes were first used for national defence purposes, then for irrigation and prevention of saline water intrusion. Sea dykes were maintained and upgraded on many occasions, at least once every four or five years since the construction.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as onions, corns were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Before 1992, local community members were allocated coastal areas for aquaculture activities. Allocated mangrove areas were located beyond sea dykes on the seaward side. Total allocation of mangrove areas were decided based on the capacity of each household. The lowest average allocated mangrove area was 1 ha.

Local community members practised aquaculture through clearance of mangroves, construction of ponds and uses of natural larvae. Ponds were constructed using cranes and gates were constructed to allow for saline water intrusion into ponds and to collect natural larvae. Channels were constructed along pond dykes and within ponds to increase farming areas. Ponds were constructed on the seaward side in parallel with sea dykes.

Natural larvae of sea shrimps, sea crabs, and sea fishes followed currents on high tides through gates into ponds. Shrimps species were mainly *Litopenaeus vannamei* and *Metapenaeus ensis*. Larvae were trapped in ponds when gates were closed on low tides. Dependant on quality of natural larvae, harvest time was on average three months. Local community members paid taxes depending on the number of harvests in a year.

Between 1992 and 1995, the Kien Giang Provincial People's Committee issued a decision No. 675 in relation to establishment of the Management Board of the Rach Gia – An Minh Coastal Mangrove Protected Areas and Islands. Aquaculture areas were legally converted into coastal mangrove protected areas. However, aquaculture areas and aquaculture practices remained unchanged. This decision promoted local involvement in transplanting mangrove species, mainly with *R. apiculata*. Local community members were paid for transplantation and caring services for 3 years. Propagules of *R. apiculata* were collected from Nam Cang, Minh Hai Province (now Ca Mau Province). propagules were transplanted in barren areas or mudflats. Plantation density varied from one location to another. The average density was 10.000 propagules per hectare.

The Kien Giang People's Committee issued the Policy No. 51 (in 2005) and Policy No. 25 (in 2011) to promote local involvement in coastal mangrove protection and management. When involved, local community members are required to protect and develop the 70% of required mangrove areas and are permitted to use the 30% allocated areas for aquaculture activities. In reality, local community members only focused on aquaculture activities on areas close to sea dykes. Local community members were not even fully aware of responsibilities and contractual requirements when involved in coastal mangrove allocation program. Local community members were not provided with technical guidance in aquaculture and uses of the 30% permitted areas. Local community members practised aquaculture activities using their own knowledge and used the permitted areas differently. Common aquaculture practices were mainly construction of channels along pond dykes to reach the 30% permitted areas. In some circumstances, many short channels were constructed within ponds to increase the 30% permitted areas for aquaculture areas. Aquaculture targets were sea shrimps and sea crabs.

Coastal erosion occurred in 2006 and began serious in 2013. Coastal erosion caused loss of mangrove areas and aquaculture ponds. Loss of mangrove areas and aquaculture ponds forced local community members to adjust their allocated areas regularly. Adjustments were undertaken in cooperation with the Management Board of An Bien – An Minh Coastal Mangrove Protected Areas. Due to serious coastal erosion, local community members lost their harvests and did not have stable incomes.

c) Causes of coastal erosion

In addition to natural factors, coastal areas in Van Khanh commune were affected by aquaculture activities. Thin pond dykes close to the sea water were broken by strong waves. There were many channels constructed among the primary mangrove belt for local boating and transportation. Strong waves on high tides propagated along the man-made channels on mudflats and the primary mangrove belt, breaking thin pond dykes and gates into farming areas through pond channels. Repeated propagation led to coastal areas being actively eroded and mangroves being lost, especially during the time of strong waves in high tides. After being eroded, allocated areas were adjusted back into sea dykes. However, aquaculture practices remained unchanged. The distance between allocated areas and national defence dykes were reduced from 280 metres to 80 metres in 2014. Remnants of sea crab and sea shrimp pond dykes were seen along these coastal areas of Van Khanh commune on low tides.

d) Recommendations by local community members

Local community members proposed that the government should invest more capitals to improve incomes and livelihoods. Local community members asked that solutions or procedures should be developed to improve aquaculture productivity to balance needs for coastal mangrove protection with demands for livelihood improvements for local community members in Van Khanh, An Minh, Kien Giang. The recommendations were as follows:

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

- Channels should be filled to provide more areas for transplantation to achieve the 70% required mangrove areas. Technical guidance in relation to transplantation should be made locally available. Dependent on locations, a variety of mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica,* and *Nypa fruticans* should be transplanted in clusters in high density to satisfy the contractual requirements of the 70% mangrove areas in return for the right to use the 30% permitted areas for aquaculture activities in the earliest time. Propagules and seeds were proposed to be provided free of charge. Technical guidance and financial support for filling channels and transplantation should be made locally for use. Time required to reach the 70% required mangrove areas should be between 2 and 3 years.

- Transplantation on accretion areas (intertidal mudflats) beyond allocated areas should be undertaken to establish strong mangrove belt sections and to create livelihood income opportunities in accordance with the Policy No. 25.

- Technical support should be made in relation to aquaculture activities, such as construction of pond dykes, pond gates for improved aquaculture productivity.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the Meeting with Community Members of Van Khanh Tay Commune, An Minh District, Kien Giang

26 February 2014

I. <u>The purpose of the meeting:</u>

A meeting was held at 15:30 AM on 26 February 2014 at a local household in Van Khanh Tay commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Van Khanh Tay commune, An Minh district.

II. <u>Participants:</u>

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Van Khanh Tay, An Minh district (see attachment 1), were invited to the meeting.

III. <u>Discussion points:</u>

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Van Khanh Tay, An Minh district, Kien Giang.

Points discussed and agreed upon were summarised as below:

a) Construction of sea dykes

Areas where sea dykes were constructed were agriculture lands. In 1983, the Military Zone No. 9 used cranes to construct sea dykes on the seaward side. Sea dykes were first used for national defence purposes, then for irrigation and prevention of saline water intrusion. Sea dykes were maintained and upgraded on many occasions, at least once every four or five years since the construction. In 1983, agriculture lands were about 72 metres from sea dykes toward the sea, followed by mangrove areas, mainly with *A. marina* and *R. apiculata*.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as onions, corns were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Between 1987 and 1988, groups were collected and approved by newly established District People's Committee. These groups were responsible for farming activities and selling sea products. In this period, local community members in Van Khanh Tay commune were allocated coastal areas (green books) for aquaculture activities. Allocated coastal areas were located beyond sea dykes toward the sea. And total allocated areas were decided based on the capacity of each group. A minimum allocated area was 1 ha.

Local community members practised aquaculture through construction of ponds and uses of natural larvae. Ponds were constructed using cranes and gates were constructed to allow for saline water intrusion into ponds and to collect natural larvae. Channels were constructed along pond dykes and within ponds to increase farming areas. Ponds were constructed on the seaward side in parallel with sea dykes. Natural larvae followed currents on high tides through gates into ponds. Larvae were trapped in ponds when gates were closed on low tides. Three months after gates were closed, local community members harvested and sold their products. Local community members paid taxes depending on the number of harvests in a year. In this period, accretion areas were located far away from sea dykes on the seaward side and had firm surface areas.

In 1992, the Kien Giang Provincial People's Committee issued a decision No. 675 in relation to establishment of the Management Board of the Rach Gia – An Minh Coastal Mangrove Protected Areas and Islands. Aquaculture areas were legally converted into coastal mangrove protected areas. However, aquaculture areas remained unchanged. In 1992, the Management Board of the Rach Gia – An Minh Coastal Mangrove Protected Areas and Islands promoted local involvement in transplanting mangrove species, mainly with *R. apiculata*. Propagules of *R. apiculata* were collected from Nam Cang, Minh Hai Province (now Ca Mau Province). Propagules were transplanted on local lands, with 20 kg of propagules of *R. apiculata* on 1/10 ha. Local community members were paid an amount of 20,000 VND for transplanting on one ha. Transplantation density was 10,000 propagules per hectare.

The Kien Giang People's Committee issued the Policy No. 51 (in 2005) and Policy No. 25 (in 2011) to promote local involvement in coastal mangrove protection and management. When involved, local community members are required to protect and develop the 70% of required mangrove areas and are permitted to use the 30% allocated areas for aquaculture activities. In reality, local community members only focused on aquaculture activities on areas close to sea dykes. Local community members were not even fully aware of responsibilities and contractual requirements when involved in coastal mangrove allocation program. Local community members were not provided with technical guidance in aquaculture and uses of the 30% permitted areas. Local community members practised aquaculture activities using their own knowledge and used the permitted areas differently. Common aquaculture practices were mainly construction of channels along pond dykes to reach the 30% permitted areas. In some circumstances, shorter channels were constructed within ponds to increase the 30% permitted areas for aquaculture areas. Aquaculture targets were sea shrimps and sea crabs.

Coastal erosion occurred in 2006 and began serious in 2013. Coastal erosion caused loss of mangrove areas and aquaculture ponds. Loss of mangrove areas and aquaculture ponds forced Local community members to adjust their allocated areas regularly. Adjustments were undertaken in cooperation with the Management Board of An Bien – An Minh Coastal Mangrove Protected Areas. Due to serious coastal erosion, local community members lost their products and did not have stable incomes.

c) Causes of coastal erosion

In addition to natural factors, coastal areas in Van Khanh Tay commune were affected by aquaculture activities. Thin pond dykes close to the sea water were broken by strong waves. There were many channels constructed among the primary mangrove belt for local boating and transportation. Strong waves on high tides propagated along the man-made channels on mudflats and the primary mangrove belt, breaking thin pond dykes and gates into farming areas through pond channels. Repeated propagation led to coastal areas being actively eroded and mangroves being lost, especially during the time of strong waves in high tides. After being eroded, allocated areas were adjusted back onto sea dykes. However, aquaculture practice remained unchanged. The distance between allocated areas and national defence dykes were reduced from 280 metres to 78 metres in 2014. Remnants of sea crab and sea shrimp pond dykes were seen along these coastal areas of Van Khanh Tay commune on low tides.

d) Recommendations by local community members

Local community members proposed that the government should invest more capitals to improve incomes and livelihoods. Local community members asked that solutions or procedures should be developed to improve aquaculture productivity to balance needs for coastal mangrove protection with demands for livelihood improvements for local community members in Van Khanh Tay, An Minh, Kien Giang. The recommendations were as follows:

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

- Channels should be filled to provide more areas for transplantation to achieve the 70% required mangrove areas. Technical guidance in relation to transplantation should be made locally available. Dependent on locations, a variety of mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica,* and *Nypa fruticans* should be transplanted in clusters in high density to satisfy the contractual requirements of the 70% mangrove areas in return for the right to use the 30% permitted areas for aquaculture activities in the earliest time. Propagules and seeds were proposed to be provided free of charge. Technical guidance and financial support for filling channels and transplantation should be made locally for use. Time required to reach the 70% required mangrove areas should be between 2 and 3 years.

- Transplantation on accretion areas (intertidal mudflats) beyond allocated areas should be undertaken to establish strong mangrove belt sections and to create livelihood income opportunities in accordance with the Policy No. 25.

- Technical support should be made in relation to aquaculture activities, such as construction of pond dykes, pond gates for improved aquaculture productivity.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the Meeting with Community Members of Nam Thai Commune, An Bien District, Kien Giang

27 February 2014

I. <u>The purpose of the meeting:</u>

A meeting was held at 10:30 AM on 27 February 2014 at a household in Nam Thai commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Nam Thai commune, An Bien district.

II. <u>Participants:</u>

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Nam Thai, An Bien district (see attachment 1), were invited to the meeting.

III. <u>Discussion points:</u>

Mr. Nguyen Tan Phong introduced himself, the contents and procedures of the meeting. The meeting procedures are as follows:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Nam Thai commune, An Bien district, Kien Giang.

Points discussed and agreed on were summarised as follows:

a) Construction of national defence dykes

There were two systems of dykes: dykes for agriculture irrigation and dykes for national defence purposes (sea dykes). Agriculture irrigation dykes were manually constructed several years ago for storing fresh water for irrigating rice fields. Agriculture irrigation dykes disappeared because local community members levelled dykes for creating more lands for rice fields.

National defence dykes were built approximately 800 metres from agriculture irrigation dykes toward the sea. In 1982, national defence dykes were manually constructed excavating sediment from either side of dykes. National defence dykes were upgraded in 2001. Local community members were compensated for their crops on their lands compulsorily acquired for dyke construction.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as onions and corns were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Between 1987 and 1988, local community members were allocated mangrove areas for aquaculture activities (issued with green book) by the District's People's Committee. Local community members gathered to establish groups undertaking aquaculture activities. Mangrove areas allocated were located beyond national defence dykes toward the sea. Total allocation areas varied from one location to another, and was decided based on the capacity of an aquaculture group.

Local community members constructed aquaculture ponds clearing mangrove areas dominated with natural grown tress of *A. marina* and *S. alba.* Aquaculture ponds were constructed perpendicular to national defence dykes on the seaward side. Pond channels and gates were manually constructed within allocated mangrove areas for farming. In many locations, many short pond channels within allocated areas were constructed to expand farming areas.

Aquaculture activities used natural larvae. Underground pond gates were opened during high tides to collect natural larvae of shrimps, fishes and crabs from the sea, and were closed during low tides. Dependent on quality of natural larvae, harvest time varied, normally was between one month and three months after underground pond gates were closed. Local community members paid taxes depending on the number of harvests in a year. Aquaculture groups were then dismissed, many group members transferred their allocated areas to those who were interested in aquaculture activities. The smallest allocation area was 1 ha.

In the 1980s, the Provincial Peoples' Committee issued a decision that changed coastal land uses. In this decision, aquaculture areas were converted into coastal mangrove protection areas. Local community members transplanted seedlings of *A. marina* at a density of 10,000 trees per hectare. Seedlings of *A. marina* were collected from the wild and local people had to be sure that their main roots were not cut. Seedlings were about 30 cm high. However, seedlings were killed by blood shell collection activities.

Since 1995, the Kien Giang People's Committee has encouraged local involvement in coastal mangrove protection and management. When allocated with mangrove areas, local community members are required to protect and develop the 70% of required mangrove areas in return for the right to use the 30% allocated areas for aquaculture activities. However, local community members said that it was very difficult to apply this model because they are not allowed to use for the 30% permitted areas for aquaculture activities until the 70% required mangrove areas are met. However, no technical guidance in relation to aquaculture and use of the 30% permitted areas for aquaculture activities. Local community members practised aquaculture activities using their own knowledge. Therefore, coastal mangrove protection and aquaculture activities were not synchronised.

A. marina were primarily cleared for constructing ponds. Channels were constructed along pond dykes to reach the 30% of permitted areas for aquaculture activities. In some circumstances, more short channels were constructed within the 30% of permitted areas to extend farming areas. Ponds were constructed for farming sea crabs and sea shrimps.

There was a conflict of interest between Local community members and lessees of sea water surface areas for aquaculture. In according with a decision issued by the Kien Giang provincial People's Committee, sea water surface areas located beyond the boundaries of the coastal mangrove protected areas were leased for aquaculture. On the ground, however, the leased water areas were located within the boundaries of the coastal mangrove protected areas. On many occasions, lessees collected blood shell using bamboo rakes equipped with nests within the boundaries of the coastal mangrove protected areas, killing transplanted seedlings.

c) Recommendations by local community members

Being mudflats, the commune stands a good chance for achieving high survival rates of transplanted seedlings of *A. marina*. Local community members recommended that their local knowledge should be used for transplantation. Below were specific recommendations:

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

- There is a need for a smooth coordination among the government agencies in charge of natural resources & environment management in the area to ensure the integrity of the coastal mangrove areas as well as to prevent any blood shell collection that killed seedlings.

- There is a need for solutions that promote natural regeneration of, and growth of *A. marina*. Melaleuca fences which were previously funded and constructed by GIZ in the areas were broken, and failed to accumulate sea mud and to break the energy of strong waves. In addition, reconstruction of the fences costs much money. Therefore, used fishing nests and the silt trap fences originally designed in Vam Ray should be studied and used for promoting natural regeneration of, and growth of *A. marina*.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the meeting with Community Members of Nam Yen Commune, An Bien District, Kien Giang

27 February 2014

I. <u>The purpose of the meeting:</u>

A meeting was held at 14:30 AM on 27 February 2014 at a local household in Nam Yen commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Nam Yen commune, An Bien district.

II. <u>Participants:</u>

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Nam Yen commune, An Bien district (see attachment 1), were invited to the meeting.

III. <u>Discussion points:</u>

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Nam Yen commune, An Bien district, Kien Giang.

Points discussed and agreed upon were summarised as below:

a) Construction of national defence dykes

Sea dykes (national defence dykes) were constructed in 1995. The construction was undertaken using machines to excavate sediment from either side of sea dykes. Dykes were used first for national defences purposes, and then for prevention of saline intrusion. Dykes were upgraded in 2000. During upgrades, local community members were compensated for their crops on lands compulsorily acquired for dyke construction.

b) Aquaculture activities

Before 1992, these areas were rich in mangrove species, dominated with *A. marina* and *S. alba* on the seaward side. *H. littoralis* grew naturally in rice fields. Aquaculture ponds were manually constructed clearing fully grown trees of *A. marina, S. alba,* and *H. littoralis.* Channels were constructed along pond dykes. Pond gates were also manually constructed to allow for saline water intrusion into ponds. More channels were constructed within the 30% permitted areas to increase farming areas. Ponds were constructed perpendicular to national defence dykes on the seaward side.

Aquaculture activities used natural larvae. Underground pond gates were opened during high tides to collect natural larvae of shrimps, fishes and crabs from the sea, and were closed during low tides. Shrimps were *Litopenaeus vannamei* and *Pandalus borealis*. Dependent on quality of natural larvae, harvest time varied, normally was between one month and three months after underground pond gates were closed. Local community members paid taxes depending on the number of harvests in a year. Aquaculture groups were then dismissed, many group members transferred their allocated areas to those who were interested in aquaculture activities.

In 1995, local community members were allocated mangrove areas for mangrove protection and livelihood improvement. Local community members were provided with propagules of *Rhizophora apiculata* which were transplanted to establish coastal mangrove protected areas. Transplantation density was 10,000 trees per hectare. Local community members were paid for transplanting and caring propagules for a period of three years. However, propagules did not survive because they were transplanted in ponds and on pond dykes. Despite recent conversion of aquaculture areas into coastal mangrove protected areas, aquaculture areas remained unchanged.

Local community members living in the Nam Yen community of An Bien district were not even fully aware of the policies, namely Policy No. 51 and Policy 25, issued by the Kien Giang Provincial People’s Committee in relation to promotion of local involvement in coastal mangrove protection and development. The local understanding was that Local community members were not entitled to use their 30% allocation area for aquaculture until the 70% forest area was achieved. Therefore, Local community members gave up fish and shrimp ponds because ponds did not bring any benefits. In addition, local community members lost their harvests recently with unknown reasons.

c)* *Recommendations by local community members

Being mudflats, the commune stands a good chance for achieving high survival rates of transplanted seedlings of *A. marina*. Local community members recommended that their local knowledge should be used for transplantation. Below were specific recommendations:

- Dependent on locations, each location should develop its own plan for mangrove restoration and transplantation.

- Local community members request to use the 30% permitted areas for aquaculture activities while transplanting mangroves to reach the 70% required mangrove areas. Time required to reach the 70% required mangrove areas should be 5 years.

- Local community members propose to use the 30% permitted areas for aquaculture activities while transplanting to achieve the 70% required areas. Aquaculture areas should be designed close to the protection zones of sea dykes. The remaining 70% should be used for transplanting *Rhizophora apiculata* toward the primary mangrove belt. Plantation should be undertaken in high density to reach the 70% required mangrove areas at the possible earliest time. *Rhizophora apiculata* was selected because local community members would benefit, especially from selective harvests of fully grown trees of *Rhizophora apiculata*.

- Ponds dykes close to the primary mangrove belt should be constructed strongly with a minimum width of 10 metres. Dykes within ponds should be approximately 3 metres wide. Sea shrimps, sea fishes and sea crabs should be main aquaculture targets.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the meeting with Community Members of Thuan Hoa Commune, An Minh District, Kien Giang

28 February 2014

I. The purpose of the meeting:

A meeting was held at 9:00 AM on 28 February 2014 at a local household in Thuan Hoa commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Thuan Hoa commune, An Minh district.

II. Participants:

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Thuan Hoa, An Bien district (see attachment 1), were invited to the meeting.

III. Discussion points:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Thuan Hoa commune, An Minh district, Kien Giang.

a) Construction of sea dykes

National defence dykes (sea dykes) were manually constructed between 1987 and 1988. Sediment was excavated on either sides. Dykes were first used for national defence purposes, and then for prevention of saline water intrusion and storage of fresh water for irrigating rice fields.

National defence dykes were mechanically upgraded in 1983. Sediment was excavated from both sides. Protection zones were demarcated with granite poles during upgrades. Local community members were compensated for their crops. National defence dykes were continuously upgraded using the same techniques.

Lands located landward of national defence dykes were used for integrated shrimp – rice production, while aquaculture activities including farming sea shrimps, sea crabs and blood shell are undertaken on allocated mangrove areas beyond national defence dykes on the seaward side.

Dykes used for agriculture irrigation located 700 metres landward of national defence dykes. Lands behind agriculture irrigation dykes were used for integrated shrimp – rice production. A Norwegian company invested in farming fresh water shrimps.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as onions, corns were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Between 1987 and 1988, many groups were established to undertake aquaculture activities. Groups were collection of many local households which contracted coastal areas for aquaculture activities. Allocated coastal areas were located beyond national defence dykes on the seaward side. Total allocation of coastal areas was decided based on the capacity of groups. Group members were allocated coastal lands and were entitled to access to bank loans, which were used for paying costs related to manual channel construction. However, the members were not provided with contracts (green books), but with a decision issued by the District's People's Committee. Groups or group members applied for being allocated coastal areas. On average, each household was allocated an area of 1.2 ha. Groups were dismissed and group members transferred their allocated lands to outsiders.

Local community members practised aquaculture activities through pond construction and uses of natural larvae. Allocated coastal areas were rich in *R. apiculata* and *A. marina*. Ponds were constructed clearing mangrove species between 1980 and 1985. Ponds were constructed in parallel with national defence dykes. Average area of a pond was 50 cm x 1.500 m. Local community members cleared mangroves on the 30% permitted areas for aquaculture activities, located close to natural rivers and / or man-made channels. Pond gates were constructed underground along the rivers to allow for saline water intrusion into ponds. Within many ponds, many short channels were constructed to expand farming areas.

Pond gates were opened during high tides to collect natural larvae of shrimps, fishes and crabs from the sea, and were closed during low tides. Dependent on quality of natural larvae, harvest time varied, normally was between one month and three months after underground pond gates were closed. Larvae of shrimps included *Pandalus borealis, Litopenaeus vannamei* and *Metapenaeus ensis.* After harvests, local community members sold their products to pay for bank loans. Then, shrimps died with unknown reasons and the locals lost their products.

In 1992, the management board of Rach Gia – An Minh Coastal Mangrove Protected Areas and Islands promoted local community members to transplant mangrove species, mainly with *R. apiculata*. Propagules of *R. apiculata* were collected from nam Cang, Minh Hai Province (now Ca Mau Province). Propagules were transplanted on local land areas. Local community members were provided with propagules and paid for transplantation and caring services for 3 years. Transplantation density was 10,000 trees per hectare.

Local community members were issued with green books for allocated mangrove areas. Local communities continued to apply the same aquaculture practices. However, pond dykes close to sea water fragmented with *A. marina* were 7 metres wide. Dykes within ponds were manually constructed with a width of 3 metres. Propagules of *R. apiculata* were transplanted in barren areas within ponds or on pond dykes.

The Kien Giang People's Committee issued the Policy No. 51 (in 2005) and Policy No. 25 (in 2011) to promote local involvement in coastal mangrove protection and management. When involved, local community members are required to protect and develop the 70% of required mangrove areas and are permitted to use the 30% allocated areas for aquaculture activities. Local community members were not even fully aware of the policies. Local community members were not provided with technical guidance in aquaculture and uses of the 30% permitted areas. Despite recent conversion of aquaculture areas into coastal mangrove protected areas, aquaculture areas remained unchanged.

The local understanding was that Local community members were not entitled to use their 30% allocation area for aquaculture until the 70% forest area was achieved. Local community members practised aquaculture activities using their own knowledge and used the permitted areas differently. Common aquaculture practices were mainly construction of channels along pond dykes to reach the 30% permitted areas. In some circumstances, many short channels were constructed within ponds to increase the 30% permitted areas for aquaculture areas. Aquaculture targets were sea shrimps and sea crabs.

The consequences were that Local community members did not meet the contractual requirements and did not use efficiently the 30% permitted areas. Therefore, Local community members had difficulties in maintain family lives. However, Local community members said that ponds needed to be mechanically upgraded so that aquaculture activities would be productive. Because not allowed to upgrade ponds mechanically, Local community members could not undertake aquaculture activities. Therefore, Local community members cut fully grown trees of *R. apiculata* for sale for additional incomes

c) Causes of coastal erosion

In addition to natural factors, coastal areas in this commune were affected by aquaculture activities. Thin pond dykes close to the sea water were broken by strong waves. Strong waves on high tides broke pond dykes and pond gates and propagated along the channels through fragmented and degraded mangroves into farming areas. Repeated propagation led to ponds being seriously eroded and mangroves within ponds being further lost, especially during the time of strong waves in high tides. The distance between allocated areas and national defence dykes were reduced from 200 metres to 80 metres in 2014. Remnants of sea crab and sea shrimp pond dykes were seen along these coastal areas on low tides.

d) Recommendations by local community members

Melaleuca fences which were previously funded and constructed by GIZ in the areas were broken, and failed to accumulate sea mud and to break the energy of strong waves. In addition, reconstruction of the fences costs much money. Therefore, Local community members expressed their interest in controlling coastal erosion using their own knowledge. Local community members made the following recommendations:

- Local community members should be permitted to dredge / construct channels mechanically for aquaculture activities while transplanting mangrove species to reach the 70% required mangrove areas. *A. marina* and *R. apiculata* were mixed in transplantation. Schedule for commitments to reach the 70% required areas should be 3 years.

- Aquaculture practice should be transformed. Local community members should be permitted to use the 30% of allocated areas for aquaculture while transplantation should be continued to reach the 70% required areas. The 30% should be close to sea dykes rather than natural rivers / man made channels. The 70% should be used for transplantation.

Transplantation used combination of *R. apiculata* and *A. marina*. Eroding areas should be controlled using granite rocks covered with iron nests located close to transplantation areas.

- The 30% of permitted areas should be located close sea dykes. Granite rocks covered with iron nests were placed on eroding areas a distance of 100 metres from the current mangrove edges to create mudflats. *A. marina* and *R. apiculata* should be transplanted at a later stage.

- The contractor and Local community members should co-implement and co-manage activities on allocated areas. Mangrove protection and management people units at communal and village levels should be involved in implementing activities.

- Status of allocation areas should be investigated. Contracts should be terminated for Local community members who did not show no more interest in allocation, did not express any cooperation in controlling coastal erosion, or did not satisfy the contractual requirements.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the meeting with Community Members of Tay Yen Commune,

An Bien District, Kien Giang

28 February 2014

I. **<u>The purpose of the meeting:</u>**

A meeting was held at 14:00 AM on 28 February 2014 at a local household in Tay Yen commune to understand sea dyke construction processes, aquaculture and status of coastal erosion in Tay Yen commune, An Bien district.

II. **<u>Participants:</u>**

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Tay Yen, An Bien district (see attachment 1), were invited to the meeting.

III. **<u>Discussion points:</u>**

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Thuan Hoa commune, An Minh district, Kien Giang.

a) Construction of sea dykes

National defence dykes (sea dykes) were manually upgraded in 1991using small paths constructed in 1975. Sediment was excavated on either sides. Dykes were first used for national defence purposes, and then for prevention of saline water intrusion and storage of fresh water for irrigating rice fields.

National defence dykes were mechanically upgraded in 1996. Sediment was also excavated from both sides. Protection zones were demarcated with granite poles during upgrades. Local community members were compensated for their crops. National defence dykes were continuously upgraded in the following years using the same techniques. 30 metres landward of national defence dykes were dykes for agriculture irrigation. Lands located between national defence dykes and agriculture irrigation dykes were used for rice production.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as onions, corns were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Between 1984 and 1985, many groups were established to undertake aquaculture activities. Groups cooperated with a Canadian own company in investing aquaculture activities. Groups were allocated by the District People's Committee coastal areas for aquaculture pond construction. Groups were accessible to bank loans that were used for constructing ponds and channels. However, groups were not provided with books of allocated areas.

A household member was provided, on average, with 3 hectares. However, in Thuan Hoa commune, a household member was provided with smaller area (1.2 hectares) due to increased demands for coastal areas for pond construction and lands not being available in Thuan Hoa.

Local community members practised aquaculture activities through pond construction and uses of natural larvae. Allocated coastal areas were rich in *R. apiculata* and *A. marina*. Ponds were constructed clearing mangrove species between 1980 and 1985. Ponds were constructed in parallel with national defence dykes. Pond gates were constructed along man made channels to allow for saline water intrusion into ponds. Channels were manually constructed. In many ponds, shorter channels were manually constructed within ponds to expand farming areas.

Pond gates were opened during high tides to collect natural larvae of shrimps, fishes and crabs from the sea, and were closed during low tides. Dependent on quality of natural larvae, harvest time varied, normally was between one month and three months after underground pond gates were closed.

In the following years, groups were dismissed. Group household members transferred their allocated areas to those who were interested in aquaculture activities between 1988 and 1990.

In 1992, the management board of Rach Gia – An Minh Coastal Mangrove Protected Areas and Islands promoted local community members to transplant mangrove species, mainly with *R. apiculata*. Propagules of *R. apiculata* were collected from Nam Cang, Minh Hai Province (now Ca Mau Province). Propagules were transplanted on local land areas. Local community members were provided with propagules and paid for transplantation and caring services for 3 years. Transplantation density was 10,000 trees per hectare.

Local community members were issued with green books for allocated mangrove areas between 1994 and 1995. Local communities continued to apply the same aquaculture practices. However, Propagules of *R. apiculata* were inundated and died and were eaten by brackish water fiddlers.

The Kien Giang People's Committee issued the Policy No. 51 (in 2005) and Policy No. 25 (in 2011) to promote local involvement in coastal mangrove protection and management. When involved, local community members are required to protect and develop the 70% of required mangrove areas and are permitted to use the 30% allocated areas for aquaculture activities. Local community members were not even fully aware of the policies. Local community members were not provided with technical guidance in aquaculture and uses of the 30% permitted areas. Local community members practised aquaculture activities using their own knowledge and used the permitted areas differently. Common aquaculture practices were mainly construction of channels along pond dykes to reach the 30% permitted areas. In some circumstances, shorter channels were constructed within ponds to increase the 30% permitted areas for aquaculture areas. Aquaculture targets were sea shrimps and sea crabs.

Local community members living in the Tay Yen community of An Bien district were not even fully aware of the policies, namely Policy No. 51 and Policy 25, issued by the Kien Giang Provincial People's Committee in relation to promotion of local involvement in coastal mangrove protection and development. The local understanding was that local community members were not entitled to use their 30% allocation area for aquaculture until the 70% forest area was achieved. In reality, many allocated areas did not achieved the 70% required mangrove areas. Shrimps were not healthy and local community members gave up fish and shrimp ponds because ponds did not bring any benefits. Some households maintained aquaculture activities due to external support or through monetary support by their relatives living abroad and working elsewhere. Some household wanted to return their allocated areas if they were not able to access to bank loans or were provided with technical guidance in aquaculture and transplantation. When ponds were returned and acquired, households required their crops to be compensated. Allocated areas less than 3 hectares were not suitable for aquaculture activities.

However, local community members said that ponds needed to be mechanically upgraded so that aquaculture activities would be productive. Because not allowed to upgrade ponds mechanically, Local community members could not undertake aquaculture activities. Therefore, local community members cut fully grown trees of *R. apiculata* for sale for additional incomes

c) Causes of coastal erosion

In addition to natural factors, coastal areas in this commune were affected by aquaculture activities. Thin pond dykes close to the sea water were broken by strong waves. Strong waves on high tides broke pond dykes and pond gates and propagated along the channels through fragmented and degraded mangroves into farming areas. Repeated propagation led to ponds being seriously eroded and mangroves within ponds being further lost, especially during the time of strong waves in high tides. However, similar aquaculture techniques remained unchanged.

d) Recommendations by local community members

Local community members expressed their interest in controlling coastal erosion using their own knowledge. Local community members made the following recommendations:

- Local community members should be permitted to dredge / construct channels mechanically for aquaculture activities while transplanting mangrove species to reach the 70% required mangrove areas. *A. marina* and *R. apiculata* were mixed in transplantation. A schedules for reaching the 70% required areas should be committed to 3 years.

- Aquaculture practice should be transformed. Local community members should be provided with funds that would be used for labelling shorter channels for transplanting *Rhizophora apiculata* and main channels should be maintained for farming sea crabs and shrimps.

- The 30% of permitted areas should be located close sea dykes. And the 70% required mangrove areas should be protected. Transplantation should mix *Rhizophora apiculata* or *Avicennia marina*.

- Coastal mangrove protection and management should be strengthened through comprehensive assessments of allocated coastal areas. Contracts should be terminated for local community members who did not show no more interest in allocation, did not express any cooperation in controlling coastal erosion, or did not satisfy the contractual requirements.

- District People's Committee leased open surface sea water areas for aquaculture activities. In reality, lessees of open surface sea water areas encroached into allocated coastal mangrove areas. Therefore, there need to be a close coordination between people's committees of all levels and the An Bien – An Minh Management Board in managing allocated mangrove areas to avoid any conflicts of interest in the future, and prevent killing of transplanted *Avicennia marina* in coastal mangrove protected areas.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the Meeting with Community Members of Dong Hung A Commune, An Minh District, Kien Giang

4 March 2014

I. The purpose of the meeting:

A meeting was held at 14:30 AM on 4 March 2014 at a local household in Dong Hung A to understand sea dyke construction processes, aquaculture and status of coastal erosion in Dong Hung A commune, An Minh district.

II. Participants:

Local community members, who have been involved in mangrove allocation for protection and livelihood improvement and aquaculture activities in Dong Hung A commune, An Minh district (see attachment 1), were invited to the meeting.

III. Discussion points:

Mr. Nguyen Tan Phong introduced himself, the contents and procedures of the meeting. The meeting procedures are as follows:

1) Self introduction by Mr. Phong.

2) Explanation of his PhD program.

3) Explanation of the purpose of the meeting.

4) Outline of points that would be discussed.

5) Assurance of anonymity and reminder of the participants of their right to decline.

6) Explanation that continued discussion assumed consent for participation.

A forestry map and a map of a sea dyke system in Kien Giang were used for discussing, analysing, and sharing experiences of causes of mangrove degradation, deforestation, coastal erosion in Dong Hung A commune, An Minh district, Kien Giang.

Points discussed and agreed on were summarised as below:

a) Construction of national defence sea dykes

National defence dykes (locally called sea dykes) were manually constructed in 1981. Sediments were excavated on both sides of sea dykes. In 1994, national defence dykes were mechanically upgraded excavating sediment from either side, resulting in deep channels being constructed in parallel with national defence dykes.

Houses were constructed temporarily within the protection zones of sea dykes. Crops such as bananas, pumpkins, lemons and Eucalyptus were grown on many surface sections of sea dikes for incomes and for domestic consumption.

b) Aquaculture activities

Before national defence dykes were constructed, these areas had been rich in mangrove species, dominated with natural grown tress of *A. marina* and *S. alba.* Between 1981 and 1982, natural grown trees of *A. marina* and *S. alba* were cleared for constructing ponds for farming fishes, crabs, and shrimps. Ponds were constructed clearing mangroves, opening short channels within ponds to expand farming areas. Pond gates were manually constructed underground towards along natural rivers or man-made channels to allow for saline water intrusion into ponds. Aquaculture ponds were constructed on the seaward side in parallel with national defence dykes in this commune.

Aquaculture activities used natural larvae. Underground pond gates were opened during high tides to collect natural larvae of shrimps, fishes and crabs from the sea, and were closed during low tides. Dependent on quality of natural larvae, harvest time varied, normally was between one month and three months. Shrimps species were mainly *Litopenaeus vannamei* and *Metapenaeus ensis.* Fishes included *Lates calcarifer, Mugiliformes,* and *Pseudapocryptes elongates* and sea crabs.

In 1995, aquaculture ponds were legally converted into coastal mangrove protected areas at a decision made by the Provincial People's Committee. Local community members were provided with propagules of *Rhizophora apiculata* which were transplanted on their contracted lands to increase mangrove areas. Propagules of *Rhizophora apiculata* were collected from Minh Hai Province (now called Ca Mau Province) and were provided free of charge. Local community members were paid for transplanting and caring propagules for a period of three years. However, propagules did not survive because they were transplanted in ponds and on pond dykes. Propagules were eaten by brackish water fiddlers (*Uca minax*). Local members said that it was difficulty to transplant propagules of *Rhizophora apiculata* in ponds. Ripe propagules and rotten leaves, when dropped, contaminated water and killed sea shrimps, sea fishes and sea crabs. Transplantation of propagules of *Rhizophora apiculata* in high density was not good for aquaculture activities (sea shrimps, sea crabs, and sea fishes).

Policy No. 51 (in 2005) and Policy No. 25 (in 2011) issued by the Kien Giang Provincial People's Committee promotes local involvement in coastal mangrove protection and management. In these policies, local community members are required to transplant and manage the 70% of required mangrove areas in return for the right to undertake aquaculture activities on the 30% permitted areas on their allocated mangrove areas.

In accordance with the technical guidance provided by technical staff of the Management Board of An Bien – An Minh Coastal Mangrove Protected Areas, local community members (called Local community members) were not permitted to use the 30% of allocated areas for aquaculture activities until the contractual requirements of the 70% required mangrove areas were met. In reality, a few Local community members satisfied the contractual requirements of the 70% required mangrove areas on their allocated mangrove areas. Those who did not satisfy the requirements, illegally opened short channels manually and mechanically within the 30% areas for aquaculture activities. Local community members also harvested illegally fully grown trees of *Rhizophora apiculata* on the 70% required mangrove areas to expand farming areas. At a later stage, Local community members were involved in growing tamarind trees on pond dykes to increase forest coverage in allocated mangrove areas.

All ponds were constructed in the secondary mangrove belt. It was hard to find original contractees of allocated mangrove areas. Ponds were transferred in many transactions.

The smallest allocated mangrove area was 1.5 ha, while the biggest 11.4 ha. An average allocated mangrove area is between 2 and 3 ha. Inter-mudflats and natural grown trees of *A. marina* were located beyond the primary mangrove belt.

c) Causes of coastal erosion

Pond dykes and underground pond gates which had been manually constructed became structurally weak. Strong waves during high tides broke structurally weak pond dykes and propagated along the channels through fragmented and degraded mangroves into farming areas. Underground pond gates were easily broken by strong waves on high tides. Repeated propagation led to ponds being seriously eroded and mangroves within ponds being further lost, especially during the time of strong waves in high tides.

d) Recommendations by local community members

To balance protection of coastal mangrove areas with demands for socio-economic development, Local community members discussed and made the following recommendations that assisted in control coastal erosion and improving aquaculture productivity for improving incomes.

- The allocation program should be continued, with the 30% of permitted areas close to a sea dyke system for aquaculture activities and the 70% to be used for mangrove transplantation on the seaward side.

- Lessons learnt in relation to mangrove restoration on actively eroding areas in Vam Ray (seven types of fences constructed gradually over time, with transplantation of different mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, and Nypa fruticans)* should be studied and replicated in the areas in response to coastal erosion.

- Channels should be filled to provide more areas for transplantation to achieve the 70% required mangrove areas. Technical guidance in relation to transplantation should be made locally available. Dependent on locations, a variety of mangrove species such as *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica,* and *Nypa fruticans* should be transplanted in clusters in high density to satisfy the contractual requirements of the 70% mangrove areas in return for the right to use the 30% permitted areas for aquaculture activities. Propagules and seeds were proposed to be provided free of charge. Technical guidance and financial support for filling channels and transplantation should be made locally for use. Time required to reach the 70% required mangrove areas should be between 2 and 3 years.

- Transplantation on accretion areas (intertidal mudflats) beyond allocated areas should be undertaken to establish strong mangrove belt sections and to create livelihood income opportunities in accordance with the Policy No. 25.

- Local authorities, Local community members and the management board of coastal mangrove protected areas should manage cooperatively aquaculture activities in open sea surface areas beyond the protected mangrove areas to prevent any damage to transplantation to be caused by farming activities from these areas. Stronger commitments should be made to reach the 70% required mangrove areas in the earliest time.

- Technical support should be made in relation to aquaculture activities, such as construction of pond dykes, pond gates for improved aquaculture productivity.

Bui Van Lung signed as the secretary of the meeting.

Minutes of the Participatory Community Meeting with Two Coastal Villages: Sawajajar And Kaliwlingi, Brebes Regency, Indonesia

27 November 2013

I. The objective of the meeting:

The meeting was held at the Community meeting hall of Sawajajar on 27 November 2013. The meeting aimed to understand causes for mangrove degradation and coastal erosion in Brebes Regency, Indonesia, and to seek for recommendations for strategic planning for sustainable coastal development.

II. Participants:

Twenty two persons from two coastal villages attended the meeting. They were representatives from the local governments, the villages, and women's union of Sawajajar and Kaliwlingi (please see the list of participants in the attachment 1).

III. Discussion points:

The leader of the organizing board began the meeting by introducing Mr. Phong and his program in Brebes Regency, Indonesia. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The following procedures were followed:

1) Self introduction by Mr. Phong.
2) Explanation of his PhD program.
3) Explanation of purposes of participatory community workshop.
4) Outline of topics that would be discussed.
5) Assurance of anonymity and reminder of the participants of their right to decline to participate.
6) Explanation that continued participation assumed consent for participation.

(please see the interview plan in the attachment 2 for more information).

Topics were discussed by the representatives. Discussion points and agreement were summarized as follows:

a) The coasts and mangroves

The coasts of Sawajajar and Kaliwlingi were wide with mangroves 20 years ago. The shoreline was 500 m offshore from the current shoreline. The mangroves have been seriously degraded in various sections along the coasts between 2008 and 2013. Many mature trees of

Rhizophora apiculata were uprooted by strong waves, either along the coasts or on the borders of abandoned ponds along the coasts.

b) Causes for degraded mangroves

Mangroves were cleared to construct ponds which were used for aquaculture purposes 30 years ago. The aquaculture mainly was farming of fish, shrimp, and crabs.

The coastlines have been vulnerable to climate change and sea level rise. Serious coastal erosion began in 2008, leading to the substantial loss of mangroves in Sawajajaar and Kaliwlingi. Strong waves dominate in the wet season, resulting into mangroves falling down.

c) Current farming techniques:

Ponds constructed along the coasts were broken by strong waves, leading to local economic loss. Ponds located on landward side were abandoned because water became contaminated. As a consequence, fishes and crabs died.

New mudflats have been leased from the local government. The current farming technique is manual construction of ponds and their borders, construction of sluice gates on the sea ward side that supplied saline water to ponds. *Rhizophora apiculata* were planted along the pond borders. Borders were so narrow that they were easily broken by strong waves. No facilities were constructed to treat waste water. Natural stocks of fish, shrimp and crabs were caught during high tides.

New mudflats are continuously leased for constructing new ponds that will be used for fish / seaweed farming. Naturally grown mangroves on new mudflats were cut to construct land for aquaculture.

d) Understanding of climate change and sea level rise and their effects

There was a good understanding of climate change and sea level rise among two coastal villages. Temperature increased remarkably. The current sea level in 2009 was 40 cm higher than that of 20 years ago. There has been a significant change in rainfall.

Effects of climate change and sea level rise included big waves, loss of mangroves, blockage of estuaries, coastal erosion, more frequent inundation / flooding, bamboo fences broken, ponds destroyed and saline intrusion into rice fields. Sea level rise appears to have happened, causing coastal properties being frequently inundated for many months in a year.

e) Community effort in planting mangroves

The local communities have been strongly committed to mangrove planting. Many mangrove restoration / replanting programs commenced in 2010 to reduce negative impacts of climate change, sea level rise and mangrove degradation. Two coastal villages have been involved in replanting *Rhizophora apiculata* along the coasts and in the abandoned ponds along the coasts. Mangrove replanting programs were funded by various sources of funding. Some came from private enterprises; for example, Microsoft Indonesia, Lintasarta, Bumikarsa Hotel, etc. Some came from non-governmental organizations such as GEF / UNDP, KEHATI, and recently Indonesian Rainforest Foundation. Propagules were transplanted in accretion area, while seedlings 6 months old were planted in permanently inundated areas along the coasts or in abandoned ponds along the coasts.

Propagules of *Rhizophora apiculata* were nursed and tended in nurseries for at least 4 months. The nursery techniques included use of small sized poly bags (5 cm x 10 cm), recommended by the local governmental departments, potting using mixture of compost and soil, irrigation of seedlings once every week, and no rotation of poly bags for a minimum of 6 months.

The survival rate was reported up to 75% for both accretion coastal areas and eroding coastal areas.

f) Support from the local government

Two areas attracted significant attention from various governmental departments in Brebes Regency of Indonesia. The departments included Environmental Department, Marine Department, and Forestry Department. The support from the local governmental departments was through training in mangrove planting techniques, financial support for mangrove planting, construction of bamboo fences, which were constructed offshore to break the energy of the waves, training and financial support in aquaculture such as fish farming, shrimp farming, seaweed farming, and crab farming. Integrated farming has been recently emphasized; for example, integrated seaweed and crab farming, integrated fish and crab farming.

g) Expectation from the local government in the future

Local representatives expected more support from the government support in terms of reduction of negative impacts of climate change, sea level rise and mangrove degradation.

The requested support included construction of rock wall, construction of stronger bamboo fences, and search for new ways of trapping sediments.

h) Search for new techniques for mangrove planting and sea mud accumulation

Lessons learnt about coastal protection from Ray area, Kien Giang province, Vietnam were shared at the meeting. The lessons included selection of seeds / propagules, mangrove nursery techniques, planting techniques, monitoring and evaluation, and use of local resource and knowledge. There was an interest in replication of Kien Giang lessons into replanting mangroves and trapping sea mud in Sawajajar and Kaliwlingi. Issues in relation to local resources were discussed in the meeting. There was a need for upgrading the current bamboo fences, either constructed to protect the active ponds or located offshore to protect seedlings of *Rhizophora apiculata* from strong waves.

i) A need for mangrove based farming system

There was a strong need for an integrated farming system / mangrove based farming system. Under this system, mangroves could possibly protect local livelihoods from sea level rise, climate change and erosion. Meanwhile, local livelihoods could be improved and / or diversified by using mangroves as nurseries that supply natural stocks of fish, crabs and shrimps and possibly help filter the waste water.

To achieve this goal, abandoned ponds, and even the active ponds along the coasts and the eroding coasts should be restored through replanting seedlings of various mangrove species to establish a mangrove green belt. Integrated aquaculture farming techniques are promoted to adapt to climate change and sea level rise, and to improve / diversify current livelihoods or create alternative livelihoods. Initial ideas of pond configuration were discussed. Technical details and guidelines in relation to pond configuration such as design and construction of sluice gates, pond construction, and farming targets and techniques shall be also discussed further at the following meetings. In the mean time, proper farming techniques could be sought for abandoned ponds on the landward side.

Representing Sawajajar signed Representing Kaliwlingi signed

Minutes of the Participatory Community Meeting with Two Coastal Villages: Karang Dempel and Limbanga, Brebes Regency, Indonesia

29 November 2013

I. <u>The objective of the meeting:</u>

The meeting was held at the house of a local people in Limbangan on 29 November 2013. The meeting aimed to understand causes for mangrove degradation and coastal erosion in Brebes Regency, Indonesia, and to seek for recommendations for strategic planning for sustainable coastal development.

II. <u>Participants:</u>

Twenty three persons from two coastal villages attended the meeting. They were representatives from the local governments, the villages, and women's union of Karang dempel and Limbangan (please see the list of participants in the attachment 1).

III. <u>Discussion points:</u>

A representative of the two villages began the meeting by introducing Mr. Phong and his program in Brebes Regency, Indonesia. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The following procedures were followed:

1. Self introduction by Mr. Phong.
2. Explanation of his PhD program.
3. Explanation of purposes of the participatory community workshop.
4. Outline of topics that would be discussed.
5. Assurance of anonymity and reminder of the participants of their right to decline to participate.
6. Explanation that continued participation assumed consent for participation (please see the interview plan in the attachment 2 for more information).

Topics were discussed by the representatives. Discussion points and agreement were summarized as follows:

a) The coasts and mangroves

The coasts of Limbangan and Karang dempel were wide with mangroves 20 years ago. The mangroves were rich with species of Avicennia, Rhizophora and Sonneratia. The mangroves have been seriously degraded in various sections along the coasts between 1997 and 2013. Many mature trees of *Rhizophora apiculata* were uprooted by strong waves, either along the coasts or on the borders of abandoned ponds along the coasts.

b) Causes for degraded mangroves

Aquaculture began in 1998. Mangroves were cleared to construct ponds which were used for aquaculture purposes. The aquaculture mainly was farming of fish, shrimp, and crabs. Some coastal areas were owned by the local people. Majority of coastal areas were leased from the local government for aquaculture.

Erosion began between 1980 and 1987. The coasts of Limbangan and Karang were serious eroded between 1987 and 2013. As a consequence, mangroves were lost in Limbangan and Karang dempel. Strong waves dominate in the wet season, resulting into mangroves falling down.

c) Current farming techniques

The current farming technique is manual construction of ponds and their borders, construction of sluice gates on the sea ward side that supplied saline water to ponds. *Rhizophora apiculata* were planted along the pond borders. Local people farmed milk fish, crabs, shrimp and blood shell. There were two harvests a year. Water quality was a serious matter for farming. No facilities were constructed to treat waste water. The second concern was ponds were destroyed by strong waves. Borders were so narrow that they were easily broken by strong waves. As a consequence, the farming was not productive at all.

d) Understanding of climate change and sea level rise and their effects

There was a fair understanding of climate change and sea level rise among two coastal villages. Temperature increased remarkably.

Effects of climate change and sea level rise included big waves, loss of mangroves, coastal erosion, more frequent inundation / flooding, bamboo fences broken, ponds destroyed and saline intrusion into rice fields. Sea level rise appears to have happened, causing coastal properties being frequently inundated for many months in a year.

e) Community effort in planting mangroves

The local communities have been strongly committed to mangrove planting. Propagules of *Rhizophora apiculata* were planted on accretion areas along the coasts and in abandoned ponds along the coasts. On eroding areas, seedlings 6 months old were planted along the coasts and in the abandoned ponds along the coasts. The recent mangrove replanting program was funded by Indonesian Rainforest Foundation.

Propagules of *Rhizophora apiculata* were nursed and tended in nurseries for at least 4 months. The nursery techniques included use of small sized poly bags (5 cm x 10 cm), recommended by the local governmental departments, potting using mixture of compost and soil, irrigation of seedlings once every week, and no rotation of poly bags for a minimum of 6 months. Propagules (*Rhizophora apiculata)* having two leaves four months were planted in a sand island in June 2013 under the Indonesia Rainforest Foundation.

The survival rate was reported up to 80% for both accretion coastal areas and eroding coastal areas.

f) Support from the local government

Two areas attracted significant funding from the local government and governmental departments. Both the local communities and the governments have been involved in planting mangroves. The Forestry Department worked with local people in planting propagules of *Rhizophora apiculata* on accretion areas in 1997. Seedlings of *Rhizophora apiculata* were begun in 2004 in eroding coastal areas. However, mangroves were observed to be naturally grown in some areas along the coasts. The local governments also assisted the local communities in pond rehabilitation along the coasts. Ponds were rehabilitated by constructing bamboo fences offshore and planting seedlings of *Rhizophora apiculata*. Bamboo fences were constructed to break the energy of the waves and protect mangroves, were broken down by strong waves during the wet season.

g) Expectation from the local government in the future

Local representatives expected more support from the government support in terms of reduction of negative impacts of climate change, sea level rise and mangrove degradation. The requested support included construction of rock wall, construction of stronger bamboo fences, and search for new ways of trapping sediments.

h) Search for new techniques for mangrove planting and sea mud accumulation

Lessons learnt about coastal protection from Ray area, Kien Giang province, Vietnam were shared at the meeting. The lessons included selection of seeds / propagules, mangrove nursery techniques, planting techniques, monitoring and evaluation, and use of local resource and knowledge. There was an interest in replication of Kien Giang lessons into replanting mangroves and trapping sea mud in Limbangan and Karang dempel. There was a need for upgrading the current bamboo fences, either constructed to protect the active ponds or located offshore to protect seedlings of *Rhizophora apiculata* from strong waves.

i) A need for mangrove based farming system

There was a strong need for improving abandoned ponds along the coasts and controlling eroding coastal areas in Limbangan and Karang dempel. Ponds should be configured in a way that mangroves could possibly protect local livelihoods from sea level rise, climate change and erosion. Meanwhile, local livelihoods could be improved and / or diversified by using mangroves as nurseries that supply natural stocks of fish, crabs and shrimps and possibly help filter the waste water. Initial ideas of pond configuration were discussed. Technical details and guidelines in relation to pond configuration such as design and construction of sluice gates, pond construction, and farming targets and techniques shall be also discussed further at the following meetings. In the meantime, proper farming techniques could be sought for abandoned ponds on the landward side.

Representing Limbagan signed Representing Karang dempel signed

Minutes of the Participatory Community Meeting with Two Coastal Villages: Karang Dempel and Limbangan, Brebes Regency, Indonesia

6 December 2014

I. <u>The objective of the meeting:</u>

The meeting was held at the house of the head of the village of Limbangan on 6 December 2014. The meeting aimed to develop strategic solutions for coastal erosion control in Brebes Regency, Indonesia.

II. <u>participants:</u>

Thirty five persons from two coastal villages attended the meeting. They are representatives from the local governments, the villages, and the Women's Union of Karang dempel and Limbangan (please see the list of participants in the attachment 1).

III. <u>Discussion points:</u>

Mr. Mashadi began the meeting by introducing Mr. Phong and his program in Brebes Regency, Indonesia. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The following procedures were followed:

1. Self introduction by Mr. Phong.
2. Explanation of his PhD program.
3. Explanation of purposes of participatory community workshop.
4. Outline of topics that would be discussed.
5. Assurance of anonymity and reminder of the participants of their right to decline to participate.
6. Explanation that continued participation assumed consent for participation (please see the interview plan in the attachment 2 for more information).

a. Local context

Nursery management was economically ineffective, with a high death rate and poor quality of seedlings.

Planting single species for many years (*Rhizophora mucronata)* has led to significantly reduced protection of coastal mangroves. Planting in straight lines has not proven efficient in wave energy dissipation.

Bamboo fences have not been efficient in protecting planted mangrove species.

A mangrove green belt is needed to strengthen resilience of coastal mangroves in response to climate change / sea level rise and to improve / diversify local income in Brebes Regency. While current measures have been proven inadequate to pursue this objective, the guidelines on coastal erosion control are urgent to establish strategically the mangrove green belt in a permitted time.

b. Points discussed and agreed

The end product was the guidelines on coastal erosion control in Brebes Regency, Indonesia. The guidelines comprise the following components: a) the gradual expansion approach, b) strategic plans for improving the resilience of the current mangrove areas and strategic solutions for controlling actively eroding areas and c) improved nursery management and operation techniques.

c. The gradual expansion approach

Gradual expansion should involve two stages. The first stage is to close gaps identified in abandoned ponds or along the eroding coasts. The closure could be undertaken using a variety of local mangrove species and more effective coastal defences and complementing protection afforded by the scattered mangrove patches. This stage aims to improve coastal resilience, to strengthen coastal protection and to avoid vulnerability to coastal erosion. The second stage commences with subsequent treatments to be established using upgraded fences to expand the area, providing additional protection to the previous treatments.

d. Strategic plans for improving the resilience of the current mangrove areas and strategic solutions for controlling actively erosion areas

- *Strategic plans for improving the resilience of the current mangrove areas*

Strategic plans involve pond configuration on active ponds on accreting areas, planting of various local mangrove seeds / propagules / seedlings and promotion of natural growth / regeneration. How ponds are configured entirely depends on site conditions, and agreement between local communities and local government agencies. Active ponds should be configured at a minimum ratio of 30/70 (mangrove area accounts for 30% of total farming area on the seaward side to construct the mangrove green belt, while 70% is designed on landward side for farming for income improvement / diversification). Below are recommended types of pond configuration, agreed and supported by the communities of

Bresbe Regency. The configuration is supported by planting of various local mangrove seeds / propagules / seedlings and promotion of natural growth / regeneration.

Current pond dykes need to be improved to protect pond from being broken by strong waves in high tides. Following is a recommended design of a pond dyke (see diagram).

- S*trategic solutions for controlling actively erosion areas*

Strategic solutions are composed of three processes that are a) maximizing chances for effective stabilization process, b) strategically planting mangrove seeds / propagules and seedlings of various local mangrove species, c) promoting natural growth / regeneration.

In relation to effective stabilization process, areas where *Rhizophora mucronata* have been planted in straight lines should be enriched with other local mangrove species, especially *Avicennia marina.* The enrichment could be undertaken in clusters in some areas in conjunction with the building of the single line silt trap fence (see the description above). The river deltas and abandoned ponds should be gradually stabilized by planting mangrove seeds / seedlings / propagules in clusters, with protection provided by the recommended coconut fences to protect sediment from run-off.

In regard to planting techniques, a list of local mangrove species should be first established as a reference for future mangrove restoration. Planting locations are entirely dependent on ecological requirements of each species. Local mangrove species should be used in mangrove restoration to avoid the introduction of exotic species to the areas. Planting should be undertaken in clusters in high density to ensure high survival rates.

With regard to natural growth / regeneration promotion, areas where current mangrove patches and / or mother trees are found should be gradually closed by construction of the recommended coconut fences, which assist in trapping seeds and propagules for natural regeneration. Inside the mangrove patches, protected by the recommended coconut fences, small dead trees / branches locally available should be constructed as entrapping microsites to collect seeds floating onshore in high tides for further natural regeneration.

Below are the recommended coconut fences. The current bamboo fences have been upgraded by using coconut square pillars, used fishing nets, and bamboo mats to construct three sediment trap fences. The upgrade utilized the experience from the Vam Ray demonstration in Vietnam to test the fences' capacity for wave energy dissipation and sea mud accumulation in Brebes Regency. Three types of coconut fences should be piloted in the first phase. Coconut fences are recommended to be constructed before the dry season, ideally in March each year in Kaliwlingi, while September is good time to test coconut trunk fences in Limbangan.

Representing Limbagan signed Representing Karang dempel signed

Minutes of the Participatory Community Meeting with Three Coastal Villages: Sawojajar, Kaliwlingi and Rudusanga Kulon, Brebes Regency, Indonesia

7 December 2014

I. The objective of the meeting:

The meeting was held at the community house of of Sawojajar on 7 December 2014. The meeting aims to develop strategic solutions for coastal erosion control in Brebes Regency, Indonesia.

II. Participants:

Thirty three persons from two coastal villages attended the meeting. They are representatives from the local governments, the villages, and the Women's Union of Sawojajar, Kaliwlingi and Rudusanga Kulon (please see the list of participants in the attachment 1).

III. Discussion points:

Mr. Mashadi began the meeting by introducing Mr. Phong and his program in Brebes Regency, Indonesia. Mr. Phong sought verbal consent to make notes of the proceedings at the beginning of the meeting. The following procedures were followed:

1. Self introduction by Mr. Phong.
2. Explanation of his PhD program.
3. Explanation of purposes of participatory community workshop.
4. Outline of topics that would be discussed.
5. Assurance of anonymity and reminder of the participants of their right to decline to participate.
6. Explanation that continued participation assumed consent for participation.

(please see the interview plan in the attachment 2 for more information).

a. Local context

Nursery management was economically ineffective, with a high death rate and poor quality of seedlings.

Planting single species for many years (*Rhizophora mucronata)* has led to significantly reduced protection of coastal mangroves. Planting in straight lines has not proven efficient in wave energy dissipation.

Bamboo fences have not been efficient in protecting planted mangrove species.

A mangrove green belt is needed to strengthen resilience of coastal mangroves in response to climate change / sea level rise and to improve / diversify local income in Brebes Regency. While current measures have been proven inadequate to pursue this objective, the guidelines on coastal erosion control are urgent to establish strategically the mangrove green belt in a permitted time.

b. Points discussed and agreed

The end product was the guidelines on coastal erosion control in Brebes Regency, Indonesia. The guidelines comprise the following components: a) the gradual expansion approach, b) strategic plans for improving the resilience of the current mangrove areas and strategic solutions for controlling actively eroding areas and c) improved nursery management and operation techniques.

c. The gradual expansion approach

Gradual expansion involves two stages. The first stage is to close gaps identified in abandoned ponds or along the eroding coasts. The closure could be undertaken using a variety of local mangrove species and more effective coastal defences and complementing protection afforded by the scattered mangrove patches. This stage aims to improve coastal resilience, to strengthen coastal protection and to avoid vulnerability to coastal erosion. The second stage commences with subsequent treatments to be established using upgraded fences to expand the area, providing additional protection to the previous treatments.

d. Strategic plans for improving the resilience of the current mangrove areas and strategic solutions for controlling actively erosion areas

- *Strategic plans for improving the resilience of the current mangrove areas*

Strategic plans involve pond configuration on active ponds on accreting areas, planting of various local mangrove seeds / propagules / seedlings and promotion of natural growth / regeneration. How ponds are configured entirely depends on site conditions, and agreement between local communities and local government agencies. Active ponds should be configured at a minimum ratio of 30/70 (mangrove area accounts for 30% of total farming area on the seaward side to construct the mangrove green belt, while 70% is designed on landward side for farming for income improvement / diversification). Below are recommended types of pond configuration, agreed and supported by the communities of

Bresbe Regency. The configuration is supported by planting of various local mangrove seeds / propagules / seedlings and promotion of natural growth / regeneration.

Current pond dykes need to be improved to protect pond from being broken by strong waves in high tides. Following is a recommended design of a pond dyke.

- S*trategic solutions for controlling actively erosion areas*

Strategic solutions are composed of three processes that are a) maximizing chances for effective stabilization process, b) strategically planting mangrove seeds / propagules and seedlings of various local mangrove species, c) promoting natural growth / regeneration.

In relation to effective stabilization process, areas where *Rhizophora mucronata* have been planted in straight lines should be enriched with other local mangrove species, especially *Avicennia marina.* The enrichment could be undertaken in clusters in some areas in conjunction with the building of the single line silt trap fence (see the description above). The river deltas and abandoned ponds should be gradually stabilized by planting mangrove seeds / seedlings / propagules in clusters, with protection provided by the recommended coconut fences to protect sediment from run-off.

In regard to planting techniques, a list of local mangrove species should be first established as a reference for future mangrove restoration. Planting locations are entirely dependent on ecological requirements of each species. Local mangrove species should be used in mangrove restoration to avoid the introduction of exotic species to the areas. Planting should be undertaken in clusters in high density to ensure high survival rates.

With regard to natural growth / regeneration promotion, areas where current mangrove patches and / or mother trees are found should be gradually closed by construction of the recommended coconut fences, which assist in trapping seeds and propagules for natural regeneration. Inside the mangrove patches, protected by the recommended coconut fences, small dead trees / branches locally available should be constructed as entrapping microsites to collect seeds floating onshore in high tides for further natural regeneration.

Below are the recommended coconut fences. The current bamboo fences have been upgraded by using coconut square pillars, used fishing nets, and bamboo mats to construct three sediment trap fences. The upgrade utilized the experience from the Vam Ray demonstration in Vietnam to test the fences' capacity for wave energy dissipation and sea mud accumulation in Brebes Regency. Three types of coconut fences should be piloted in the first phase. Coconut fences are recommended to be constructed before the dry season, ideally in March each year in Kaliwlingi, while September is good time to test coconut trunk fences in Limbangan. The designs for coconut fences are described below.

Representing Limbagan signed Representing Karang dempel signed

APPENDIX 4: PUBLISHED MANUSCRIPTS

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Capacity-building paper

Community perspectives on an internationally funded mangrove restoration project: Kien Giang province, Vietnam

T.P. Nguyen [a, *], Nguyen Van Tam [b], Le Phat Quoi [c], Kevin E. Parnell [a]

[a] College of Marine and Environmental Sciences Centre for Tropical Environmental & Sustainability Sciences, James Cook University, Australia
[b] Vam Ray Resident, Hon Dat district, Kien Giang province, Viet nam
[c] The Centre for Environmental Science and Ecology, Institute for Environment and Natural Resources, Vietnam National University of Ho Chi Minh City, Viet nam

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ABSTRACT

It is common for environmental restoration projects to be reviewed by the administering organizations but it is much less common for the communities that the projects are meant to serve to detail their experiences and perceptions of the outcomes. We evaluate an internationally funded mangrove restoration project and reflect upon the lessons learned in regard to the project strategies and interventions, particularly from the perspective of the local community.

The Vam Ray coast, Kien Giang Province, Vietnam, was seriously eroded by 2008. In May 2009, a demonstration project was established which achieved a high survival rate of transplanted mangroves and sea mud accumulation. This study used participatory action research methods (literature review, semi-structured interviews, field visits, and peer debriefing) to evaluate the project outcomes. Despite the project being generally very successful, its implementation and results were inadequately documented by agencies involved due in large part to insufficient local involvement during the reporting process, even though the local community was fully involved in the project planning and implementation. Inadequate documentation has led to mistakes being made when attempts have been made to replicate the project elsewhere, and incomplete findings have been incorporated into mangrove management plans at the provincial and regional levels. Using the community knowledge from the time of the project implementation and since, we detail the successes and problems encountered to provide more complete reporting, to assist transferability of the methods to other eroding muddy coasts in Vietnam and potentially elsewhere.

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MANGROVE RESTORATION: ESTABLISHMENT OF A MANGROVE NURSERY ON ACID SULPHATE SOILS

TP Nguyen[1, *], VA Tong[2], LP Quoi[3] & KE Parnell[1]

[1]*Centre for Tropical Environmental and Sustainability Sciences, College of Marine and Environmental Sciences, James Cook University, 4811 Australia*
[2]*Vam Ray Resident, Hon Dat District, Kien Giang Province, 920000 Vietnam*
[3]*The Centre for Environmental Science and Ecology, Institute for Environment and Natural Resources, Vietnam National University of Ho Chi Minh City, 760000 Vietnam*

**phong.nguyen@my.jcu.edu.au*

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NGUYEN TP, TONG VA, QUOI LP & PARNELL KE. 2016. Mangrove restoration: establishment of a mangrove nursery on acid sulphate soils. Mangrove restoration requires the cultivation of healthy seedlings and propagules for transplantation. Nurseries established near the restoration sites provide local employment and involvement. Using a participatory action research methodology, this study showed the successful establishment and operation of a mangrove nursery on the landward side of a sea dyke, on acid sulphate soils normally considered unsuitable for mangrove growth. This nursery in Vam Ray area, Kien Giang province, Vietnam produced 37,500 seedlings of five mangrove species, *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba* and *Nypa fruticans*. The seedlings had 100% survival and were available for transplantation within three months, at a reasonable cost. The nursery procedures and techniques were based on local practices and knowledge. The study showed that a successful nursery on acid sulphate soils was achievable. Key differences compared with other mangrove nursery projects were land-based location, use of sea-bed mud to improve acid sulphate soils, use of local resources and locally traded products to minimise cost, reduced waste, local livelihood improvement and planting of multiple individuals per pot for selected species.

Keywords: Mekong Delta, community participation, livelihoods, local knowledge, muddy coastal erosion, mangrove seedling production

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APPENDIX 5: TECHNICAL REPORT

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Mangrove Restoration for Climate Change Adaptation and Mitigation in Brebes, Indonesia: Lessons learnt and Strategic Recommendations

Authors:

Nguyen Tan Phong[1], Kevin E. Parnell[2]

1) **Nguyen Tan Phong**

School of Earth & Environmental Sciences, Faculty of Science and Engineering,
James Cook University, Australia
Email: phong.nguyen@my.jcu.edu.au

2) **Kevin E. Parnell**

School of Earth & Environmental Sciences, Faculty of Science and Engineering,
James Cook University, Australia

Report to:

The Regional Development and Planning Board of Brebes Regency

April 2014

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We would also like to extend our thanks to Dr. John Quayle, Dr. Agus, Dr. Francisca, the Indonesian Rainforest Foundation, Indonesia, for their administrative assistance and technical advice for my visits to Brebes Regency, Indonesia.

Our sincere thanks are extended to Mr. Peter Mackay for logistics in the first visit to Indonesia.

Our true thanks go to Mr. Mashadi b. Rukayat for his photographs and assistance in the field, technical support and facilitation in community's discussions and consultations. We also thank Mr. Driwanto and Mr. Agung for their support in organizing workshops at the Bappeda office.

Our special thanks go to communities who welcomed us into their communities and to local farmers who invited us to their houses for lunches and dinners as well as for their help in providing information.

I. Context

Brebes Regency, Indonesia has had coastal mangrove areas totally cleared for socio-economic development for a long time. Current mangrove areas have been dramatically degraded both by unplanned shrimp pond construction and uncontrolled influx of people moving to the area for economic reasons, particularly by participation in aquaculture (Mackay, 2012). Total clearance of mangroves and mangrove degradation has contributed significantly to significant coastal erosion in Brebes. The Brebes coast has been predicted to be negatively impacted by sea level rise and storm surge (Mackay, 2012).

Various steps have been taken to reverse mangrove degradation and coastal erosion in Brebes Regency, Indonesia. Mangrove protection and restoration was recognized as a significant component in coastal spatial plans in Brebes in 2004 and 2011. Coastal mangroves, riparian areas, and aquaculture ponds were zoned to ensure effective, efficient and sustainable coastal development (Mayor of Brebes, 2004 and 2011). In 2011, Brebes Regency was selected as a pilot a green belt on the North Coast of Central Java, launched by the Environment Minister Gusti Muhammad Hatta (Burhani, 2011). Under the North Coast Central Java Green Belt program, mangrove restoration was promoted along the coastal communities in Brebes Regency to reduce negative impacts by climate change, sea level rise and coastal erosion. Mangrove resource rehabilitation and conservation groups were established to promote coastal mangrove restoration and protection (Mayor of Brebes, 2013).

Mangrove restoration has been undertaken through community based mangrove planting programs in Brebes Regency to control coastal erosion and to prevent further loss of coastal mangroves. The planting programs were funded either by the local government agencies or private companies. Under the planting programs, propagules of *Rhizophora mucronata* were planted in accretion areas, while six month seedlings were planted in permanently inundated areas along the coasts or in abandoned ponds along the coasts. Seedlings of *Rhizophora mucronata* were transplanted with supporting bamboo sticks along the edge of actively eroding coastal areas. The planting was undertaken in straight lines, spaced 2 metres apart.

In support of the North Coast Central Java Green Belt progam, a mangrove restoration and reforestation for climate change adaptation and mitigation project was established by the Indonesian Rainforest Foundation in 2012. The proposed project aimed to increase coastal resilience, and to improve and / or diversify local livelihoods (Mackay, 2012). An amount of 30,000 USD was provided for the first project phase for the period between May and December 2013. The first phase was implemented through a memorandum of understanding signed by representatives of local villages and Indonesian Rainforest Foundation. The implementation was undertaken by applying similar mangrove planting techniques to those traditionally used in the Brebes communities.

II. The objectives of the report

The authors have been involved as technical advisors in the Brebes mangrove restoration program on a voluntarily basis in Brebes Regency, Indonesia between July 2013 and April 2014. The Brebes mangrove restoration program was implemented by the Indonesian Rainforest Foundation in close cooperation with the Bappeda office in Brebes Regency.

This report aims to incorporate lessons learnt from a number of mangrove restoration projects and aquaculture ventures that have been undertaken on the Brebes coast, and to link the findings from these projects to the future identification, design, analysis and development of coastal mangrove restoration at Brebes Regency, Indonesia.

III. The methods used

3.1. Methods for data collection

The report required information from a variety of resources including regional / national staff of various governmental agencies, field observations, provincial documents and other legal records, and local partners and communities. Various methods were adopted to achieve the objectives of this project.

- *Secondary data collection*

Written reports, polices, and outputs from pilot programs related to land use planning, mangrove restoration, and fisheries have been collected from various meetings organized with the Brebes Regency agencies (Environmental Department, Marine Department, and Forestry Department), and the Indonesian Rainforest Foundation who has been implementing projects in Brebes Regency. The result was a list of discussion points that were used in meetings with local fishers / farmers at the later stage.

- *Field visits and observations*

Visits were held along the Brebes coastline with administrative assistance from the Indonesian Rainforest Foundation staff. Field inspections by boat were organized. Emphasis was given to abandoned ponds and eroding coastal areas. The remaining coastal mangrove areas were further observed to gain an insight into mangrove degradation, deforestation and coastal erosion. The visits provided additional information of coastal erosion and mangrove degradation, deforestation, and observations of potential areas that would benefit from future coastal planning.

- *Participatory community meetings*

Various meetings were held with fishers / farmers in 5 coastal villages of the Brebes coast (Kaliwlingi, Sawojajar, Pulogading, Karang dampel, Limbangan, and Desa Randusanga Wetan) with assistance from the mangrove protection units in the Brebes Regency and the Indonesian Rainforest Foundation. During the meetings, photographs taken previously in the area were used to support various discussions points, promote local involvement in discussions, and share local knowledge and lessons. This process provided an opportunity to cross check and / or update the information provided by scientific reports, field visits and observations, and a broad understanding of local perspectives of the provincial policies, technical reports, plans, and pilot projects.

- *Debriefings*

Two debriefings were held at the Bappeda office in 2013 and 2014. The debriefing aimed to cross-check and / or update the information provided by local communities and / or by scientific reports, and to further discuss issues in relation to aquaculture, mangrove degradation and deforestation, land use planning, and mangrove planting in the area.

3.2. Methods for data analysis

- *Reflective diaries*

After each meeting / field visit was completed, diaries were written to reflect issues brought up in discussions, issues of concern, feedbacks and personal observations and views in relation to mangrove protection and replanting, coastal protection and defence, and land use planning.

- *Development of matrix of issues in relation to coastal protection and defence*

Data and information collected during the project were systematically recorded, the result of which was a multi-dimensional summary that would be used to promote subsequent, more intensive analysis.

- *Thematic analysis*

The data collected and the process of data collection was analyzed, collated and categorized into themes. The thematic category assisted in identifying and refining important concepts, and assist in writing thematic reports.

3.3. Validation and corroboration

The information gained from participatory community meetings was validated and corroborated by minutes of the community meetings and the debriefing at the Bappeda office.

IV. Preliminary findings

4.1. The Brebes coastal status

There are two rivers located at the ends of the Brebes bay: Pemali River is located in the areas of Kaliwlingi and Randusanga kulon, and Cisangkung River is situated in Karang dempel and Limbangan. The areas of Sawojajar, Kaliwlingi, Limbangnan, and Kareng dempel were entirely cleared for aquaculture pond construction, resulting in sediment run-off to the river mouth because sediment was not adequately protected by coastal mangroves. The run-off has completely blocked Pemali River. This river flow has been redirected to the sea through a small branch in Randusanga kulon. Cisangkung River has been gradually narrowed by sediment gradually deposited along the river bank and river mouth. The blockage and gradual narrowing caused a deficit of sediment transported to the sea.

The Brebes coast is frequently impacted under the influence of strong seasonal waves on high tides. Sediment deposited at two ends of the Brebes bay has been continuously transported to Pulogading by strong waves during both wind seasons. This means that Limbangan, Karang dampel, Kaliwlingi, Sawojajar, which have already experienced a deficit of sediment, have been facing further loss of sediment, while Pulogading has new mudflats being deposited. The coasts of Limbangan, Karang dampel, Kaliwlingi, Sawojajar have, therefore, been actively eroding and the Pulogading coast has been increasingly accreting.

The majority of the Brebes coast has been heavily colonized by stands of pure *Rhizophora mucronata* and there are now mature trees of *Rhizophora mucronata,* which have been planted over previous years. *Rhizophora mucronata* along the coasts and / or on abandoned pond dykes have been found uprooted and / or damaged by strong waves in high tides, resulting in reduced protection of the Brebes coast by mangroves for future sea level rise, coastal erosion and storm surge.

Sawajajar and Kaliwlingi were connected with the sand island located offshore up to 1991. There were a number of aquaculture ponds constructed on the connection area. The entire connection area was permanently inundated in 1999. The permanent inundation arguably caused the exposure of ponds located on land ward side.

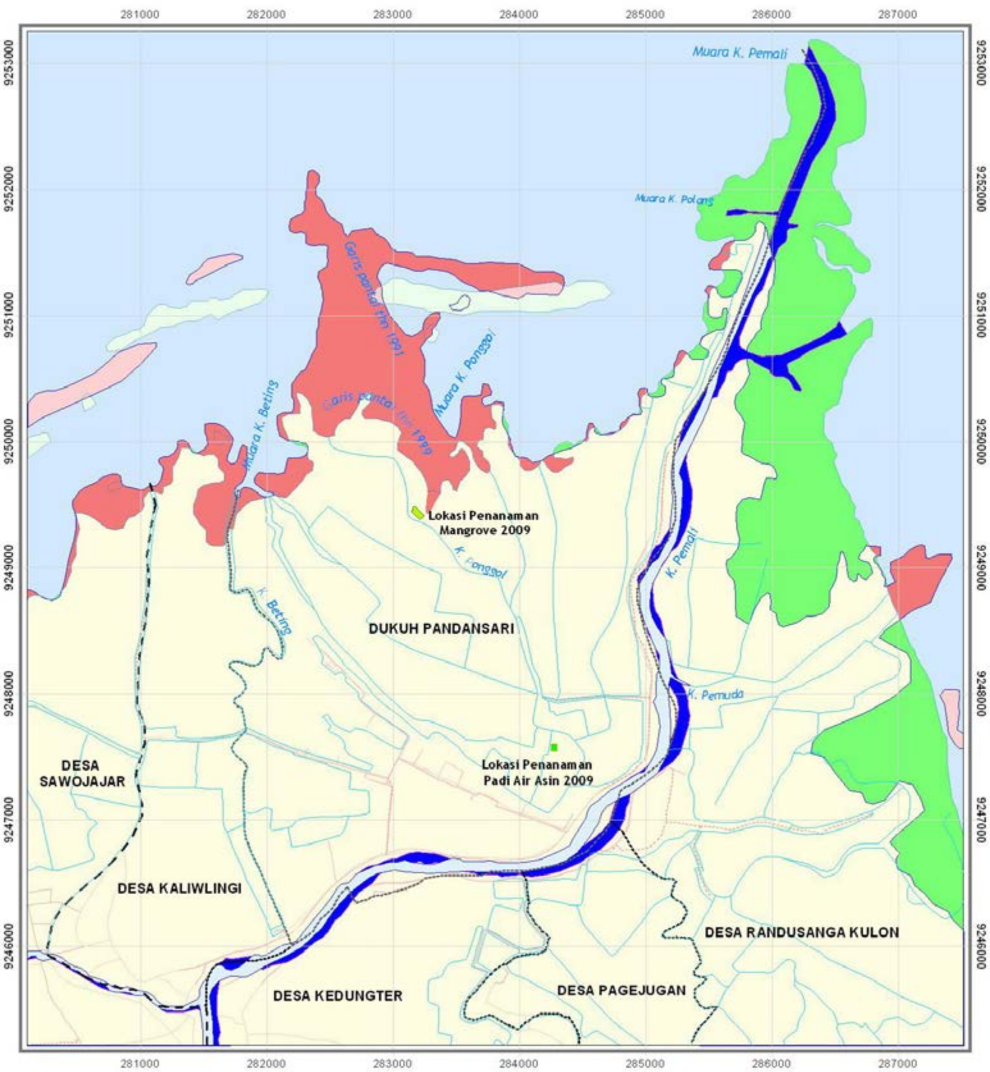

Figure 1: The recolour showing areas permanently inundated by 1999.

4.2. Aquaculture techniques

The Brebes coast was rich in coastal mangrove species 50 years ago. The Brebes coastal areas were unofficially leased in the 1970s to construct ponds for aquaculture purposes. Ponds were constructed for fish, crab, and shrimp farming, by clearing coastal mangroves with narrow pond dykes and gates manually constructed. The construction of pond dykes and gates were undertaken by using sediment excavated from within the pond areas, resulting in deep channels being opened along pond dykes. In Limbangan, Karang dampel, Kaliwlingi, Sawojajar, propagules of *Rhizophora mucronata* were planted on the narrow and narrow pond dykes trying to protect pond dykes. Since the 1980s, the pond dykes on the seaward side have been breached by strong waves in high tides. Strong waves penetrated inside ponds and caused breaking other pond dykes.

As a consequence, ponds along the coasts of Limbangan, Karang dampel, Sawojajar, Kaliwlingi have been abandoned. Meanwhile, active ponds on the landward side have been extensively used for sea weed farming, crab and fish farming. *Rhizophora mucronata* were planted on narrow pond dykes.

In Pulogading, where there is significant coastal accretion, newly deposited mudflats have been leased to construct new ponds for aquaculture. New ponds were constructed with narrow dykes, using sediment manually excavated within pond areas. No *Rhizophora mucronata* were planted on pond dykes. New ponds close to the sea have been operated by allowing saline water into the ponds through gates in high tides, bringing mussels and shrimp larvae which are trapped for farming. Ponds located on the landward side, have been supplied with water from rivers / channels connected to the sea.

Ponds have not been constructed with water treatment systems. The water was gradually contaminated, resulting in fish dyeing. As a consequence, more ponds have been increasingly abandoned over time.

Figure 2: Dead fish in ponds in Pulogading.

4.3. Production of seedlings

Nursery techniques detailing production techniques, provided by the local governmental agency have been closely followed in Brebes Regency. Seedlings of *Rhizophora mucronata* were nursed and tended in nurseries for at least six months. Mangrove nurseries were operated by local farmers under contracts to the local governmental agency. Mangrove nurseries were constructed behind the current stands of *Rhizophora mucronata* in Sawojajar, while other coastal areas had their mangrove nurseries constructed on rice paddy fields, which are far away from rehabilitation / restoration locations.

Propagules of *Rhizophora mucronata* were collected along the rivers and the ponds where mother trees are present. Propagules were tied into bundles before being transported to nursery sites by boats. Poly bags (5 cm x 15 cm) were filled with locally sourced compost and dry clay soil. In Sawojajar, shallow trenches were constructed on the nursery ground before poly bags were transported into the nursery sites. In Pulogading and Karang dempel, poly bags were placed on rice paddy areas. Poly bags were placed closely packed in nurseries. As soon as they were placed in nursery grounds, the filled poly bags were potted with one propagule per bag and there was no rotation of poly bags over the period of 6 months that they were in the nursery. Seedlings were daily irrigated with fresh water and / or brackish water pumped from nearby rivers and / or reservoirs.

Because potted poly bags have not been rotated, seedlings grew and developed their roots quickly through the poly bags into the base ground, making transplant very difficult without damage.

A substantial number of propagules were observed to have been discarded around nurseries during the field visits. The reasons for discard were that propagules were either too young or were damaged during transport.

Nearly all of the propagules in one mangrove nursery in Pulogading died as the seedlings were permanently inundated by fresh water. It was reported that roots were cut before transplanting. As a consequence, only 50% of total seedlings propagated in the nurseries survived on eroding areas after one month of transplanting.

Figure 3: Seedlings in a nursery in Sawojajar developing roots into soil base.

Figure 4: Waste propagules found outside a nursery in Sawojajara

Figure 5: Seedlings were permanently inundated with freshwater in a nursery in Pulogading.

4.4. Community mangrove restoration efforts

In recognition of the effects of climate change and sea level rise, the local communities in the Brebes Regency have been strongly committed to mangrove restoration. Many mangrove restoration programs commenced in 2010 to reduce negative impacts of climate change, sea level rise and mangrove degradation. Under the mangrove restoration programs, *Rhizophora mucronata* was the only species used and seedlings and propagules were planted in straight lines. Six month old seedlings were planted in eroding areas and on abandoned ponds, propagules were directly planted on accreting areas.

However, it was observed in 2013 and 2014 that *Rhizophora mucronata* has provided a low level of protection against strong waves. The Brebes coast was dominant by *Rhizophora mucronata,* planted for many years, but remains increasingly vulnerable to mangrove degradation and coastal erosion. Mature trees of *Rhizophora mucronata*, along the coasts, and on the abandoned pond dykes along the coasts have been uprooted by strong waves.

Figure 6: Mature trees of *Rhizophora mucronata* found uprooted on abandoned pond dykes.

Figure 7: Mature trees of *Rhizophora mucronata uprooted* in strong energy areas.

Stands of mature trees of *Rhizophora mucronata* close to new planting areas have been already damaged by strong waves in high tides. Seedlings planted with poly bags were found dead in many places because of roots being cut in transplant. In some cases, seedlings having roots growing through poly bags experienced substantial stresses because they were tended and nursed in terrestrial conditions, using compost for potting and irrigation by fresh water.

Seedlings planted by removing poly bags filled with compost experienced compost being lost by strong waves. The loss of compost resulted in seedlings not being well supported, and eventually being washed away by strong waves in high tides.

Propagules died in firm surface areas because they were pushed hard into firm surface areas in planting, damaging their root systems. Roots being damaged in planting caused low survival rates.

Figure 8: Mature trees of *R. mucronata* transplanted many years ago, near new planting sites started falling down in Sawojajar.

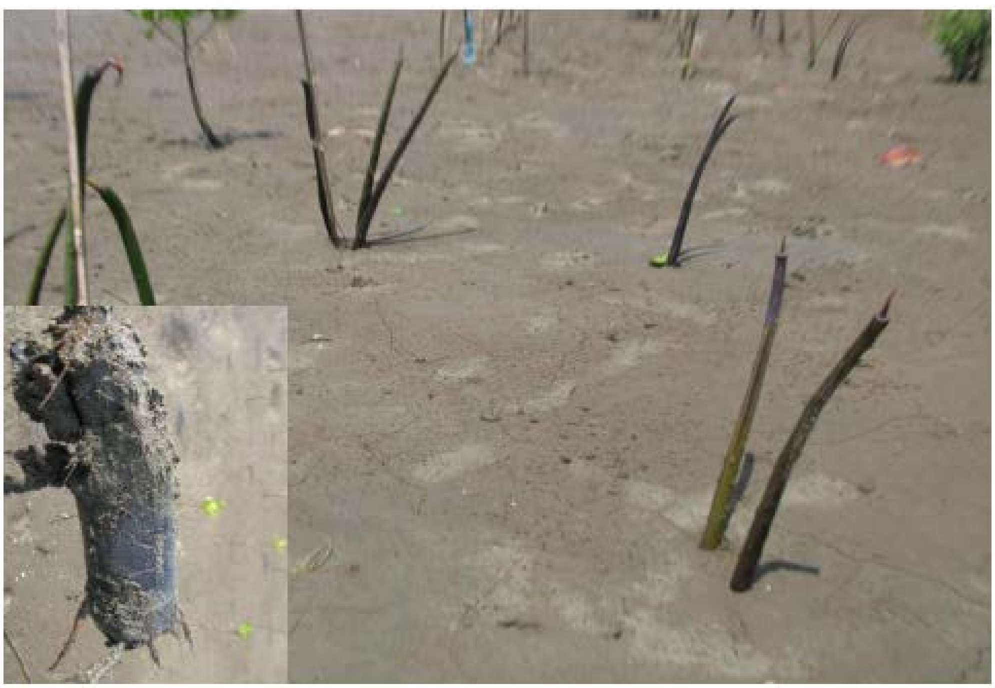

Figure 9: Seedlings were stressed in transplantation in Pulogading.

4.5. Natural growth / regeneration

Participatory community meetings revealed that the Brebes coast used to be vegetated with a variety of coastal mangrove species. However, aquaculture pond construction and continued planting of single species of *Rhizophora mucronata* for decades significantly contributed to gradual eradication of other mangrove species in the areas. However, mature trees of *Avicennia marina* have been naturally regenerated / grown on the edge of the coast and along the river delta in Limbangan and Karang dempel, Sawajajar and Kaliwlingi. Planted trees of *Rhizophora mucronata* are found to be mixed with naturally regenerated trees of *Avicennia marina* along the channels in Randusanga kulon. Stands of *Avicennia marina* have been surviving well strong waves in the areas, where mature trees of *Rhizophora mucronata* were uprooted in Randusanga kulon. *Avicennia marina* has been observed naturally growing with spreading roots on the sand island of Randusanga kulon, that possibly assisting in protecting the sand. The natural growth is highly likely to assist in protecting sand and soil. Stands of *Avicennia marina* have been found naturally regenerated among the planted *Rhizophora mucronata* in Limbangan and Karang dempel.

Figure 10: *A. marina* having a strong root system that assists in soil stabilization.

4.6. The Brebes coastal defences

Various structures have been constructed in response to coastal erosion and mangrove degradation. Bamboo wave break fences were constructed offshore on the Sawojajar coast in 2010. The bamboo wave break fence was composed of many triangular bamboo units (1.5 m x 1.5 m x 1.5 m), with a distance of 0.5 m between two units. Triangular bamboo wave break fences were reported to have been broken in May 2013. New triangular bamboo wave break fences have been recently constructed in the same place in July 2013.

Two types of bamboo fences were constructed to protect active ponds against high tides and strong waves in Randusanga kulon, while there are many abandoned ponds around the area. One is the fence made of bamboo mat and bamboo stems. The other is the fence constructed with fishing nets and bamboo stems. The average width of the above two bamboo fences is approximately 01 metre. Seeds of *Avicennia marina* have been grown within the bamboo fences. However, the bamboo fences were observed to have been broken by strong waves.

A rock wall was established to dissipate the energy of strong waves in Randusanga kulon. The rock wall is made of granite rocks, piled up into a wall. The rock wall has been reported to be successful in wave energy dissipation and protection of mangroves inside it.

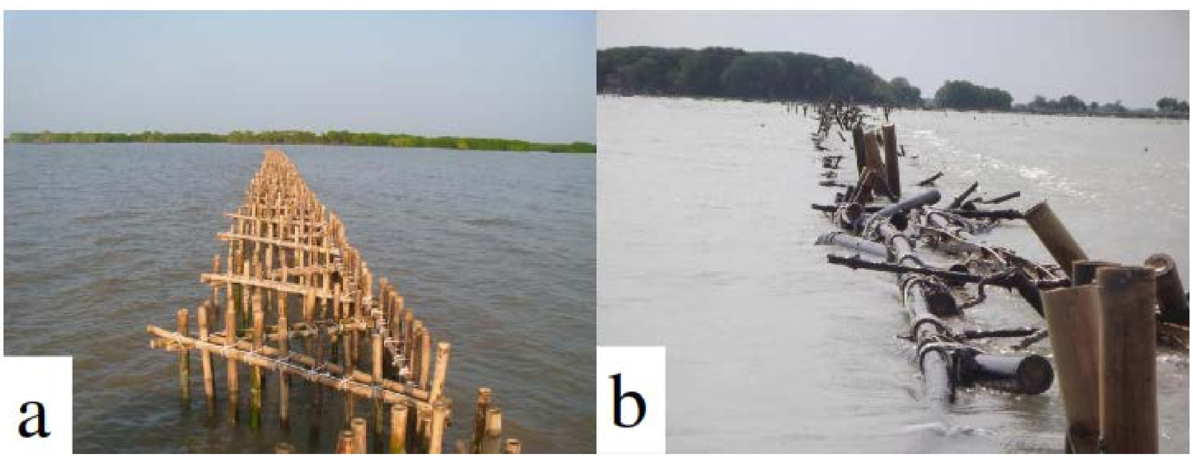

Figure 11: Bamboo fences in Sawajajar, a) new bamboo fence, b) bamboo fences broken after one year.

Figure 12: Rock wall was constructed to dissipate the energy of strong waves in Randusanga kulon

V. Issues for consideration

5.1. Importance of integrating local knowledge and scientific understanding

Local knowledge was an important contributor to understanding of interventions for mangrove restoration in the Brebes Regency, Indonesia. Local knowledge is built up over time by those who have been living in the Brebes Regency for decades. The locals, who are often called ‘bare foot scientists’, know their areas better than any outsiders and they understand that erosion has been a problem for people in the Brebes Regency. On many occasions, local knowledge is individual owned and narrow. Access to local knowledge requires that the technical advisers have a good reputation in the area, local references, and adequate knowledge of the specific issues that the locals are facing.

The Brebes people could not be aware of consequences of having limited scientific knowledge and were not sure if the knowledge from outsiders could help solve problems. To assist the locals in solving their specific problems, local knowledge has been systematically collected and connected and collated with experience elsewhere and scientific understanding to develop a complete picture of cause and effect relationship in relation to current interventions for mangrove restoration in the Brebes Regency. By integrating local knowledge with scientific understanding in a meaningful way, the Brebes people have been empowered to make decisions to solve their own problems. The integration of local knowledge and scientific understanding can not only help avoid the same mistakes in mangrove restoration, but also provides opportunities for possible interventions in the future, and developing feasible solutions to coastal erosion.

5.2. Local understanding of the mangrove green belt program

The mangrove green belt program was established to restore abandoned ponds and the actively eroding coastal areas, using various mangrove species, together with active pond configuration to establish the mangrove green belt. In return, the mangrove green belt would provide a protection for local aquaculture / livelihoods behind the mangroves, while integrated aquaculture farming techniques are promoted to adapt to climate change and sea level rise and to create alternative livelihoods and / or diversify current livelihoods.

However, it has been found that the concepts of mangrove green belt program have not been well understood among the local communities and local authorities. Common local understanding was that the program primarily involved planting propagules of *Rhizophora mucronata* in landward abandoned ponds, and planting seedlings of *Rhizophora mucronata* supported by bamboo sticks on eroding coastal areas in Limbangan, Karang dampel, Kaliwlingi, Sawojajar. The planting was undertaken offshore on the sand island in Sawajajar and Kaliwlingi. Meanwhile the construction of new ponds on newly deposited mudflats for aquaculture purposes has been legally permitted in Pulogading.

5.3. Land tenure

There has been a controversial issue in relation to land use planning and management in Brebes Regency. The Brebes coastal spatial planning and development plans in 2004 and 2011 (Mayor of Brebes, 2004 and 2011) aimed to ensure coastal sustainable development through zoning process. In these strategic plans, agriculture, aquaculture ponds and coastal mangrove areas should be zoned in an integrated way to ensure coastal sustainable development. In reality, areas of Limbangan, Karang dampel, Kaliwlingi, Sawojajar where coastal mangroves were cleared for aquaculture pond construction under official contracts have been actively eroding and / or vulnerable to coastal erosion. Meanwhile, newly deposited mudflats have been increasingly leased to construct new ponds in Pulogading.

5.4. Aquaculture pond construction and operation

Aquaculture pond construction and operation have raised a challenge to sustainable muddy coastal development in the Brebes Regency. Aquaculture ponds constructed with clearance of coastal mangroves and no wasted water treatment and / or no drainage gates have been proven to be economically not viable, resulting in ponds being abandoned due to unprofitability caused by ecological degradation. Many ponds have been abandoned along the Brebes coast. The abandonment will definitely continue if no solutions are provided to treat and / or drain waste water.

Various techniques have been developed to deal with ecological degradation in aquaculture ponds, for example, construction of drainage gates (Food and Agriculture Organization, 1986), adequate understanding of important biological / biochemical processes in closed re-circulating and open seaweed culture (Troell *et al.,* 2003), aquaculture integrated with herbivorous and omnivorous species (Primavear, 2006), reduction of the concentration of dissolved inorganic matters and increae of the concentration of dissolved oxygen in aquaculture water bodies (Peng *et al.,* 2009), farming of seaweed as bio-filtration to turn nutrient rich effluents into profitable resources (Neori *et al.,* 2004), or utilization of mangrove areas in maintaining water quality (Wong *et al.,* 1997; Peng *et al.,* 2009; Wang *et al.,* 2010). These techniques should have been considered and contextualized to suit the Brebes situation.

5.5. The need for more efficient nursery management

The current nursery construction and management guidelines In Bali and Lombok and elsewhere in Indonesia have recommended that small size poly bags are used for potting. No attention is given to rotation of poly bags in nurseries. Soils to be used for potting are collected from nearby locations, in some cases, is mixed with cow dung, fertilizers, or compost. Propagules and seeds are placed closely in nurseries, tended and nursed for a minimum period of 3 months. Propagation depth, especially for *Rhizophora mucronata, Rhizophora apiculata, Bruguiera gymnorrfiza* is not proportional to sizes of propagules and poly bags (Ministry of Forestry and Estate Crops of Indonesia, 1999; Ministry of Forestry of Indonesia, 2007; Priyono, 2010).

It has been proven that the local communities in Brebes Regency followed strictly the current guidelines on nursery construction and management. However, the efficiency and effectiveness has been a matter of concern. Compost and poly bags were locally purchased. Payment was made for collection and transportation of propagules of *Rhizophora mucronata* to nursery locations. A substantial number of wasted propagules of *Rhizophora mucronata* were found around a mangrove nursery established in Sawajajar because the propagules were young and / or damaged during transport. High mortality of seedlings of *Rhizophora mucronata* was observed in a nursery in Pulogading because seedlings were permanently inundated by fresh water. Wasted propagules and high mortality mean extra local income loss in addition to purchases of compost and poly bags. It means that the current nursery techniques used in Brebes Regency were not ideal, resulting in considerable waste of money, time, and effort.

The Vam Ray demonstration showed effectiveness and efficiency in producing high quality seedlings through the use of a bed of sea mud to overcome problems associated with the acid sulphate soils, the use of local resources and locally traded products to minimize cost, reduce waste and provide local livelihood improvement, and the planting of some species with multiple individuals per pot (Nguyen, 2014, submitted).

Therefore, it is urgent to develop a technical guideline on mangrove nursery techniques that are specifically contextualized in Brebes Regency to reflect successes and failures so far to ensure high survival rates in future transplant in Brebes Regency

5.6. Mangrove restoration using single species

Mangrove restoration using single species has shown to be a matter of concern. Mature individual trees *Rhizophora mucronata* have been uprooted or damaged under the influence of strong waves during high tides. Stands of pure *Rhizophora mucronata* do not survive well under strong waves and storm surges. However, planting a single species of *Rhizophora mucronata* has been the common practice for mangrove restoration in the Brebes Regency. Planting a single species of *Rhizophora mucronata* does not provide enough guarantees of improved coastal resilience and strengthened coastal mangroves.

Surveys should be undertaken to develop a list of mangrove species locally present in the areas, which will be used as reference for future mangrove restoration. Planting local mangrove species would also help avoid the introduction of exotic species to the areas (Nguyen, 2014, submitted).

In regard to species of choice, *Avicennia marina* is a pioneer species growing well on mudflats (Nguyen, 2014, submitted), and has an ecological function of holding mud during re-colonization (Duke, 2006). *Rhizophora mucronata* grows well on well protected and / or high elevation areas (Nguyen, 2014, submitted). When *Rhizophora mucronata* and *Avicennia marina* sre grown together, these two species would facilitate the natural regeneration of other species (Nguyen, 2014, submitted).

Mangrove restoration using a variety of local mangroves not only serves ecological purposes, but also provides alternative incomes for local communities (Nguyen, 2014, submitted). In North Sumatra, *Rhizophora mucronata* and *Avicennia marina* have been planted under the mangrove restoration. *Rhizophora mucronata* were planted for income purposes, while *Avicennia* *marina* was valuable for ecological reasons (Mackay *et al.,* 2013). The mixed planting should be recommended in the future mangrove restoration in Brebes.

5.7. Planting techniques

Planting in straight lines and utilization of bamboo sticks to support seedlings and / or propagules is the recommended practice in Indonesia (Ministry of Forestry and Estate Crops of Indonesia, 1999). However, planting of seedlings / propagules of *Rhizophora mucronata* in straight lines did not prove any efficiency in wave energy dissipation in Brebes. Waves have propagated into coastline through planted mangroves.

The Vam Ray demonstration showed that seedlings and propagules should be mixed in clusters, whether the areas are actively eroding or accreting areas. Planting in clusters could establish strong foundation by the combination of seedlings and / or seedlings that assists with dissipation of strong wave energy. Roots of seedlings and propagules should be protected in planting to avoid low survival rates (Nguyen, 2014, submitted).

Attention should be given to density in planting. Current guidelines on mangrove planting have recommended a minimum planting distance of 1 metre between two seedlings / propagules (Ministry of Forestry and Estate Crops of Indonesia, 1999; Suprayogi and Bayu, 2009, in press; Mackay *et al.,* 2013). However, in Brebes, coastal mangrove species are planted to rapidly establish a mangrove green belt that provides adequate protection of local properties and increases coastal resilience, reduces coastal degradation, and avoids coastal erosion. It would be better to mimic the nature by mixing seedlings / seeds / propagules of various local mangrove species at high density to ensure high survival rates.

5.8. Effectiveness of planting

Although mangrove restoration has been undertaken for many years, it has not been particularly effective in the Brebes Regency. The majority of seedlings of *Rhizophora mucronata* planted with poly bags on the sand island of Limbangan were observed to die. There was a low survival rate of *Rhizophora mucronata* because their roots were cut off before transplanting. Dead seedlings and low survival rates have caused substantial economic loss for both local communities and local governmental agency. Planting should be regularly monitored and evaluated to ensure high survival rates and efficiency.

5.9. Promotion of natural regeneration / growth

Natural regeneration / growth of coastal mangroves, especially *Avicennia marina* has occurred with natural germination of seeds that were trapped in many locations along the Brebes coast. Naturally regenerated grown coastal mangroves have shown their better adaptation to current situations than planted mangrove species. Therefore, it would be more effective and efficient to promote natural regeneration / growth that greatly contributes to the success of mangrove restoration.

Natural regeneration / growth could be increased through establishment of entrapment microsites. Entrapment microsites can be rocks or remnant vegetation trapping seeds at the site (Galatwitsch, 2012). Entrapment microsites, using branches and small sticks of Melaleuca have been proven effective in increasing natural regeneration / growth and re-colonization through trapping seeds / propagules floating onshore and / or around mother trees (Nguyen, 2014, submitted).

5.10. The need for more effective coastal defences

Bamboo fences constructed in the Brebes Regency so far have not proven effectiveness in response to mangrove protection, and coastal erosion, mangrove degradation. The reality is that it was expensive to construct rock walls, despite its effectiveness and the Brebes people could not afford new expensive technologies. Therefore, it is requisite to design more effective muddy erosion control measures by upgrading the current bamboo fences.

Coconut trunks and used bamboo mats are available in the areas. Coconuts and used bamboo mats should be tested in upgrading the current bamboo fences. The upgrade could be done through the incorporation of local knowledge and scientific understanding using the experience from the Vam Ray demonstration in Vietnam. The upgrade will not only help reduce substantially the costs of mangrove restoration, but also provide encouragement for replication elsewhere in the Brebes Regency.

5.11. Mangrove green belt program and the joint carbon credit program between Indonesia and Japan

The government of Japan has signed the bilateral document with the government of Indonesia on 26 August 2013 as a result of various consultation meetings held. Under this signed bilateral document, the joint crediting mechanism has been developed to promote low carbon growth in Indonesia and Japan. The joint crediting mechanism is expected to ultimately contribute to United Nations Framework Convention on Climate Change by facilitating global actions for greenhouse gas emission reduction / removals and complementing clean development mechanism.

If mangrove restoration and protection were included as an integrated emission reduction component of the bilateral document, the joint crediting mechanism would be an important source of income for the Brebes coastal local community, and a motivational factor for protecting and developing coastal protection forests by the private sector, who plan to or already undertake forest based businesses in the coastal area.

VI. *Strategic recommendations*

In consideration of the above issues and challenges, there is a potential for both increased environmental protection and livelihood improvement in Brebes Regency in Indonesia. The Brebes coast is recommended to be strategically planned to strengthen the resilience of coastal mangroves for adaptation to storm surges, sea level rise, and climate change, and to improve / diversity local livelihoods. The strategic recommendation is to improve strategically the establishment of the mangrove green belt program in Brebes Regency. The mangrove green belt program should be established through mangrove restoration in abandoned ponds and on actively eroding coasts, pond configuration on abandoned ponds and active ponds on accreting areas, stabilization of river delta areas, and capacity building in terms of technical trainings on nursery, planting techniques, pond management, farming techniques, and awareness raising on climate change, integrated coastal zone management, and adaptive co-management.

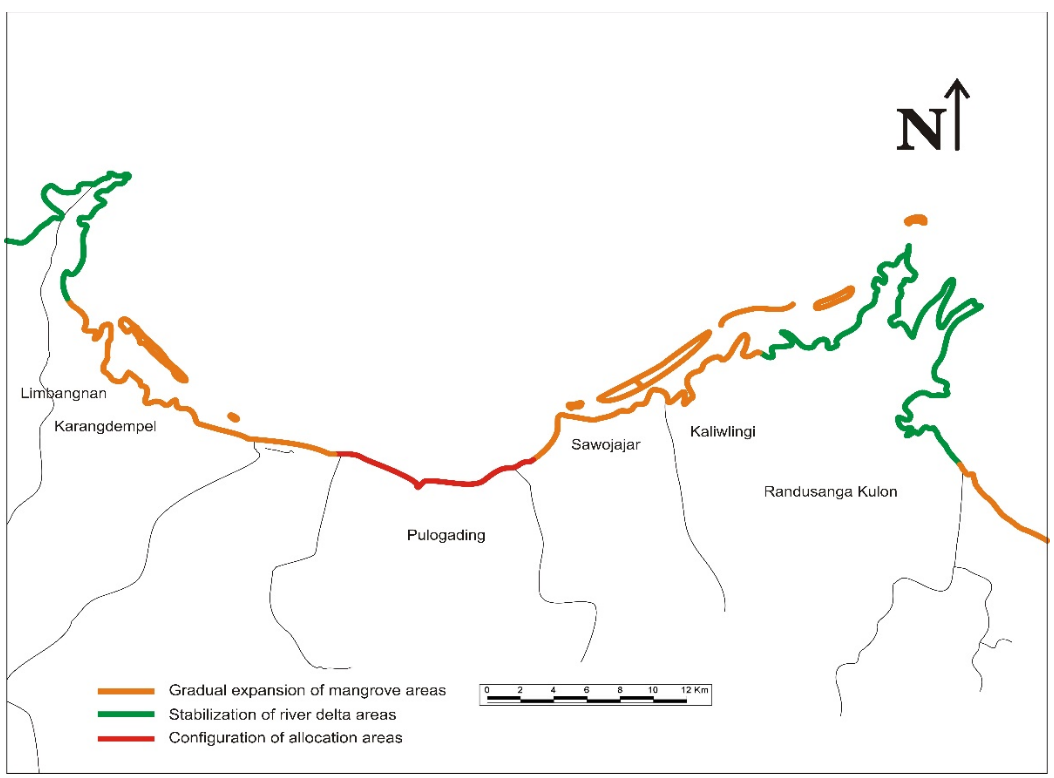

Figure 13: Strategic establishment of the mangrove.

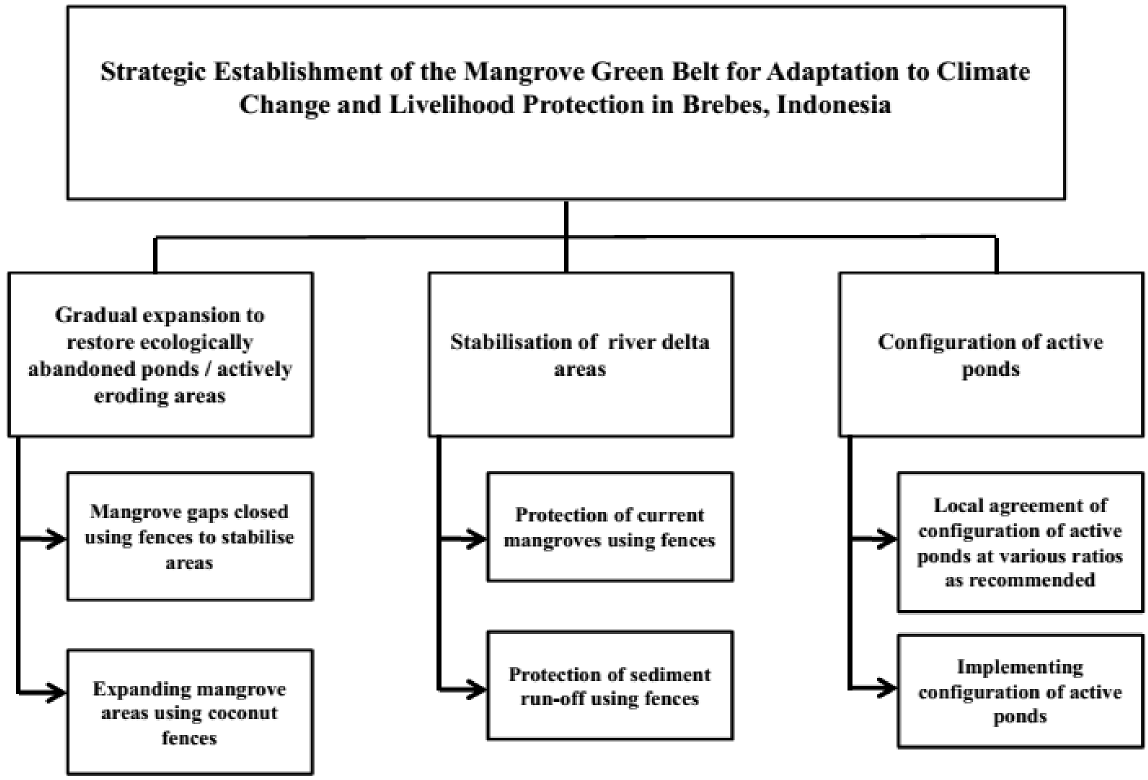

Figure 14: The components of strategic establishment of a mangrove belt in Brebes Regency, Indonesia

VII. *Conclusions*

The integration of local knowledge and scientific understanding has in other locations contributed greatly to understanding the physical characteristics and dynamics of the restoration areas, the reasons for past failures, and empowering local communities to make decisions to solve their own problems.

The Brebes coastline has been significantly influenced by natural sedimentary processes and consequences of anthropogenic activities. In relation to natural sedimentary processes, sediment loss was caused by inadequate protection of sediment by natural coastal mangroves. Seasonal sediment fluctuation and land permanent inundation contributed significantly to morphological change in the Brebes coast. With respect to anthropogenic activities, aquaculture techniques involving construction of ponds with clearance of coastal mangroves, narrow pond dykes and gates manually constructed, and poor water treatment resulted in further loss of mangroves, coastal erosion, and ponds being abandoned.

Community mangrove restoration using *Rhizophora mucronata* has arguably led to reduced protection of coastal mangrove in response to climate change, sea level rise and storm surge. There has been a limited monitoring and evaluation in mangrove restoration.

Current mangrove nursery techniques have been inefficient in terms of costs and revenues. Seedlings produced from mangrove nurseries did not survive well in transplant. Bamboo fences were not effective in protecting seedlings and coastal erosion. Naturally regenerated / grown mangroves, especially *Avicennia marina* have shown their better adaptation to current situations than the planted mangrove species, and its use should be encouraged.

The strategic establishment plan includes ecological restoration of abandoned ponds using gradual expansion of mangrove areas, configuration of active ponds, and the stabilisation of the two delta areas.

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APPENDIX 6: SUBMITTED MANUSCRIPTS

Journal of Coastal Conservation: Planning and Management

Human Activities and Coastal Erosion on the Kien Giang Coast, Vietnam

--Manuscript Draft--

Manuscript Number:	
Full Title:	Human Activities and Coastal Erosion on the Kien Giang Coast, Vietnam
Article Type:	Original Research
Keywords:	Muddy coastal erosion; local knowledge; scientific understanding; sustainable muddy coastal development; mangrove degradation; coastal protection
Corresponding Author:	Phong Tan Nguyen, MAppSc College of Marine and Environmental Sciences Townsville, Queensland AUSTRALIA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	College of Marine and Environmental Sciences
Corresponding Author's Secondary Institution:	
First Author:	Phong Tan Nguyen, MAppSc
First Author Secondary Information:	
Order of Authors:	Phong Tan Nguyen, MAppSc
	Kevin E. Parnell, Dr.
	Alison Cottrell, Dr.
Order of Authors Secondary Information:	
Funding Information:	
Abstract:	By 2009, the Kien Giang coast, Vietnam, had experienced significant coastal erosion and mangrove degradation. Recent mitigation strategies, developed through policies, plans and mangrove planting programs have not been successful, in part because the causes of coastal erosion were not adequately identified. This paper investigates the relationship between human activities and coastal erosion in Kien Giang province. This study used mixed methods to understand the causes of coastal erosion with an emphasis on human activities. In this investigation, local communities were involved as co-investigators to explore the causes of coastal erosion in Kien Giang province. While natural factors (adverse effects of climate change and sea level rise) have been widely reported as main causes of coastal erosion, human activities initially were not recognised by local communities as significant contributors to coastal erosion and mangrove degradation. Human activities such as poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels, and the interaction of anthropogenic activities and physical processes are significant contributors to erosion. The study resulted in the awareness of the impact of community activities on the coast being improved. Knowledge gaps and necessary policy changes are identified.
Suggested Reviewers:	John Quayle, Dr. Managing Director, Indonesian Rainforest Foundation john.quayle@indonesianrainforest.org This suggested reviewer has a profound knowledge of coastal resource management
	Rudhi Pribadi, Dr. Senior Lecturer, Universitas Diponegoro rudhi_pribadi@yahoo.co.uk This reviewer has a good knowledge of coastal resource management

10 September 2015

Dear Editors of Journal of Coastal Conservation

This manuscript is being submitted as an 'original research' paper and describes the underlying causes of coastal erosion in Kien Giang province. By 2009, the Kien Giang coast, Vietnam, had experienced significant coastal erosion and mangrove degradation. Recent mitigation strategies, developed through policies, plans and mangrove planting programs have not been successful, in part because the causes of coastal erosion were not adequately identified. While adverse effects of climate change and sea level rise have been widely recognised, the people in the communities, when asked, did not recognize the links between human activities and erosion and mangrove degradation. This paper used mixed methods to understand the causes of coastal erosion with an emphasis on human activities. In this investigation, we engaged communities to explore the causes of coastal erosion in Kien Giang province. Human activities have jeopardized the structural integrity of the mangroves and contributed to coastal erosion. The interaction of anthropogenic activities and physical processes are significant contributors to erosion. The study resulted in the awareness of the impact of community activities on the coast being improved. Knowledge gaps and necessary policy changes are identified.

This manuscript has not been published elsewhere and is not being considered for publication elsewhere either in print or electronically.

Kind regards,

NGUYEN Tan Phong

Corresponding Author

Human Activities and Coastal Erosion on the Kien Giang Coast, Vietnam

Authors:

Nguyen Tan Phong[1*], Kevin E. Parnell[1], Alison Cottrell[2]

1) College of Marine and Environmental Sciences
   Centre for Tropical Environmental & Sustainability Sciences
   James Cook University, Australia
   * Corresponding author
   Email: phong.nguyen@my.jcu.edu.au
   Phone: +61 747814531
2) College of Marine and Environmental Sciences
   Centre for Disaster Studies
   James Cook University, Australia

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Abstract

By 2009, the Kien Giang coast, Vietnam, had experienced significant coastal erosion and mangrove degradation. Recent mitigation strategies, developed through policies, plans and mangrove planting programs have not been successful, in part because the causes of coastal erosion were not adequately identified. This paper investigates the relationship between human activities and coastal erosion in Kien Giang province. This study used mixed methods to understand the causes of coastal erosion with an emphasis on human activities. In this investigation, local communities were involved as co-investigators to explore the causes of coastal erosion in Kien Giang province. While natural factors (adverse effects of climate change and sea level rise) have been widely reported as main causes of coastal erosion, human activities initially were not recognised by local communities as significant contributors to coastal erosion and mangrove degradation. Human activities such as poor aquaculture pond construction, poor construction of new and upgraded sections of the sea dyke system, mangrove afforestation using only a single species, mangrove cutting for commercial and domestic uses, and construction of local boating channels, and the interaction of anthropogenic activities and physical processes are significant contributors to erosion. The study resulted in the awareness of the impact of community activities on the coast being improved. Knowledge gaps and necessary policy changes are identified.

Key words: Muddy coastal erosion, local knowledge, scientific understanding, sustainable muddy coastal development, mangrove degradation, coastal protection

1. Introduction

Muddy coastal areas have been used to expand agriculture, aquaculture, industry and settlements (Han 2002; Primavera 2006), especially in Southeast Asia (Food and Agriculture Organization of the United Nations 2007; Ramesh et al., 2011). Expansion into coastal areas has adversely impacted the muddy coasts (Othman 1994; Masalu 2000; Paez-Osuna 2001; Valiela et al. 2001; Alongi 2002; Han 2002; Food and Agriculture Organization of the United Nations 2003; Food and Agriculture Organization of the United Nations 2007; Bhandari et al. 2004; Martin et al. 2005; Thampanya et al. 2006; Primavera 2006; Clark 1996; Ramesh et al. 2011; Sohel & Ullah 2012; Cong et al. 2014) and contributed greatly to coastal erosion (Han 2002).

Erosion of muddy coasts can be caused by changes in sedimentation patterns and other natural processes as well as by anthropogenic influences (Augustinus 1989; Yan et al. 1989; Wells et al. 1990; Lee et al. 1994; Amos 1995; Liefting 1998; Wang et al. 2002; Cong et al. 2012; Fan et al. 2004), and in places has caused significant economic loss, ecological damage and social unrest (Ramesh et al. 2011).

In 2009, 30% of the 208 km coastline of Kien Giang was reported as being severely eroded (Conservation and Development of the Kien Giang Biosphere Reserve Project (CDBRP) 2010 a; CDBRP 2010 b). In 2011, an Asian Development Bank funded project was undertaken using modeling (regional climate modeling, hydrological and coastal modeling) in Ca Mau and Kien Giang provinces to identify key areas of erosion vulnerability with respect to socio-economic conditions, agriculture, livelihoods, urban settlements, transport, energy and industry, under the influence of climate change up to 2050. Changes in sedimentation, climate change and sea level rise were concluded to pose negative impacts on the coasts of Kien Giang and Ca Mau (Asian Development Bank 2011). In 2011, a number of studies were undertaken using field investigations and observations, SPOT imagery and aerial photographs, and a rapid video survey, to understand mangrove biodiversity, to interpret historical shoreline changes, and to estimate biomass and carbon sequestration (CDBRP 2010 a; CDBRP 2010 b; CDBRP 2012 a; CDBRP 2012 b). Uncontrolled shoreline mangrove harvesting, the unexpected occurrence of plant eating insects, mangrove roots being buried by litter accumulation, and direct mangrove removal for channel, dyke and industrial construction were reported as likely causes of coastal erosion in Kien Giang. It was recommended that coastal erosion be primarily managed using mangrove protection and mangrove afforestation (CDBRP 2010 a; CDBRP 2010 b; CDBRP 2012 a; CDBRP 2012 b).

Kien Giang province is investing considerable resources into developing strategic solutions such as the upgrade of current earth sea dykes with concrete and the transplantation of mangrove species to protect the coast, adapt to and mitigate climate change effects and improve livelihoods in local communities (Department of Agriculture & Rural Development of Kien Giang province (DARD) 2012; Kien Giang Provincial People’s Committee (Kien Giang PPC) 2011 c; DARD 2009; DARD 2010; DARD 2011; Kien Giang PPC 2005; Kien Giang PPC 2009; Kien Giang PPC 2011 c). However, the solutions have not been effective in protecting mangrove areas (CDBRP 2010 a; CDBRP 2010 b). Many areas of Kien Luong, Hon Dat, An Bien and An Minh districts have been severely eroding at an alarming rate since the implementation of control measures (CDBRP 2010 a; CDBRP 2010 b; DARD 2012; Nguyen et al. 2010).

Sea level rose at a rate of approximately 3 mm per year between 1993 and 2008 in Vietnam (World Bank 2010). Sea level has been projected to increase by at least 65 cm in the next 100 years in the Mekong Delta region

(Ministry of Natural Resources and Environment of Vietnam 2010; Asian Development Bank 2013) and the effects on the province will be severe (Kien Giang PPC 2012).

To manage erosion, an understanding of the causes of the erosion is needed, particularly when many sections of the Kien Giang coast continue to erode despite management interventions. Limited local involvement and insufficient recording of local knowledge in studies undertaken between 2008 and 2012 led to a poor understanding of the problems. This paper investigates the relationship between human activities and coastal erosion in Kien Giang province. In this investigation, local communities were involved as co-investigators to explore the causes of coastal erosion in Kien Giang province.

2. Materials and methods

2.1. Site description

Kien Giang province has a coastline of 208 km (CDBRP 2010 a; CDBRP 2010 b) with four coastal districts, one town and one city. The coastline is rich in mangrove species, with 27 of the 39 species reported to be found in Vietnam (CDBRP 2010 a; CDBRP 2010 b). More than 70% of the length of the Kien Giang shoreline comprises mangrove areas (CDBRP 2010 a; CDBRP 2010 b).

The earth sea dyke system was first constructed in the 1970s along the entire coastline of Kien Giang province for irrigation and national defence purposes. Sluice gates were constructed across the natural rivers and channels to complete the sea dyke system. To date, 31 sluice gates have been built between Ha Tien and An Minh. A further 64 new sluice gates are proposed (Kien Giang PPC 2011 a; Kien Giang PPC 2011 b).

In the 1980s, households along the Kien Giang coastline were allocated mangrove areas for agriculture and aquaculture purposes. Ponds were constructed for shrimp, fish and crab farming on the seaward side of a sea dyke that extends along much of the coastline in Kien Luong, An Bien and An Minh. In Hon Dat, agricultural areas were developed for growing winter melon, sweet potato, pumpkin and rice on adjacent coastal land.

In 1992, areas that had been used for aquaculture and agriculture were converted into legally protected mangrove belts. Local fishers were encouraged to plant propagules of *Rhizophora apiculata* and seeds of *Avicennia marina* within their own ponds and were reimbursed for the costs of growing and protecting trees for up to three years.

From 1993, the Kien Giang coastline was managed by the Mangrove Sea and Border Management Board. Between 1999 and 2000, the Mangrove and Border Management Board was split into three entities: the Kien – Hai – Ha Management Board, the HonDat Management Board, and the An Bien – An Minh Management Board. In 2009, the Hon Dat – Kien - Ha Management Board was established combining two of the three, and is presently responsible for managing the mangroves from Ha Tien (the Vietnam – Cambodia border) to Hon Dat. The two current management boards are under the direct management of DARD (Figure 1).

The Kien Giang coast was significantly eroded by 2005 and the situation became serious by 2008 (CDBRP 2008). Approximately 60 km of the coastline has been experiencing mangrove loss due to erosion (CDBRP 2010 a; CDBRP 2010 b).

2.2. Methods

This study was undertaken between July 2012 and July 2014 using mixed methods (Creswell 2009). Methods for data collection included secondary data analysis (a desk review) (Schutt 2009), semi-structured interviews (Ayres 2008 a), field visits (participant observation), and photo voice (Kindon et al. 2008). Methods for data analysis are community meetings (Kindon et al. 2008; Kindon et al. 2009), thematic analysis (Ayres 2008 b), and participatory diagramming (Kindon et al. 2008), and peer debriefings (Schutt 2009). Mixed methods provided opportunities to bring the knowledge held by individuals (particularly fishers and farmers) and field observations into a broader framework, relating these data to published reports in order to more fully understand the erosion problems and causes.

Reports and documents related to land use planning, mangrove restoration, sea dyke construction and aquaculture and agriculture from government agencies (DARD, Department of Natural Resource & Environment of Kien Giang province (DonRE), the An Bien – An Minh Management Board, the Kien – Hai – Ha Management Board, the District People's Committees of An Bien, An Minh, Kien Luong and Hon Dat) were collected, reviewed, and analyzed. Semi-structured interviews were conducted with staff working for local government agencies to obtain relevant data and information. The literature review and semi-structured interviews with key stakeholders resulted in eight themes related to mangrove restoration and coastal erosion: climate change, sea level rise, flooding and inundation, changes in sedimentation, aquaculture techniques, agriculture techniques, mangrove cutting and sea dyke, and sluice gate construction.

A series of participatory community meetings, with administrative assistance from the Women's Union, the Farmers' Union, local government agencies and the two management boards, were held involving 325 fishers and farmers from both eroding coastal areas and areas with extensive inter-tidal mudflats where erosion was not of concern. The meetings used the previously identified eight key themes to discuss and to understand better coastal erosion processes. Only four themes (climate change, sea level rise, flooding and inundation, changes in sedimentation) were recognized in the communities as the main reasons for coastal erosion.

Field visits along the Kien Giang coastline were undertaken between July 2013 and May 2014, with administrative assistance from DARD and the two management boards. The field visits were undertaken using boats and small motorbikes. While emphasis was placed on erosion areas (Vam Ray, Hon Dat district, Tay Yen, An Bien district, Thuan Hoa, Dong Hung A, Van Khanh Dong, Van Khanh and Van Khanh Tay, An Minh district), almost the entire Kien Giang coastline was visited. During the field visits, photographs previously taken in the areas, Google based maps of the area, maps of forestry planning and inventory, maps of land use planning were used to provide an overview of coastal change, to promote involvement in discussions and the sharing of local knowledge and lessons on coastal erosion and mangrove degradation and deforestation.

Additional eleven peer debriefings (Schutt 2009) were then organized with communities at a later stage. In the meetings, the information and data collected previously in the study were diagrammed into sequences of relationship between aquaculture and agriculture practice and mangrove degradation and coastal erosion. The debriefings provided opportunities to avoid methodological and personal researcher's bias, to enrich the data, and to verify the relationship. The relationship was acknowledged by detailed minutes that were signed by community representatives.

3. Results

3.1. Local perceptions of causes of coastal erosion

Thematic analysis from the literature review and stakeholder reviews identified eight issues - climate change, sea level rise, flooding and inundation, changes in sedimentation, aquaculture and agriculture techniques, sea dyke and sluice gate construction, and mangrove cutting for timber use- as critical to the Kien Giang coastline, and these were then further explored in semi-structured interviews and participatory community meetings. Of the eight issues, climate change, sea level rise, flooding and inundation, and changes in sedimentation were believed to be the main causes of coastal erosion. Aquaculture and agriculture techniques, and sea dyke and sluice gate construction were not believed to contribute at all to coastal erosion. Mangrove cutting for timber use was not thought to pose any significant harm to the Kien Giang coastline (Figure 2). That is, members of the local community only recognized external factors with coastal erosion, none of their own actions.

3.2. Human uses of the Kien Giang coast

3.2.1. Aquaculture in Kien Luong, An Bien and An Minh districts

In the 1980s, aquaculture development was promoted in Kien Giang province. In Kien Luong district, mangrove areas (*Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Bruguiera gymnorhiza, Sonneratia alba, Nypa fruticans, etc.)* were unofficially allocated to local fishers for aquaculture without any contracts being issued by the local government. In some cases, mangroves were cleared illegally during pond construction. Ponds were constructed manually and mechanically by cutting mangroves, opening short deep channels along pond dykes and within ponds to extend farming areas. The mechanically constructed pond dykes were narrow with a maximum width of 3 meters and close to the open coast. Pond gates constructed across the thin mangrove edges (*Avicennia marina* and *Sonneratia alba)* towards the sea were opened to allow saline water into ponds during high tides, and were closed during low tides. Wild larvae of shrimp, and barramundi fish and crabs were collected through the pond gate operation for farming.

Aquaculture techniques in An Bien and An Minh districts are similar to those of Kien Luong district in many ways. Between 1980 and 1992, collectives voluntarily established by local fishers were allocated mangrove areas (*Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Bruguiera gymnorhiza, Sonneratia alba, Nypa fruticans, etc.)* in a decision issued by the An Bien district people's committee (now separated into two districts: An Bien and An Minh), depending on their capacity to clear mangrove areas to construct ponds for shrimp farming. The collectives were not issued with any contracts for the allocated areas. Ponds were mainly constructed on the seaward side of the sea dyke in An Bien, while ponds were built perpendicular to the sea dyke in An Minh area. Construction was undertaken by cutting mangroves, digging deep channels along pond dykes, opening more short deep channels within ponds and leaving high elevation areas for either planting propagules of *Rhizophora apiculata* or growing crops. Pond dykes were manually constructed with a minimum width of 2 metres. Ponds were protected by a thin line of mangroves on the seaward side. Propagules of *Rhizophora apiculata* were planted on pond dykes. Pond gates were manually constructed along natural rivers or man-made channels to allow for saline water intrusion into ponds. Pond gates were opened during high tides to collect natural larvae of shrimp, fishes and crabs from the sea. In areas where there were no natural rivers or man-made channels, gates were built through thin mangrove edges to allow the passage of saline water and wild larvae (Figure 3).

3.2.2. Agriculture on private lands in Hon Dat district

Mangroves were cleared by early migrants for agriculture in the 1970s in Vam Ray, Hon Dat district. In 1980, the Vietnamese Government's New Economic Program began with the resettlement of Vietnamese citizens from elsewhere to the coastal area behind the mangroves of Hon Dat district. Agriculture areas were constructed by cutting mangroves, opening deep channels within ponds to store fresh water for irrigation, and leaving high elevation areas for growing winter melon, sweet potato, pumpkin and rice (Figure 4).

3.2.3. Sea dyke construction and uses

Earth sea dykes have been constructed in coastal areas rich in mangrove species. The sea dykes were manually and mechanically constructed by clearing mangroves and excavating sediment on both sides of the sea dykes. During various upgrades, sediments were taken directly from the surface of the sea dyke, especially in the Hon Dat area. The sea dyke construction and upgrades resulted in channels being dug on either side of the sea dyke. These deep channels are still found along the earth sea dykes (Figure 5).

While a small number of sluice gates were constructed further inland, most were constructed at the channel mouths in the coastal mangrove edges. The construction at the channel mouths was undertaken by closing channels, clearing mangroves and using sediment from the seaward side.

The surface of the sea dykes has been used by local fishers to grow crops for additional income. Crops included sugar canes, bananas, mustard greens, winter melons, pumpkins, water melons, and okra. Sections of the earth sea dyke in areas of Vam Ray, T 5 and T 6 of Hon Dat district were excavated to place water pipes across the dykes to pump saline water to ponds landward of the sea dyke.

3.2.4. Local boating channels and mangrove cutting

In the 1970s, when mangroves still exhibited a diversity of many mangrove species, many natural small creeks were dredged and more deep channels were opened through the mangroves for boating and transportation of goods between the land and the sea. These small but deep channels and creeks are still to be found in many areas along the coastline.

Mangroves along the shoreline were cut for charcoal and firewood, or for constructing fish nets. As a consequence, mangroves became degraded or lost, and remnants were fragmented with *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Bruguiera gymnorrhiza* dominating.

In 1985, Vam Ray's agriculture land was extensively flooded. To save local agricultural production, the dyke was purposefully breached. A long channel was also opened across the mangrove belt in front of the sea dyke by the locals to discharge flood water into the sea, despite the opposition of the local authorities.

Storm Linda in 1997 caused significant mangrove destruction. Disastrous flash flood events in 2000, 2001 and 2002 caused local communities to cut through the earth sea dyke system and mangroves, to discharge flood water from Kien Luong, Hon Dat, An Bien and An Minh districts.

3.3. Afforestation using a single mangrove species

In 1992, most of the Kien Giang coastline was legally protected with the establishment of coastal mangrove protection areas, including areas used for aquaculture. Local communities were encouraged to plant the propagules of *Rhizophora apiculata* and seeds of *Avicennia marina* along the shoreline, even within their ponds. The communities were provided with propagules and seeds, and were paid for costs of planting (at a density of one tree per square metre) and protecting trees for up to three years. As there were no specific guidelines on transplantation, mature trees of *Avicennia marina* were cut and replaced with propagules of *Rhizophora apiculata.* The communities grew the propagules of *Rhizophora apiculata* on the high elevation areas within ponds, on pond dykes, and even in pond channels because *Rhizophora apiculata* was easy to transplant. As a consequence, the whole Kien Giang coastline is now dominated by *Rhizophora apiculata*.

3.4. Land uses and land use planning

Some local farmers living within the boundaries of the Hon Dat – Kien – Ha Coastal Mangrove Area Management were issued with land use right certificates (red books). In 2015, 8 households from Ta Sang village, Duong Hoa commune, Kien Luong district covering 11ha of the coastal area, and 22 households from Tho Son and Luynh Huynh communes, Hon Dat district covering 71ha were issued with red books. Farmers issued with land use right certificates are legally permitted to cultivate and / or farm aquaculture and agriculture on their land, normally resulting in mangrove clearance, aquaculture pond construction and construction of bunds for growing agricultural crops along the coast.

Residential areas, industrial zones, tourism facilities, and administrative areas were constructed with permission from the Kien Giang provincial people's committee. This construction disconnected coastal mangrove belts and created substantial gaps in the mangrove belts between Kien Luong district and Ha Tien town.

The open sea water areas located beyond the boundary of coastal mangrove belts are administratively managed by the district people's committees of Kien Luong, Hon Dat, An Bien, An Minh and the city people's committee of Ha Tien. The open sea area in An Bien and An Minh has been leased for farming bivalves and molluscs for many years. Kien Luong district established a 500 ha pilot program for the same purpose. An application was lodged to the Hon Dat people's committee to lease the sea area for blood shell culture. Young blood shell is either purchased elsewhere or collected from intertidal mudflats in front of mangrove belts. However, in some areas, the open sea administered area overlaps intertidal mudflats located beyond the primary coastal mangrove belt leading to conflicts of interest between the coastal mangrove contractors and open sea water lessees. Despite boundaries demarcated clearly in places, lessees expanded their farming areas illegally into mangrove belts, by clearing naturally regenerated mangroves. Further, lessees used push nets to catch wild young blood shell on intertidal mudflats, where young trees of *Avicennia marina* regenerated naturally, resulting in the trees being killed.

3.5. Coastal erosion processes

Between 2000 and 2008 strong waves during high tides propagated along the boating channels through fragmented mangroves and agriculture areas and caused erosion in the deep channels, leading to further loss of mangroves and the sea dykes being seriously breached in Vam Ray area, Hon Dat district. Agricultural products behind the sea dyke were badly damaged by saline intrusion and damage to the earth sea dyke. As a consequence, the whole area was isolated, resulting in the local people, especially school children, having to cross the sea dyke on foot in May 2009 (Figure 6).

Strong waves together with high tides breached the thin pond gates and destroyed the thin and weak pond dykes, with waves propagating into the channels, causing serious coastal erosion in some areas along the coastlines of Tay Yen (An Bien district), Thuan Hoa, Dong Hung A, Van Khanh Dong, Van Khanh and Van Khanh Tay (An Minh district) between 2000 and 2008. Abandoned ponds and remnants of pond dykes can still be seen along the shoreline on low tides (Figure 7).

Burrows of brackish water fiddlers (*Uca minax*) occur at high density among the roots of *Rhizophora apiculata* in Vam Ray (Hon Dat district), Thuan Hoa, Tan Thanh (An Bien district) Dong Hung A, Van Khanh Dong, Van Khanh, Van Khanh Tay (An Minh district). Many mature trees of *Rhizophora apiculata* experienced sediment deficit around their roots. Strong waves on high tides were observed to have penetrated into burrows, weakening the coastal soil structure and making it susceptible to collapse. Many mature trees of *Rhizophora apiculata,* which experienced sediment deficit around their roots, were observed to have been uprooted under the influence of strong waves on high tides or to die (Figure 8).

4. Discussion

4.1. Sea dyke construction and upgrades, and coastal erosion

There is a clear evidence of poor sea dyke construction processes. Article 7 of the 2006 Law on Dykes clearly stipulates that the use of soil, rocks, sands and minerals and the construction of fish ponds are prohibited within the sea dyke protection corridor. Under Article 23 a and b, the sea dyke protection corridor is defined as at least 5 meters from the sea dyke toe on the landward side in urban areas and tourism destinations, and 25 meters in other areas, and 200 metres from the sea dyke toe on the seaward side of the dyke. The dyke upgrade in the 1980s using sediment excavated mechanically on both sides of the dyke and from the dyke surface, therefore violated Article 7, Article 23 a and b of the 2006 Law on Dykes (Vietnamese National Assembly 2004) and the Design Guideline on the Sea Dyke System and Sea Dyke Protection Works (Ministry of Agriculture & Rural Development of Vietnam 2002). The sea dyke construction has jeopardized the structural integrity of the mangroves. As a consequence, the mangroves have become more vulnerable to erosion, especially during the rainy season. The findings are in accordance with those by Paez-Osuna (2001), Valiela et al. (2001), Han (2002), Bhandari et al. (2004), Thampanya et al. (2006), Martine et al. (2005), and Ramesh et al. (2011).

Between 2009 and 2020 the sea dykes in Kien Giang are to be raised and reinforced with cement and new sluice gates are to be constructed in response to climate change and sea level rise. If techniques for constructing sea dykes (using sediment from either side) and sluice gates (clearing mangroves and excavating sediment from the same location) remain unchanged, the erosion will continue and potentially worsen.

4.2. Sluice gate operation and density, and impacts on the shoreline

In Kien Luong and Hon Dat districts, silts and clay are deposited behind the sluice gates in the dry season, when they are closed. When sluice gates are opened in the wet season, flood water transports fine sediments into the nearshore, and they are then carried onshore by currents developed by the dominant north-east winds, and potentially deposited in the mangroves. Where mangroves have been removed, natural processes of sediment accumulation are disrupted and in the following dry season, south-west winds transport the silts out of the areas devoid of mangroves.

The density of sluice gates is another controversial issue. At present, 31 sluice gates have been constructed between Ha Tien and An Minh. No comprehensive studies have been undertaken to understand if there is a link between the operation and density of sluice gates and the impacts on the coastline. A further 64 new sluice gates are proposed (Kien Giang PPC 2011 a; Kien Giang PPC 2011 b) and the impact on the coast is not known.

4.3. Aquaculture and coastal erosion

Othman (1994), Clark (1996), Masalu (2000), Primavera (2006) and Sohel & Ullah (2012) and CDBRP (2010 a; 2010 b) identified aquaculture as a likely cause of mangrove loss. It is clear from this study that pond construction techniques (mangrove areas cleared to construct aquaculture ponds, construction of narrow pond dykes and the opening of boating channels) contributed significantly to severe mangrove deforestation and coastal erosion. The Ben Tre coastline, on the eastern side of Mekong Delta of Vietnam was eroded by similar activities (Nguyen 2015 a; Nguyen 2015 b).

While mangrove areas continued to be allocated for both protection and mangrove based aquaculture under a provincial level decision, the same pond construction techniques continue to be used. If the techniques are not redesigned or improved, coastal erosion, as has occurred in Kien Luong, Hon Dat, An Bien and Minh districts, will occur elsewhere, especially under the influence of climate change, and sea level rise.

4.4. Afforestation using a single species and coastal erosion

As a result of the application of planting programs, since 1982, the Kien Giang coast has become dominated by *Rhizophora apiculata,* changing the previously mixed mangrove community, and weakening the resilience of the community and the coastal protection that mangroves provided. The dominance by *Rhizophora apiculata* contributed significantly to coastal erosion processes and mangrove degradation in Ben Tre province of Vietnam (Nguyen 2015 a; Nguyen 2015 b). In addition, Nguyen (2015 a) showed that Avicennia species developed their root systems in the mud, which led to resilience to strong wave events, while Rhizophora species spread their roots on the surface and were easily damaged.

4.5. Land uses and land use planning

The coastal mangrove areas were established as a strategic measure to control coastal erosion, reduce negative impacts of natural hazards and promote sustainable coastal development. However, local farmers and local government agencies promoted coastal development (saline water aquaculture development, agriculture development residential areas and coastal industrial zone development) for socio-economic purposes in overlapping areas (Kien Giang PPC 2012). Land use rights conflicts, management overlaps and uncoordinated land use planning resulted in coastal mangroves being degraded or deforested. Providing a balance between coastal natural resource management and the demand for socio-economic development is a major challenge. If a balance is not achieved in the future, the coastal mangroves will be further degraded and deforested.

4.6. Reporting of, and community understanding of, causes of coastal erosion and mangrove deforestation

Apart from causes of coastal erosion reported by CDBRP (2010 a; 2010 b; 2012 a; 2012 b), other causes of coastal erosion discussed in Section 3, evident from field visits, analysis of historical sequences of maps and aerial photos, and exploring with communities possible causal links between erosion and the construction of coastal infrastructure and management interventions on the coast were not reported in previous studies and government documents.

At the start of this study, communities recognized and highlighted the adverse effects of sea level rise and climate change as causes of coastal erosion. As demonstrated in Figure 2, the communities of Kien Giang province did not link their activities, and activities sanctioned by, or caused by, present or past government policies, with coastal erosion and mangrove degradation. Sea dyke and sluice gate construction, aquaculture pond construction and operation, agricultural production techniques, afforestation using a single species of mangrove (*Rhizophora apiculata),* mangrove cutting for commercial and domestic uses, and construction of local boating channels are, however, all significant contributors to the problems. By the end of the study, and through participation in the debriefing sessions, people in the communities and staff of governmental agencies were very aware of, and accepted that their practices, current and past management of the coast were significant contributors to coastal erosion.

5. Conclusions and recommendations

While adverse effects of climate change and sea level rise have been widely recognised, human activities have also jeopardized the structural integrity of the mangroves and contributed to coastal erosion. The interaction of anthropogenic activities and physical processes are significant contributors to erosion. Importantly, when asked, the people in the communities did not appear to recognize the links between human activities and erosion and mangrove degradation. The integration of local knowledge, field observations and scientific understanding through mixed methods is an important process that assists in both understanding the underlying causes of coastal erosion, and improving local awareness of the issues.

To develop provincial level policies and work plans and strategies and to revise the current strategic plans for mangrove protection in Kien Giang and in the Mekong Delta, a more comprehensive list of, and understanding of, the causes of coastal erosion needs to be promoted. Specifically, a) proper application of the 2006 Law on Dykes should be promoted to sea dyke construction agencies and local coastal communities to avoid the use of sediments from the sea dyke protection corridors, b) studies should be undertaken to understand negative impacts of sluice gates on sedimentation and current flows before more sluice gates are constructed, c) the lessons learned from previous inappropriate pond construction and single species planting need to be incorporated into future coastal management programs to avoid the same mistakes elsewhere in the Mekong Delta region and in other South and Southeast Asian countries, and d) long term monitoring and a broader analysis are needed to further understand the previously unreported probable causes of erosion discussed above.

Figure 1: The mainland area of Kien Giang province, Vietnam. Black dots indicate locations of areas with the most severe erosion.

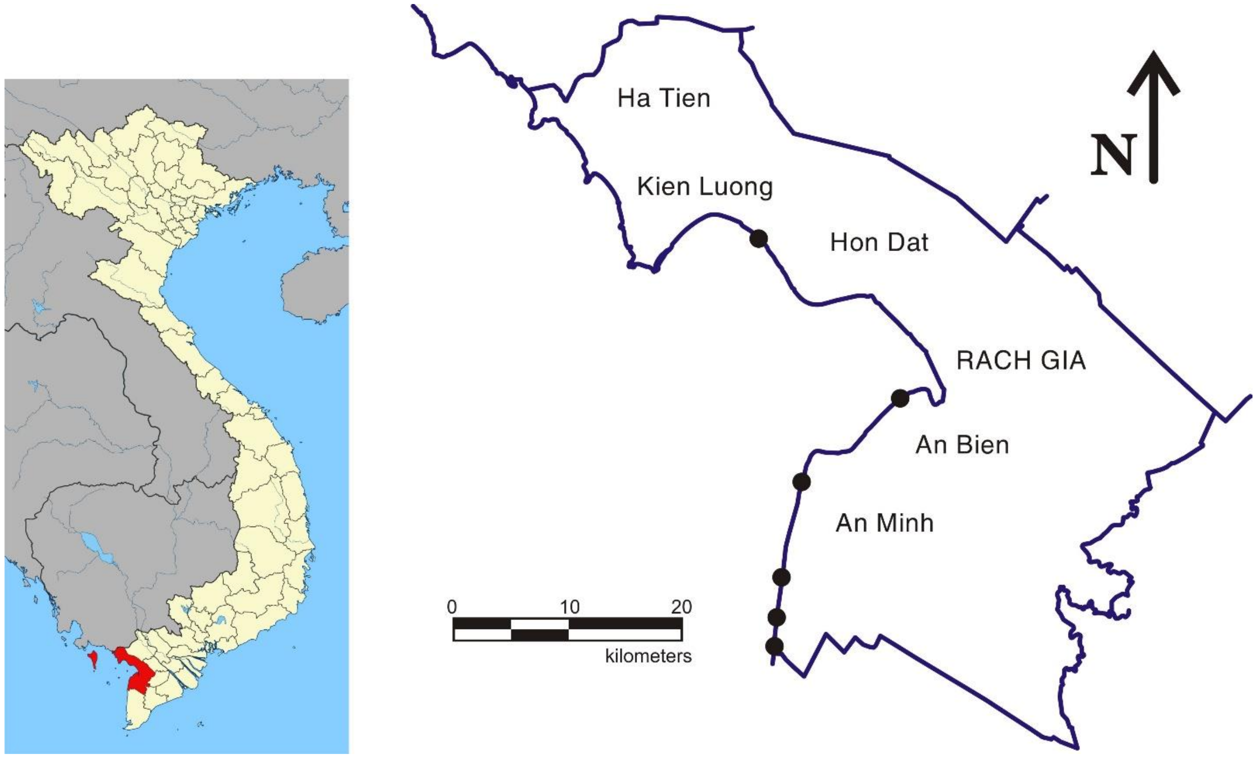
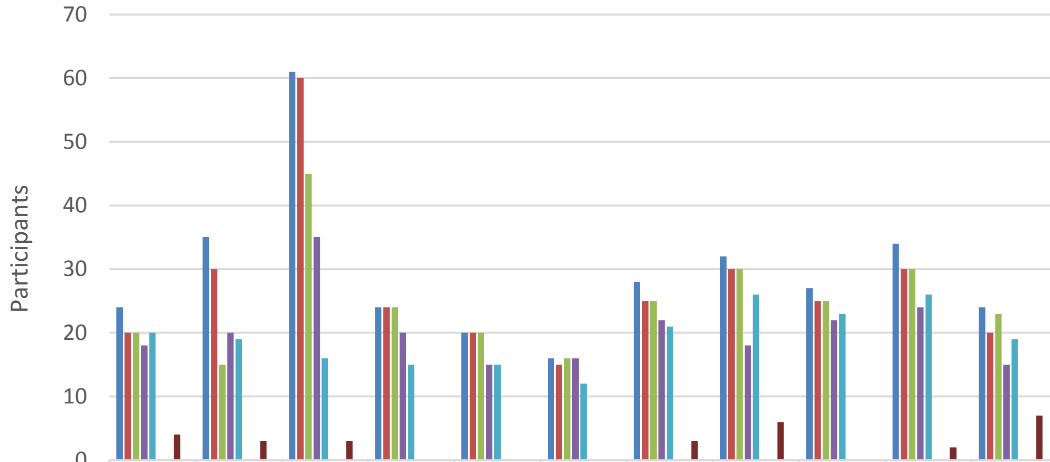


Figure 2: Local perceptions of the causes of coastal erosion in Kien Giang province, Vietnam.



	Binh Tri commune	T 6 commune	T 5 commune	Vam Ray commune	Nam Yen commune	Nam Thai commune	Tay Yen commune	Van Khanh commune	Thuan Hoa commune	Dong Hung A commune	Van Khanh Tay commune
Total participants	24	35	61	24	20	16	28	32	27	34	24
Climate change	20	30	60	24	20	15	25	30	25	30	20
Sea level rise	20	15	45	24	20	16	25	30	25	30	23
Flooding / inundation	18	20	35	20	15	16	22	18	22	24	15
Changes in sedimentation	20	19	16	15	15	12	21	26	23	26	19
Aquaculture techniques	0	0	0	0	0	0	0	0	0	0	0
Agriculture techniques	0	0	0	0	0	0	0	0	0	0	0
Mangrove cutting for timber use	4	3	3	0	0	0	3	6	0	2	7
Sea dyke / sluice gate construction	0	0	0	0	0	0	0	0	0	0	0

Figure 3: Two pond construction techniques have been repeatedly used over time in Kien Giang province, (1) pond construction and operation in Kien Luong district, a) pond area, b) pond dyke, and c) a pond gate was opened across the mangrove edges towards the sea to allow saline water into ponds during high tides, and were closed during low tides. 10^{0}15’48.27” N and 104^{0}34’37.06” **E. Google Earth.** 25 December 2014. [viewed 3 April 2014].
(2) pond construction and operation in An Bien district, a) natural river, b) a gate was constructed adjacent to the river to supply water to ponds, c) coastal mangrove areas cleared to construct ponds for aquaculture and d) mangrove edges. 9^{0}49’30.68” N and 104^{0}53’36.80” **E. Google Earth.** 21 February 2014. [viewed 3 April 2014].

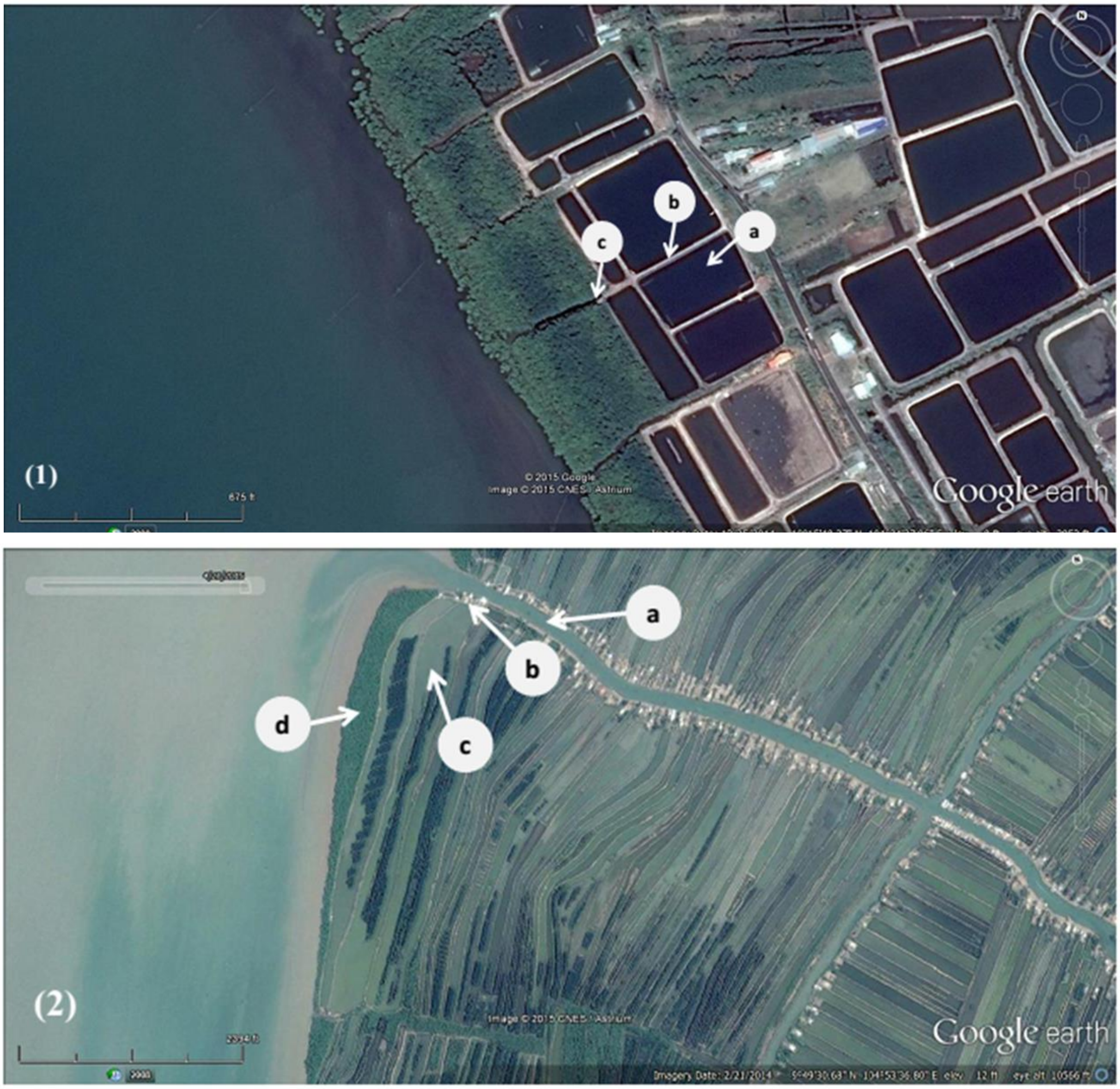


Figure 4: Typical agriculture production on private lands in Hon Dat district, a) the earth sea dyke, b) the deep channel on the sea ward side, c) crops planted on high elevation areas within ponds, and d) deep channels within ponds to store fresh water for irrigation. 10^{0}12’26.64” N and 104^{0}47’22.92” **E. Google Earth.** 31 December 2014. [viewed 3 April 2012].

Figure 5: A typical mangrove belt in Kien Giang province, a) intertidal mudflats, b) the primary mangrove belt, c) the secondary mangrove belt, d) seaward aquaculture ponds, e) a local boating channel, f) the channel on the sea ward side, g) the earth sea dyke and h) the channel on the landward side. The mangrove belts, intertidal mudflats and eroding coastal areas are managed by the management boards, while open sea water surface are under direct administration of the district people's committees of Kien Luong, Hon Dat, An Bien, An Minh and the city people's committee of Ha Tien. $10^0 10'22.95''$ N and $104^0 49'34.82''$ **E. Google Earth.** 21 February 2014. [viewed 3 April 2012].

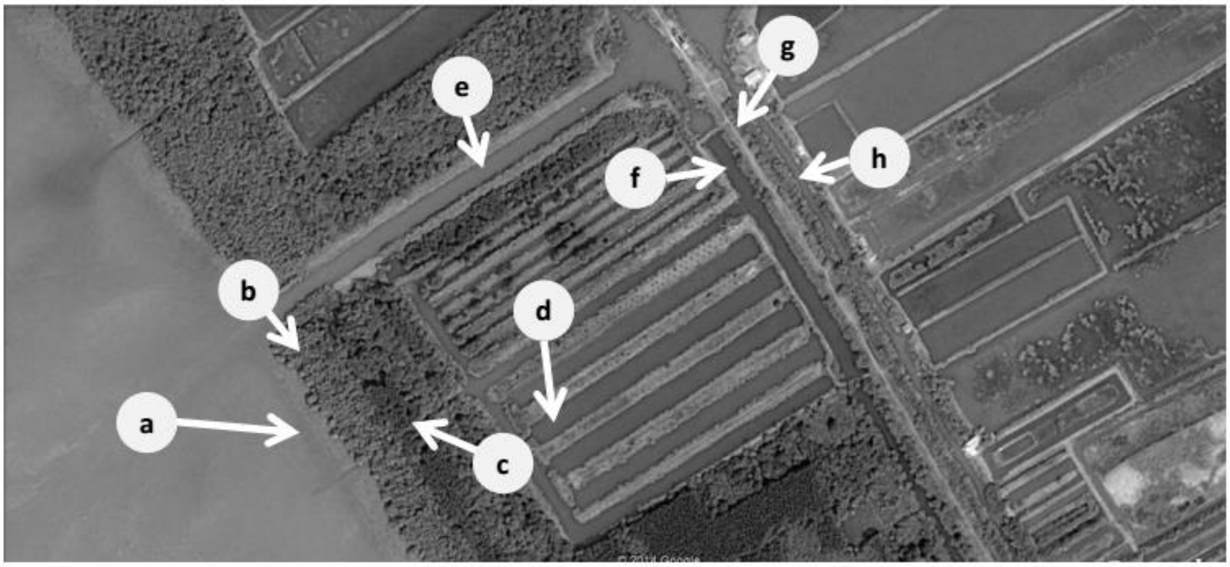


Figure 6: The Vam Ray severely eroding area in 2006, a) the breached earth sea dyke, b) the deep channel, c) the local boating channels, d) the mangrove edge in the 1980s. The presence of the deep channel on the seaward side, the boating channels and fragmented mangroves contributed significantly to the severe erosion. Source: “the Vam Ray coast.” 10^{0}11’51.28” N and 104^{0}48’09.17” E. **Google Earth**. 12 January 2006 [viewed 3 April 2012].

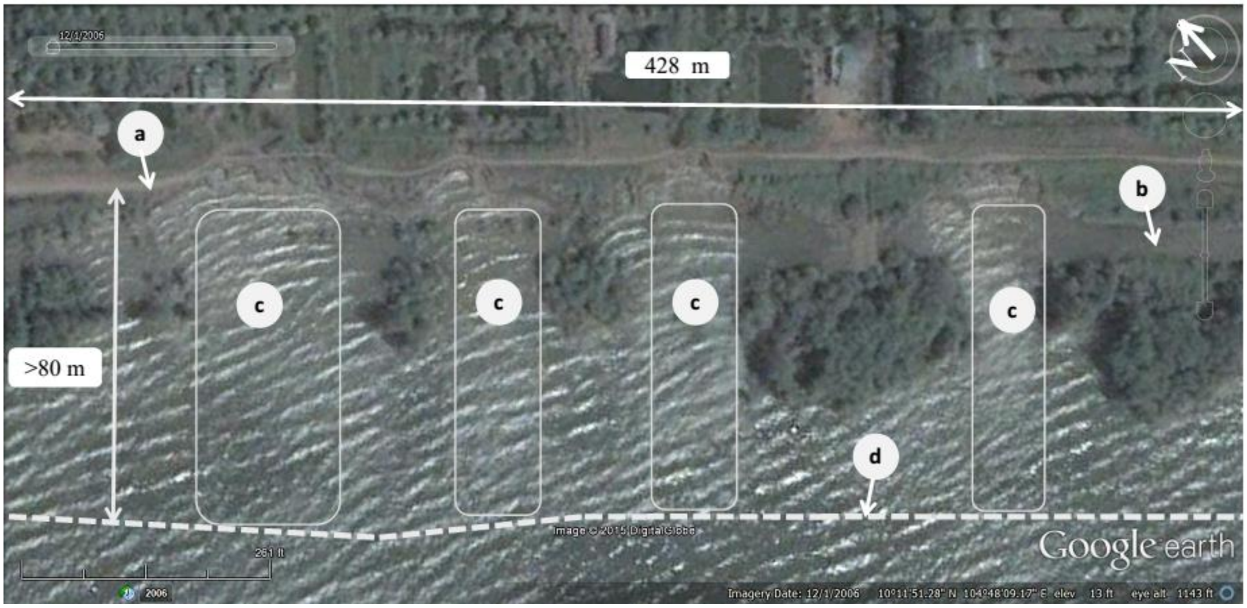


Figure 7: A coastal section of Thuan Hoa commune, An Bien district was actively eroded over time. On the top image in 2008, a) thin mangrove edge, b) pond area. On the bottom image, the white coloured line represents the thin mangrove edge in 2008. Thin mangrove edges were lost and narrow and thin pond dykes were broken, resulting in ponds being abandoned. Source: "the coast of Thuan Hoa." $9^0$47'09.63" N and $104^0$52'54.54" E. **Google Earth.** 21 February 2014. [viewed 31 January 2015].

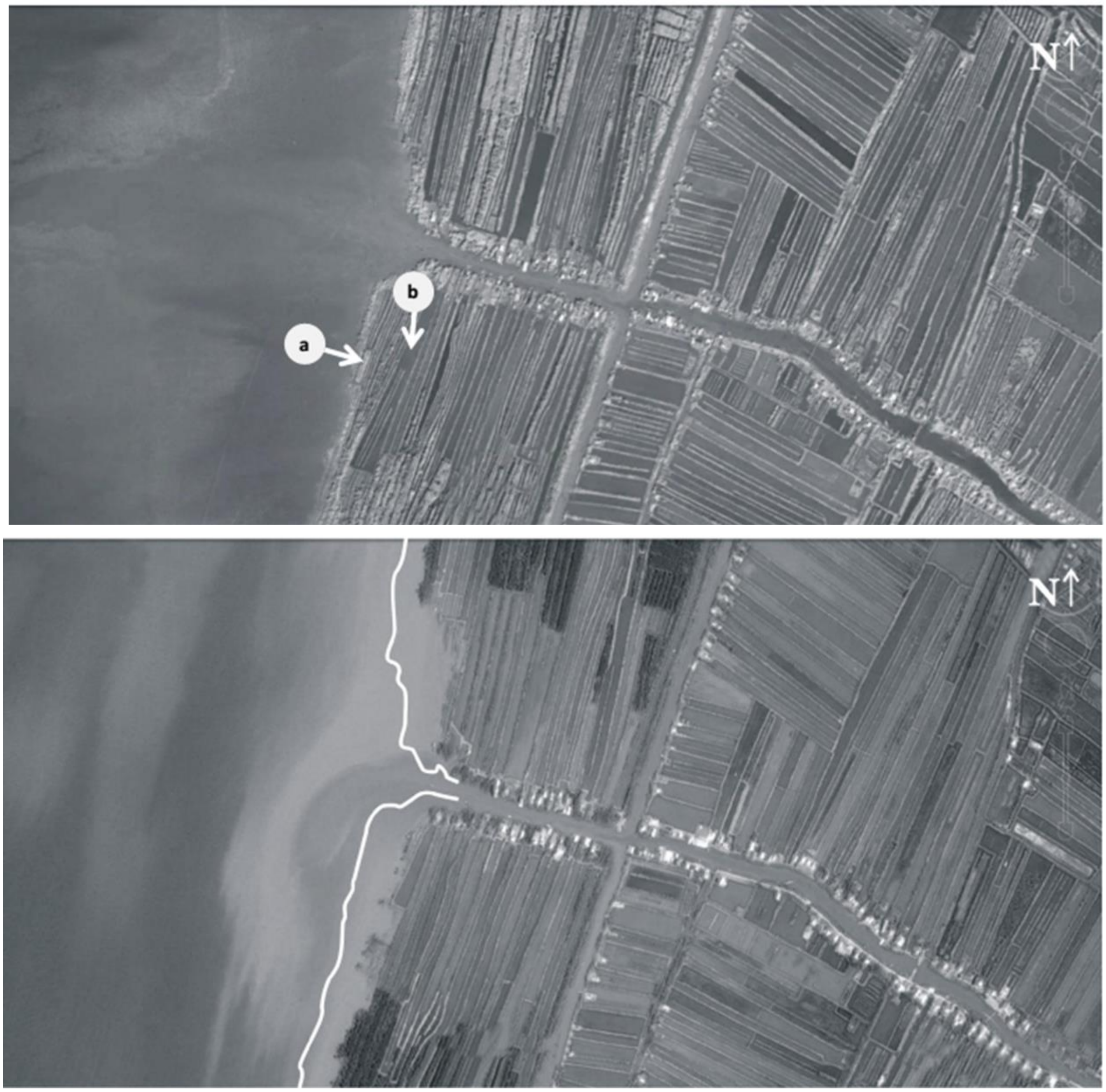
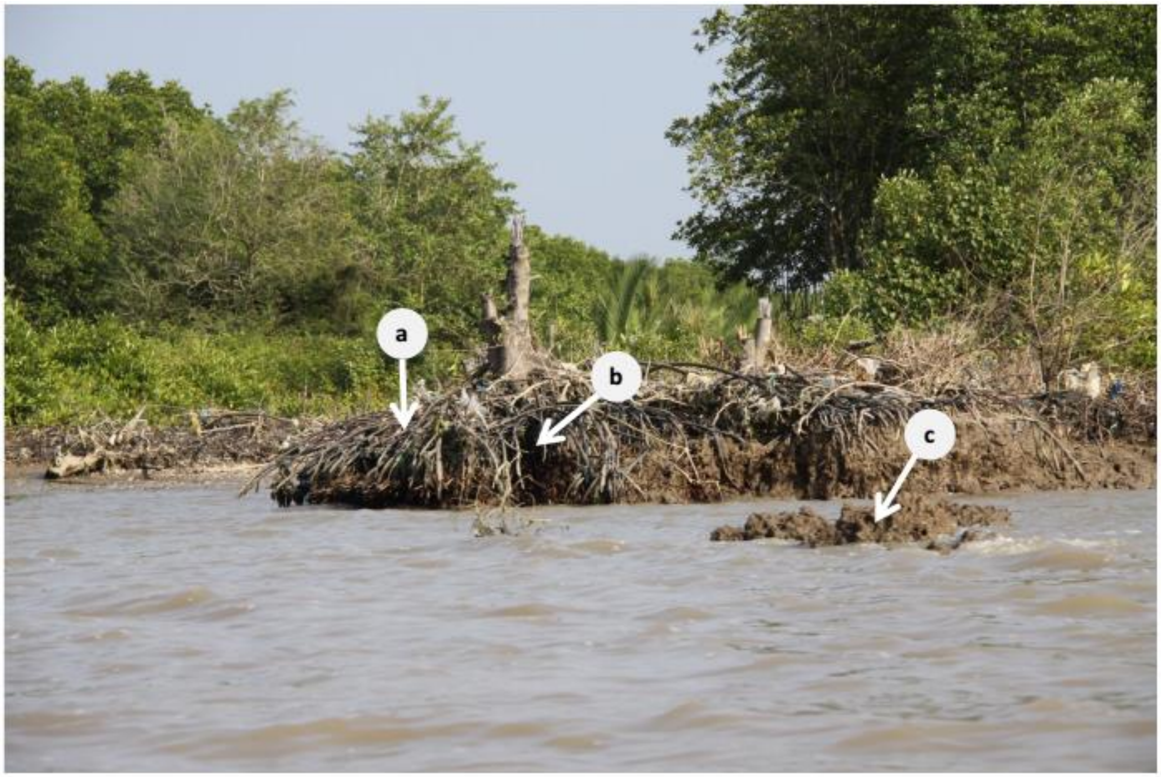


Figure 8: A location in Van Khanh Dong commune, An Minh district was badly eroded, a) a mature tree of *Rhizophora apiculata* experienced sediment deficit around the roots, causing the tree to die, b) a burrow enlarged over time, and c) a massive vertical collapse as a consequence of strong waves propagating into dense burrows with force.



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Corresponding Author: Mr. Phong Tan Nguyen, M.App.Sci (JCU)

Corresponding Author's Institution: College of Marine and Environmental Sciences

First Author: Phong Tan Nguyen, M.App.Sci (JCU)

Order of Authors: Phong Tan Nguyen, M.App.Sci (JCU); Kevin E Parnell, PhD

*Cover Letter

19 November 2015

Dear Editors

This manuscript is being submitted as a 'short communication' paper and describes gradual expansion of mangrove areas, used for stabilizing the Vam Ray eroding coast, Kien Giang province, Vietnam. Gradual expansion was a key factor in strengthening the capacity and resilience of established scattered mangrove patches, expanding the mangrove area, and at the same time, improving local livelihoods. Gradual expansion has a potential for replication elsewhere as an adaption to muddy coastal erosion.

This manuscript has not been published elsewhere and is not being considered for publication elsewhere either in print or electronically.

Kind regards,

NGUYEN Tan Phong

Corresponding Author

Gradual Expansion of Mangrove Areas to Stabilize an Eroding Muddy Coast

Nguyen Tan Phong[a], Kevin E. Parnell[a]

Nguyen Tan Phong - Corresponding author:

College of Marine and Environmental Sciences

Centre for Tropical Environmental & Sustainability Sciences

James Cook University, Australia

Email: phong.nguyen@my.jcu.edu.au

Phone: +61 747814531

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Abstract

Muddy coasts have been eroded by human induced and natural processes. Muddy coastal erosion has caused significant loss of coastal habitats, economic problems, and social unrest. Current solutions including engineering solutions, ecological engineering solutions, managed realignment, and no active intervention have had limited success in controlling erosion. Gradual expansion of mangrove areas was a key factor for successfully stabilizing the Vam Ray, Kien Giang province, Vietnam eroding coast, and crucial in strengthening the capacity and resilience of established scattered mangrove patches, expanding the mangrove area, and at the same time, improving local livelihoods. Gradual expansion has a potential for replication elsewhere in adaption to muddy coastal erosion.

Key words: Gradual expansion, Melaleuca fences, muddy coastal erosion, mangroves, livelihood improvement, and stabilization of muddy coasts.

I. Managing eroding muddy coasts

Erosion of muddy coasts can be caused by natural factors (Bao & Healy 2002, Jelgersma et al. 2002) or result from human activities (Han 2002). Coastal erosion has caused a significant loss of important coastal habitats (Han 2002), economic loss, and social unrest (Ramesh et al. 2011) particularly in developing countries. Common methods used to respond to coastal erosion include engineering solutions, ecological engineering solutions, managed realignment, and no active intervention. Engineering solutions use shoreline structures and offshore or detached structures to mitigate or stop coastal erosion (Weigel 2002, Dugan et al. 2011). Ecological engineering solutions attempt to combine engineering principles with ecological processes to reduce negative environmental impacts (Bergen et al. 2001). Ecological engineering solutions include beach replenishment, sand dune stabilization, beach drainage, mangrove transplantation or a combination of mangrove transplantation and engineering solutions (Bergen et al. 2001, Winterwerp et al. 2005). Managed realignment, also called managed retreat or set back, involves the movement of the defence line landwards or to higher land, creating new intertidal mudflats and salt marshes (Pethick 2002, French 2006). No active intervention, also known as the 'do nothing strategy', involves no capital investment in coastal protection (Department for Environment, Food and Rural Affairs (DEFRA) 2006). This strategy allows nature to take its course, normally resulting in further erosion when the process drivers of erosion are not addressed.

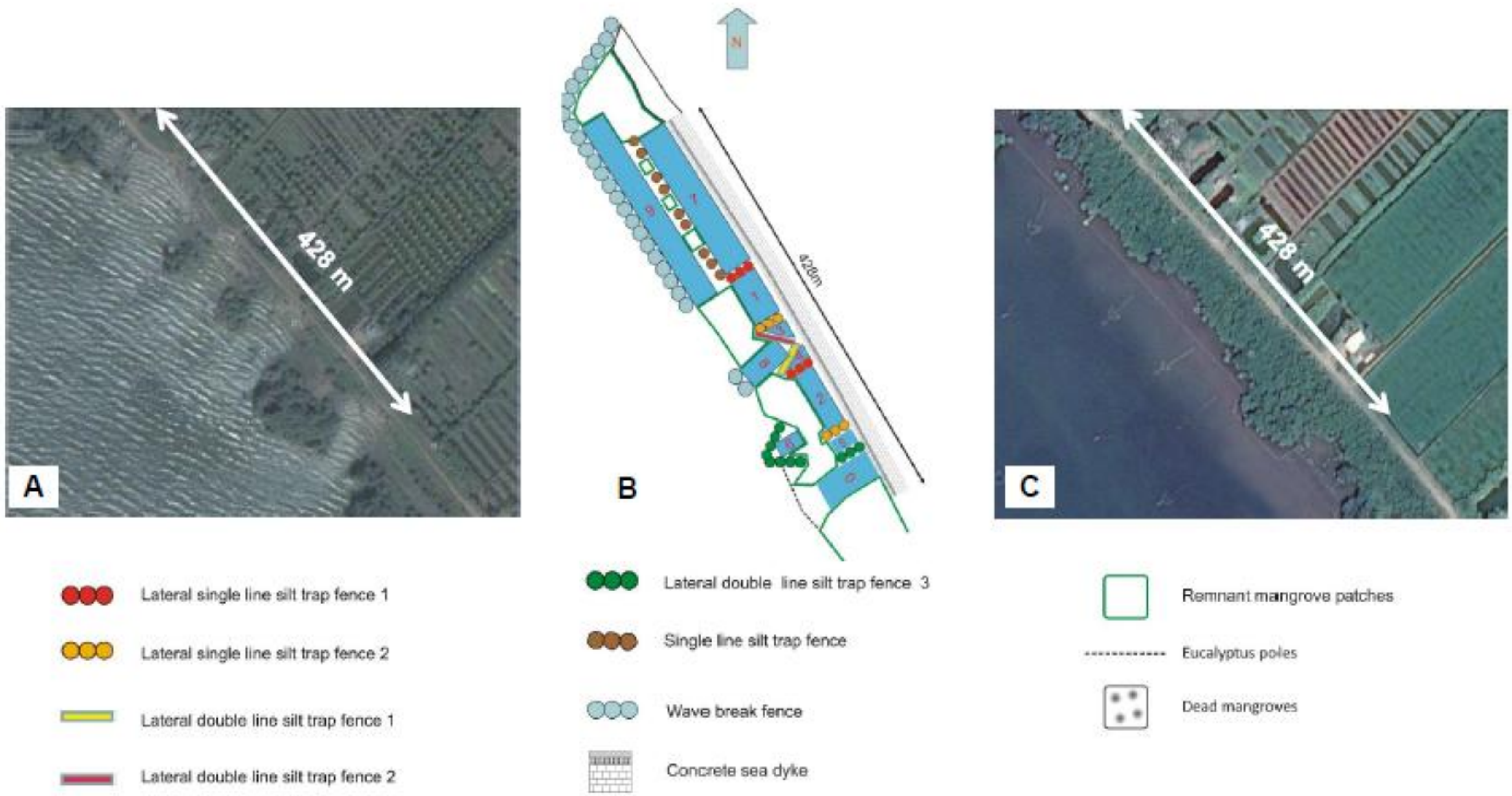
Each solution to muddy coastal erosion has a number of challenges. Engineering solutions modify the processes of deposition and erosion of sediments (Miles et al. 2001), alter tidal currents, can result in significant habitat loss, erosion, and shoreline change (Dugan et al. 2011), and can cause lagoon stagnation due to overfill of fine or muddy sediment and organic matter (Martin et al. 2005). Ecological engineering solutions can lead to conflicting demands, and require sufficient understanding of the assemblages in the coastal habitats and frequently, significant ecological research (Holling 1996, Chapman 2011). The knowledge of the long term impacts of coastal retreat and the likely ecosystem impacts are required for a managed realignment strategy to be accepted (Morris 2012, Morris 2013). Consequent erosion and flooding in areas where there has been no active intervention has caused coastal communities to lose residential and farmed areas (French 2006, Morris 2012). In highly populated coastal areas in Southeast Asia, managed realignment and no active intervention strategies are unlikely to be accepted or promoted by government agencies (Linham & Nicholls 2010).

In developing countries of South East Asia, an ecological engineering approach widely used is mangrove restoration by transplanting seedlings and propagules (Samarakoon 2012). Frequently undertaken as one-off projects funded by international aid agencies, the projects often fail or do not fully achieve their aims, often because they are undertaken over short periods of time with no follow up maintenance, or because knowledge gained from previous projects, both successful and unsuccessful, has not been transferred (Nguyen et al. 2016). With reference to a successful mangrove restoration project in Kien Giang province, Vietnam, we provide an example of a project that used a gradual expansion approach, as opposed to a one-off planting method, designed to restore mangroves to provide protection from erosion, resilience to sea level rise and improve local livelihoods.

II. Gradual expansion of mangrove areas

A project undertaken between 2009 and 2011, using gradual expansion of mangrove areas, was successful in stabilizing the Vam Ray, Kien Giang Province, Vietnam, muddy coast (Kien Giang Provincial People's Committee (Kien Giang PPC) (Kien Giang PPC 2009). The project was funded by the Australian Aid Program, AusAID and implemented by the German Agency for Technical Cooperation (GIZ). The donor and government agencies worked in partnership with the Vam Ray community in developing the project. The gradual expansion method involved the use of seven different fences constructed of Melaleuca poles, fishing nets, bamboo mats, and the transplantation of seedlings of five mangrove species (Nguyen et al. 2016), with the treated area gradually expanded. Gradual expansion required a two stage process. The first stage involved closing gaps between the established scattered mangrove patches by transplanting mangroves protected by fences, complementing the protection afforded by the scattered mangrove patches. In the second stage, treatments were established using fences for expanding the area, providing additional protection to the previous treatments (Figure 1). Seedlings of five local mangrove species (*Avicennia marina, Bruguiera cylindrica, Nypa fruticans, Rhizophera apiculata, Sonneratia alba*) were potted and transplanted in four phases between September and October 2009. Biodiversity returns with a high survival rate of transplanted and naturally regenerated mangroves and an apparent increase in the number and density of animal species in all stabilized treatment areas (crustacean, bivalves, gastropods, and fish species) were found by 2011, evidenced by Conservation and Development of the Kien Giang Biosphere Reserve Project (CDBRP) (CDBRP 2012 a, CDBRP 2012 b, Nguyen et al. 2016).

Figure 1: Vam Ray coast changed over time; a) Vam Ray status in 2008; b) Gradual expansion employed between May and December 2009. Treatments 1, 2, 3, 4 and 5 filled the gaps between the established scattered mangrove patches as the first stage. The second stage (Treatments 6, 7, 8 and 9) expanded the stabilized area. Treatment 0 was a control site; c) Vam Ray coast in December 2014, with a firm sea mud surface and established mangroves. Source: $10^{0}11'53''$ N and $104^{0}48'11''$ E. E. Google Earth.



There are many examples of failed mangrove restoration projects where a single species was transplanted over a short time frame in straight lines in deeper water or extending from the shoreline for a substantial distance seawards and left without further intervention, a common practice for government funded programs or aid funded projects (Mackay & Manuri 2013) (Figure 2).

Figure 2: Transplantation of a single species of mangrove in ’traditional’ straight lines has often failed. Two examples are shown a) *Avicennia marina* were not well protected from strong waves or plastic bags floating offshore in Vam Ray, Kien Giang, Vietnam in 2005 (left photo). B) Propagules of *Rhizophora mucronata* were transplanted in exposed areas in Sawojajar, Brebes Regency, Indonesia in 2013 (right photo).

Mangroves transplanted in straight lines, are vulnerable to being uprooted by strong waves on high tides as they are not generally protected by fences or other mangroves. When some mangroves die, it is uncommon and difficult to replace dead mangroves among those that remain.

There are also examples of marginally successful ecological engineering attempts at mangrove restoration. T-shaped double line bamboo fences were constructed offshore in 2012 in Vinh Tan commune of Soc Trang province, and Vinh Trach Dong commune of Bac Lieu province, the lower Mekong Delta of Vietnam. The fences resulted in a low level of sea mud accumulation two years following construction (Albers et al. 2013, Schmitt & Albers 2014). The reason given for the low level of sea mud accumulation was that the fence designs were not particularly suitable for trapping sediments transported onshore. Double cylinder concrete poles constructed offshore of the coast of Cong Rach Dinh, Khanh Tien commune, U Minh district of Ca Mau province,Vietnam, although expensive, aimed only to protect transplanted seedlings of *Avicennia marina* from strong waves (Tung 2013). The crest of the double cylinder concrete poles was far higher than king tide levels, resulting in little sea mud accumulation. Low crested revetment, sand filled geo-containers, and double line bamboo fences were constructed offshore in combination with mangrove planting to control eroding areas of Chachoengsao province, Thailand. The geo-containers broke and transplanted mangroves behind the fence were uprooted right after the project was completed. Sediment was slowly trapped and mangroves started growing recently, only when reconstruction was implemented (Saengsupavanich 2013). Gabion breakwaters and geo-textile tubes were constructed offshore in combination with planting of mangrove between the breakwaters and the coastline in Sungai Haji Dorani project in Selangor on the Malaysian Peninsula. The sea mud accumulation was negligible because hydrology and topography did not support seedlings (Stanley & Lewis 2009).

Gradual expansion in the Vam Ray project served ecological purposes, but also provided alternative short term and long term incomes for the local community. Maintenance and gradual expansion requires labor, best supplied locally, as opposed to a single large scale planting that may use imported labor. Another good example of this was the use of *Nypa fruticans,* a mangrove palm commonly found in Vietnam, which lives along river or channel areas. This species was very effective at accumulating fine sea mud, and survived well in strong waves (Nguyen et al. 2016), and the mature leaves of *Nypa fruticans* can be commercially harvested and sold as an alternative income source (Mcleod & Salm 2006). Mature leaves of *Nypa fruticans* are used to roof Vietnamese traditional houses (Nguyen et al. 2016).

It is common for one-off plantings to use a single species (commonly *Rhizophera apiculata* or *Avicennia marina*). The species are found locally but rarely in isolation from other species. Gradual expansion is particularly effective where multiple local mangrove species are transplanted, as recommended by Primavera & Esteban (2008) and Mangrove Action Project (2006). As also found by Lewis (2005), Winterwerp et al. (2005, 2013), and Kamali & Hashim (2011), the Vam Ray project demonstrated that as soon as the site is stabilized and favorable conditions were provided, mangroves naturally regenerate.

Gradual expansion has a potential applicability in the lower Mekong Delta of Vietnam and probably in other Asian developing countries. In Vam Ray, without intervention, erosion would almost certainly be continuing and natural re-colonization would not have occurred. The strategy assisted in trapping fine sediment on intertidal mudflat areas, dissipating the energy of strong waves at high tide, and restoring hydrological conditions through rehabilitating deep channels with mangrove species. In Vietnam as in other Asian countries, mangrove restoration is seen as a necessity (Samarakoon 2012). In Vietnam, there are many strategies and plans in place to try to achieve this goal such as the Programme of Reinforcing and Upgrading the Sea Dyke System from Quang Ngai to Kien Giang provinces (Vietnamese Prime Minister 2009), the Program for Rehabilitation and Development of Mangrove Forests for the period 2008 to 2015 (Ministry of Agriculture and Rural Development of Vietnam 2008). Where other planting programs have failed, gradual expansion methods, if implemented, are more likely to succeed and at the same time promote local community involvement and potentially improve local livelihoods.

III. Conclusions

Gradual expansion was a key factor for successfully stabilizing the Vam Ray eroding area. Key elements of gradual expansion include closing gaps, providing adequate protection to seedlings using appropriate fences, and gradually extending the mangrove belt seawards. In contrast to a short term planting project, in Vam Ray, using local labor and materials and harvesting products of *Nypa fruticans* over an extended period ensured proper care and monitoring of the newly established mangroves. The result was a high survival rate, long term regeneration, and natural re-colonization. To meet urgent demands for more feasible action plans and strategies that encourage mangrove transplanting to help address coastal erosion in Kien Giang province and on the Mekong Delta, gradual expansion methods should be encouraged.

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Figure 1

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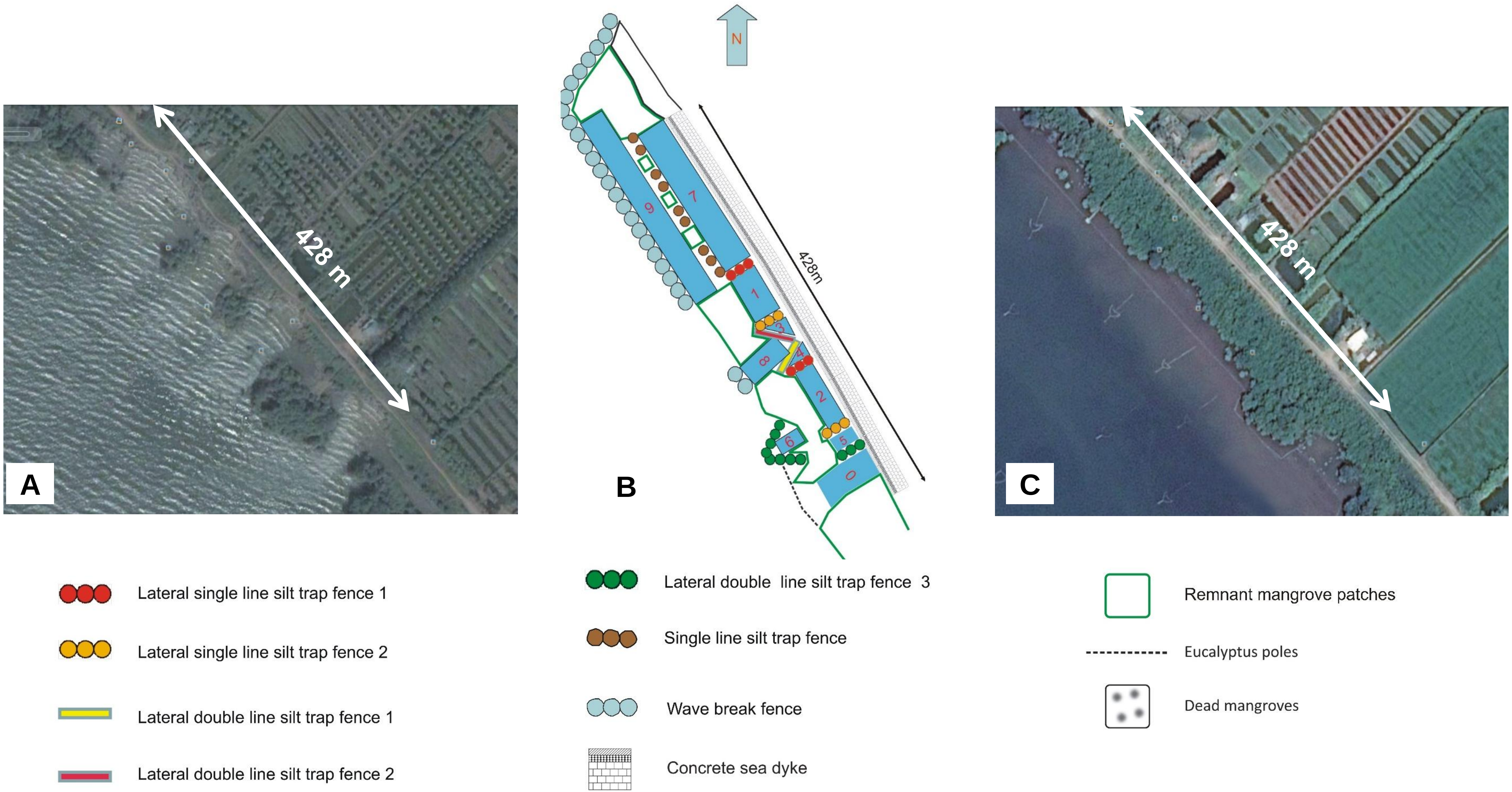

Figure 2

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APPENDIX 7: CONFERENCE PAPER

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Abstract translation:

Muddy coasts around the world, especially in Southeast Asia were severely eroded by climate change impacts, over-exploitation of coastal resources or those factors combined. Science based approaches have not been effective in controlling eroding muddy coasts, while local knowledge based approaches were difficult to maintain and to secure funding and legal assistance from local governments at all levels. Two case studies undertaken in Kien Giang, Vietnam and Brebes Regency, Indonesia between 2009 and 2014 showed that science based knowledge and local knowledge are complementary to each other and integrated through participatory action research methods for better managing eroding muddy coasts, improving livelihoods for coastal communities using coastal resources, and creating trust between local communities and governments in Kien Giang and Brebes.

TÍCH HỢP KIẾN THỨC ĐỊA PHƯƠNG VỚI KHOA HỌC TRONG VIỆC QUẢN LÝ BÃI BÙN BỊ XÓI LỞ

Nguyễn Tấn Phong
Đại học James Cook, Australia

Tóm lược: *Nhiều khu vực bãi bùn trên thế giới, đặc biệt là ở Đông Nam Á đang bị xói lở nghiêm trọng do biến đổi khí hậu, do con người khai thác nguồn tài nguyên ven biển quá mức hoặc do cả hai yếu tố này kết hợp lại. Nhiều giải pháp dựa trên thông tin khoa học hiện nay vẫn chưa phát huy hiệu quả trong việc quản lý khu vực xói lở. Trong khi đó, các giải pháp sử dụng kiến thức địa phương rất khó duy trì cũng như khó nhận được sự hỗ trợ tài chính và pháp lý từ chính quyền địa phương. Hai nghiên cứu điển hình được thực hiện tại Kiên Giang, Việt Nam và Brebes, In-đô-nê-xi-a từ năm 2009 đến 2014 cho thấy rằng kiến thức địa phương và khoa học có thể bổ sung cho nhau và việc tích hợp kiến thức địa phương và khoa học thông qua việc áp dụng Phương pháp Nghiên cứu Hành động có người dân tham gia (PAR) góp phần quản lý tốt hơn các khu vực bãi bùn bị xói lở, giúp cải thiện đáng kể sinh kế của các cộng đồng sống phụ thuộc vào tài nguyên ven biển và tạo sự tin cậy giữa người dân và chính quyền địa phương.*

1. Con người và bãi bùn

1.1 Con người và bãi biển

Trên thế giới có 5 loại bãi biển: bãi đá, bãi san hô, bãi cát, vùng cửa sông và đồng bằng và bãi bùn (Woodroffe, 2002). Nhiều bãi biển trên thế giới có nguồn tài nguyên thiên nhiên phong phú có giá trị về kinh tế cũng như môi trường (Fabbri, 1998). Vị trí của những bãi biển luôn luôn hấp dẫn người dân đến định cư. Hiện có 3.2 tỷ người đang sinh sống trong phạm vi 200 km (chiếm 10% tổng diện tích trên trái đất) dọc theo bãi biển (Hinrichsen, 2011). Nhiều nước đang pháp triển, đặc biệt là các nước Châu Á đang đối phó với vấn đề di cư ồ ạt từ vùng nông thôn ra bãi biển để tìm kiếm công ăn việc làm cũng như cơ hội cải thiện thu nhập (Hinrichsen, 2011). Nhiều bãi biển được khai phá để xây dựng nhiều công trình ven biển, phát triển du lịch, xây dựng cảng và vũng tàu, khai thác tài nguyên ven biển, nuôi trồng thủy sản, xây dựng nhiều công trình bảo vệ bờ biển, để làm nơi đổ rác, phục vụ cho an ninh quốc phòng (Clark, 1996; Connolly *và các cộng sự*, 2001). Hậu quả là, nhiều bãi biển bị ô nhiễm nặng và bị suy thoái do khai thác tài nguyên quá mức (Fabbri, 1998; Hewawasam, 2000; Tolvanen và Kalliola, 2008; Ko và Chang, 2012).

Theo Ủy ban Liên Chính phủ về Biến đổi khí hậu (1990, 2007, 2010 a và b) nhiều bãi biển rất dễ bị tổn thương do biến đổi khí hậu, cụ thể là bị ảnh hưởng bởi nước biển dâng. Nước biển dâng có thể gây ra ngập lụt và xói lở bờ biển. Ngoài các tác động tiêu cực của nước biển dâng, các hoạt động của con người ví dụ như du lịch, nuôi trồng thủy sản và đánh bắt đã cho các ảnh hưởng tiêu cực này xảy đặc biệt là xói lở bờ biển xảy ra nhanh hơn và ngày càng trầm trọng hơn (Hinrichsen, 2011) và làm tăng tính tổn thương của đường bờ biển (Fan *và các cộng sự,* 2004).

1.2 Định nghĩa bãi bùn

Bãi bùn được định nghĩa là 'một loại hình thái trầm tích có đặc trưng chủ yếu là sự bồi tụ trầm tích hạt mịn, chủ yếu là bùn và đất sét, bên trong môi trường trầm tích ven biển. Sự bồi tụ này thường có độ dốc thấp, và thường, nhưng không phải duy nhất, có liên quan đến bãi triều rộng' (Wang *và các cộng sự*, 2002, trang 9). Trong định nghĩa này, môi trường trầm tích ven biển, nơi động lực học sông ngòi và vùng ven biển ảnh hưởng đến quá trình xói mòn, vận chuyển và bồi tụ trầm tích thường thay đổi theo độ sâu, có thể lên đến 10 mét ở vùng biển hoặc nông hơn ở các vùng cửa sông nội địa và vùng vịnh bị ảnh hưởng trực tiếp và hạn chế từ vùng biển (Wang *và các cộng sự*, 2002).

1.3 Tác động của con người đối với bãi bùn

Bãi bùn được khai phá lấy đất nuôi trồng thủy sản, canh tác nông nghiệp, xây dựng các khu công nghiệp cũng nhưng xây dựng khu dân cư (Han, 2002). Việc khai phá này đã có tác động trực tiếp cũng như gián tiếp đến bãi bùn. Tác động trực tiếp là rừng ngập mặn ven biển bị chặt hạ để hầm than, đốn củi; lấy đất xây dựng các khu thị tứ, xây dựng cảng và vũng tàu, canh tác nông nghiệp, cũng như nuôi tôm, cá (Paez-Osuna, 2001; Valiela *và các cộng sự,* 2001; Han, 2002; Bhandari *và các cộng sự,* 2004; Thampanya *và các cộng sự,* 2006; Martine *và các cộng sự,* 2008; Ramesh *và các cộng sự,* 2011); mất nhiều sinh cảnh ven biển và khu vực sinh sản quan trọng của các loài động vật trên cạn cũng như dưới biển; mất thảm thực vật rừng; và bị xói lở bờ biển (Han, 2002; Thampanya *và các cộng sự,* 2006; Ramesh *và các cộng sự,* 2011). Tác động gián tiếp là sụp đất do khai thác nguồn nước ngầm, dầu khí và khí hóa lỏng (Han, 2002; Ramesh *và các cộng sự,* 2011).

1.4 Tác động thiên nhiên lên bãi bùn

Động lực học hình thái của bãi bùn có thể bị tác động do nước biển dâng do bão vào lúc triều cường; gió mạnh trên đất liền; và các ảnh hưởng liên đới của nước biển dâng do bão (Bao và Healy, 2002). Những tác động chính bao gồm xói lở bờ biển, và ngập lụt trên diện rộng trong thời gian ngắn (Wells *và các cộng sự,* 1990; Amos, 1995; Wang *và các cộng sự,* 2002; Augustinus, 1989; Yan *và các cộng sự,* 1989; Lee *và các cộng sự,* 1994; Liefting, 1998; Fan *và các cộng sự,* 2004; Bao và Healy, 2002). Những tác động này sẽ trở nên tồi tệ hơn ở các vùng biển rộng và thấp cũng như vịnh kín gió và nông (Bao và Healy, 2002).

1.5 Xói lở bờ biển và người dân sống dựa vào tài nguyên thiên nhiên ven biển

Xói lở bờ biển là quá trình xảy ra trong tự nhiên mà qua đó đường bờ biển thay đổi theo mực nước, năng lượng sóng, nguồn cung cấp trầm tích và địa hình hiện tại (Coopeer và McKenna, 2008). Xói lở bờ biển có thể buộc hàng triệu người phải di cư đến nơi ở khác (Hinrichsen, 2011). Xói lở bờ biển ngày càng có nhiều tác động tiêu cực đối với đường bờ biển và các cộng đồng sống ven biển ở Việt Nam (Chính phủ Việt Nam, 2007). Xói lở bờ biển cũng tạo ra nhiều bất ổn xã hội (Ramesh *và các cộng sự,* 2011)

2. Các phương pháp quản lý bãi biển, kể cả bãi bùn

Nhiều phương pháp khác nhau được xây dựng nhằm thiết lập hoặc tái thiết lập sự cân bằng giữa nhu cầu phát triển kinh tế-xã hội và nhu cầu bảo vệ môi trường ven biển, và từ đó tạo ra sự bền vững trong tương lai.

2.1 Giải pháp công trình

Giải pháp công trình áp dụng kiến thức chuyên môn thuần túy, mặc dù các quá trình quản lý khác có thể song song tồn tại cùng một lúc. Giải pháp công trình, như thuật ngữ được sử dụng ở đây, sử dụng các công trình để bảo vệ các công trình ven biển và cơ sở hạ tầng không bị xói lở, giảm thiểu và ngăn chặn xói lở bờ biển, hoặc để bảo vệ tài sản của cộng đồng dọc theo đường bờ biển, hoặc để bảo vệ các khu vực đất đã được khai hoang (Weigel, 2002). Giải pháp công trình bao gồm các công trình được xây dựng ven bờ cũng như các công trình thiết bị ở ngoài khơi hoặc các công trình có thể tách rời (Dugan *và các cộng sự,* 2011). Công trình ven bờ bao gồm tường bờ chắn sóng, đê bờ chắn sóng, mỏ hàn, đập mỏ hàn, cảng và vũng tàu (Dugan *và các cộng sự,* 2011). Công trình thiết bị ngoài khơi là các công trình nổi và có đỉnh thấp hoặc đê chắn sóng có thể tách rời (Nordstrom, 2000). Công trình thiết bị ngoài khơi bao gồm công trình dạng ống hoặc ống đựng cát được làm từ vải địa kỹ thuật, rạn san hô nhân tạo hoặc gò đất cố định hoặc đập phá sóng chìm (Koffler *và các cộng sự,* 2008; Dugan *và các cộng sự,* 2011). Công trình thiết bị ngoài khơi thường được xây dựng song song và cách xa đường bờ một khoảng cách nhất định (Nordstrom, 2000; Dugan *và các cộng sự,* 2011). Các công trình này thường được xây dựng để xử lý những thay đổi ở đường bờ và xói lở bờ biển bằng cách giảm năng lượng sóng như tản sóng, khúc xạ sóng hoặc phản xạ sóng (Nordstrom, 2000).

Tuy nhiên, giải pháp công trình có thể có tác động tiêu cực đến môi trường sinh thái, đa dạng sinh học, và các chức năng của các hệ sinh thái ven biển, cũng như làm thay đổi quá trình tự nhiên ven biển. Các tác động tiêu cực bao gồm làm thay đổi quá trình bồi tụ và xói lở trầm tích; làm thay đổi dòng thủy triều; làm mất sinh cảnh quan trọng; gây ra xói lở; làm thay đổi đường bờ biển; làm giảm diện tích bãi bồi; làm mất đi nhiều bãi biển kín gió, làm mất đi rạn san hô, bãi bồi và thảm thực vật đầm lầy (Marsworth và Long, 1986; Douglass và Pickle, 1999); làm xảy ra tình trạng ứ đọng ở đầm phá do tích tụ quá nhiều trầm tích hạt mịn và chất hữu cơ (Martin *và các cộng sự,* 2005).

2.2 Giải pháp dựa vào hệ sinh thái:

Giải pháp dựa vào hệ sinh thái là một công cụ mang tính công trình giúp tạo ra môi trường sống tự nhiên hơn cho các loài sinh vật (Bergen *và các cộng sự*, 2001). Giải pháp dựa vào hệ sinh thái kết hợp các nguyên tắc mang tính công trình với các quá trình sinh thái nhằm giảm tác động tiêu cực do việc xây dựng cơ sở hạ tầng gây ra đối với môi trường (Bergen *và các cộng sự*, 2001). Giải pháp dựa vào hệ sinh thái gồm nuôi bãi, ổn định cồn cát, thoát nước bãi biển, trồng rừng ngập mặn hoặc kết hợp trồng rừng ngập mặn với các giải pháp công trình (Nordstrom, 2000; Bergen *và các cộng sự,* 2001; Woodroffe, 2002). Tuy nhiên, giải pháp dựa vào hệ sinh thái đòi hỏi nhiều nhu cầu tự mâu thuẫn với nhau và thay đổi tự nhiên theo không gian và thời gian (Holling, 1996). Ngoài ra, cũng cần có sự hiểu biết đầy đủ về sự quần hợp các loài trong sinh cảnh ven biển và cũng cần tiến hành nghiên cứu sinh thái nhiều hơn để hiểu đầy đủ các khía cạnh của giải pháp dựa vào hệ sinh thái (Chapman, 2011).

2.3 Kiến thức địa phương và quản lý nguồn tài nguyên thiên nhiên

Kiến thức địa phương được xem là kho kiến thức và thực hành của một dân tộc cụ thể nào đó, tuy không chính thức nhưng rất đầy đủ và được duy trì liên tục và phát triển theo thời gian. Kiến thức địa phương dựa trên kinh nghiệm và đã được thử nghiệm qua nhiều thế kỷ và được làm phù hợp với văn hóa địa phương. Tuy có tính năng động và thay đổi nhưng kiến thức địa phương ít khi được sao chép lại (Warren 1993; Ngân hàng Thế giới (World Bank), 1998; Huntington, 1998; Berkes, 1999; Boven và Morohashi, 2002; Tổ chức Lương Nông (Food and Agriculture Organization, 2005; Nakashima *và các cộng sự,* 2012).

Trong nhiều trường hợp, nghiên cứu khoa học không xét đến nhu cầu ở địa phương cũng như kiến thức địa phương, tuy có tạo ra kết quả có giá trị về mặt khoa học, nhưng không thể áp dụng được ở địa phương (McDougall và Braun, 2012). Việc tích hợp kiến thức địa phương và khoa học tạo ra hai lợi ích rõ ràng cho việc quản lý môi trường. Một là giúp chứng thực dữ liệu mang tính khoa học và lấp đầy các khoảng trống của các dữ liệu được tạo ra từ khoa học (Scholz *và các cộng sự*, 2004). Hai là kiến thức khoa học được sử dụng để kiểm tra nguyên nhân nhằm bổ sung kiến thức địa phương (Moller *và các cộng sự*, 2004).

Kiến thức địa phương đóng vai trò quan trọng trong việc đưa ra quyết định trong nhiều tình huống ví dụ như nông nghiệp, y tế, chuẩn bị thực phẩm, giáo dục, quản lý tài nguyên thiên nhiên ở cấp địa phương. Hơn nữa, kiến thức địa phương cũng là cơ sở mà dựa vào đó xây dựng các chiến lược để giải quyết vấn đề cho cộng đồng địa phương (Liên Hiệp Quốc (United Nations), 1992; Ngân hàng Thế giới (World Bank), 1998). Do tầm quan trọng của nó nên kiến thức địa phương đã được chính thức công nhận là nền tảng cơ bản để xây dựng các chiến lược quản lý nguồn tài nguyên thiên nhiên trong nhiều chương trình nghị sự của Liên Hợp Quốc (Ủy ban Liên Chính phủ về Biến đổi khí hậu (International Panel on Climate Change), 2007 & 2010 a và b; Công ước của Liên Hiệp Quốc về Biến đổi Khí hậu (United Nations Convention on Climate Change), 2010).

Việc tích hợp giữa kiến thức địa phương và khoa học trong vấn đề quản lý tài nguyên thiên nhiên không phải là vấn đề mới. Lịch sử đã cho thấy nhiều sự tương tác thành công giữa những hiểu biết khoa học của phương Tây và kiến thức địa phương trong việc giải thích các hệ sinh thái (Hội đồng Khoa học Quốc tế (International Council for Science) và UNESCO, 2002; Nakashima *và các cộng sự,* 2012). Hiện có nhiều ví dụ điển hình áp dụng kiến thức địa phương trong quản lý bền vững các nguồn tài nguyên ven biển (Lowry *và các cộng sự,*1999; Shivakoti và Ruddle, 2003; Pomeroy *và các cộng sự,* 2004; Heylings và Bravo, 2007; Cinner *và các cộng sự,* 2009; Gustavson *và các cộng sự*, 2009; Saunders *và các cộng sự,* 2010; Tuyen *và các cộng sự,* 2010; Wells *và các cộng sự,* 2010; Ukwe và Ibe, 2010; Carr và Heyman, 2012; Liberty *và các cộng sự,* 2012; Mathew *và các cộng sự,* 2013; von Essen *và các cộng sự,* 2013; Mackinson, 2001; De Freitas và Tagliani, 2009; Terer *et al,* 2012; Giorgano và Liersch, 2012).

Tuy nhiên, việc tích hợp kiến thức địa phương vào khoa học trong quản lý nguồn tài nguyên thiên nhiên gặp phải hai vấn đề khó khăn. Một là làm sao tích hợp kiến thức địa phương vào trong văn hóa phương Tây cũng như hệ thống kiến thức quản lý bền vững các nguồn tài nguyên thiên nhiên (Ruddle và Johannes, 1983; Charnley *và các cộng sự,* 2007; Raymond *và các cộng sự,* 2010). Hai là làm sao phương pháp sử dụng kiến thức địa phương có thể hoạt động độc lập mà không có sự hỗ trợ về cơ chế pháp lý và tài chính của chính quyền (Kay và Alder, 2005).

3. Tích hợp kiến thức địa phương và khoa học vào trong quản lý bãi bùn bị xói lở: Nhu cầu và Phương pháp

Trong khi các giải pháp hiện nay vẫn còn có nhiều hạn chế và chưa phát huy được hiệu quả thì nhiều bãi bùn đang đối mặt với nhiều thách thức và đe dọa ngày càng tăng. Do đó việc tích hợp kiến thức địa phương vào khoa học trong việc quản lý bền vững bãi bùn là điều cấp bách hơn bao giờ hết (Ruddle and Johannes, 1983; Charnley *và các cộng sự,* 2007; Raymond *và các cộng sự,* 2010).

Khoa học cần phải được chia sẻ cũng như kết hợp đầy đủ với kiến thức địa phương thông qua sự tham gia thiết thực của công chúng nhằm quản lý bền vững vùng ven biển cũng như góp phần tăng cường hiểu biết lẫn nhau giữa các bên liên quan, chia sẻ các hoạt động một cách cân bằng (Stojanovic *và các cộng sự,* 2004; Cliquet *và các cộng sự*, 2010; United Nations, 2012). Sự tham gia thiết thực của công chúng sẽ tạo ra một xã hội học tập, mà trong đó các cá nhân và các nhóm có thể tìm hiểu kiến thức về quy tắc, kỹ năng, chiến lược, niềm tin và thái độ bằng cách quan sát những người khác và hành động phù hợp với niềm tin và sự hiểu biết của mình (Bandura, 1977). Xã hội học tập giúp nâng cao khả năng chống chịu, tăng cường tính bền vững, vượt qua những khó khăn do sự phức tạp, bất ổn và xung đột nảy sinh từ vấn đề trong quá trình ra quyết định gây ra (Fiorino, 1990; Liard, 1993; Webbler *và các cộng sự*, 1995; Parson và Clark, 1995; Schusler *và các cộng sự,* 2003; Brugnach *và các cộng sự*, 2008; Garmendia và Stagl, 2010).

Nghiên cứu hành động có sự tham gia của người dân là phương pháp làm việc cùng nhau để làm cho mọi việc được tốt hơn vì đây là một quá trình có sự hợp tác, có tầm quan trọng và có xu hướng phát triển thông qua hệ thống minh bạch, công khai, theo hệ thống, phù hợp về văn hóa, linh hoạt và năng động (Crane và O 'Regan, 2010). Nghiên cứu hành động có sự tham gia của người dân thúc đẩy sự tham gia tích cực của các nhà nghiên cứu cũng như cộng đồng trong việc cùng xây dựng kiến thức, và nhấn mạnh quá trình cùng học tập, tạo ra việc thay đổi của cá nhân, tập thể hay xã hội (McIntyre, 2008). Thêm vào đó, nghiên cứu hành động có sự tham gia nhấn mạnh quá trình dân chủ, mà qua đó làm giảm đi sự bất bình đẳng trong xã hội, xung đột cũng như bất công, khuyến khích việc tạo ra tri thức và hành động tập thể (Neuman, 2011). Do đó, việc tích hợp kiến thức địa phương và khoa học sử dụng phương pháp nghiên cứu hành động có sự tham gia của người dân sẽ rất thích hợp để giải quyết vấn đề xói lở bãi bùn và sinh kế địa phương tìm kiếm cho quản lý bãi bùn bền vững.

4. Ví dụ điển hình

Phục hồi rừng ngập mặn tại bãi bùn bị xói lở ở Vàm Rầy, Kiên Giang, Việt Nam (được viết lại từ Bài viết: Phục hồi Rừng ngập mặn ven biển ở Vàm Rầy, tỉnh Kiên Giang, Việt Nam - Nguyễn Tấn Phong, 2015).

Mô tả vị trí sơ lược:

Vàm Rầy thuộc huyện Hòn Đất, cách Thành phố Rạch Giá, tỉnh Kiên Giang 40 km về phía đông bắc (Hình 1). Năm 2008 có 14 hộ dân đang sinh sống tại khu vực này. Phần lớn những hộ dân này đến đây từ thập niên 1980 theo chương trình kinh tế mới.

Vàm Rầy nằm trong khu vực nhiệt đới gió mùa và có 02 mùa rõ rệt. Mùa mưa bắt đầu từ tháng 5 đến tháng 11 với chế độ gió Tây Nam. Tháng 7, 8 và tháng 9 là những tháng có lượng mưa nhiều nhất. Mùa khô bắt đầu từ tháng 11 đến tháng 4 năm sau và có chế độ gió Đông Bắc (Sở Nông nghiệp & Phát triển Nông thôn, Kiên Giang (DARD), 2007).

Vàm Rầy chịu ảnh hưởng chế độ triều vịnh Thái Lan. Thủy triều phần lớn có tính nhật triều thuần nhất, đôi khi là nhật triều không đồng đều. Mực nước đỉnh triều cao nhất thường xuất hiện vào tháng 10, mực nước chân triều thấp nhất xuất hiện vào tháng 5 và tháng 6 (DARD, 2007).

Sơ lược về hiện trạng:

Trong khu vực này có tuyến đê đất được xây dựng trong thập niên 1970 phục vụ cho mục đích quốc phòng và tưới tiêu trong nông nghiệp. Sau đó, tuyến đê biển này được nâng cấp nhiều lần lên thành đường giao thông nông thôn. Rừng ngập mặn chủ yếu là các loài *Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Bruguiera gymnorhiza và Nypa fruticans* (Dự án Bảo tồn và Phát triển Bền vững Khu Dự trữ Sinh quyển Kiên Giang (CDBRP) (2008). Người dân khai phá rừng ngập mặn lên liếp để trồng hoa màu (khoa lang, bí ngô, bí đỏ, dưa hấu), mía, cây ăn trái, lúa hoặc đào vuông nuôi cua và tôm ở hai bên đê biển để tạo thu nhập cho gia đình.

Khu vực Vàm Rầy bị xói lở nghiêm trọng trong giai đoạn 2006 và 2008. Rừng ngập mặn bị sóng đánh ngã đổ và cuốn trôi đi. Đoạn đê đất bị phá vỡ và nước biển tràn vào khu vực đất canh tác của dân. Hậu quả là toàn bộ khu vực Vàm Rầy bị cô lập và cây trồng bị hư hại nặng.

Giải pháp của cơ quan chuyên môn:

Năm 2007, Ban Quản lý các dự án chuyên ngành thuộc Sở Nông nghiệp & Phát triển Nông thôn, tỉnh Kiên Giang (DARD) đã áp dụng giải pháp dựa vào hệ sinh thái nhằm ngăn chặn quá trình xói lở bờ biển tại khu vực Vàm Rầy (3.66 ha). Theo phương án này, đoạn đê đất bị vỡ được xây mới bằng bê tông và bên ngoài đê biển trồng mắm (*Avicennia marina*) được bảo vệ bằng hàng rào được làm bằng cây Bạch đàn có chiều dài 890 m (DARD, 2007 a và b). Cây mắm được nhổ từ tự nhiên sau đó ươn vào bầu ở vườn ươm trong khu vực Vàm Rầy. Cây mắm được nuôi ươm trong thời gian 6 tháng trước khi đem trồng. Cây mắm con được ba cây tràm nhỏ chống đỡ khi trồng vào tháng 11 và tháng 12. Tuy nhiên, hàng rào cây Bạch đàn không phát huy tác dụng trong việc che chắn cây mắm không bị sóng đánh. Cây mắm con bị sóng đánh bật gốc, hoặc bị rác, đặc biệt là túi ny lông trôi dạt vào bờ đè chết (DARD, 2009). Hậu quả là, sau 2 năm triển khai thực hiện, chương trình thất bại và không có cây mắm nào sống sót.

Giải pháp kết hợp giữa người dân địa phương và cơ quan chuyên môn:

Từ năm 2008 và 2009, CDBRP, cơ quan chuyên môn địa phương và người dân Vàm Rầy tổ chức nhiều cuộc họp và tham vấn để rút ra bài học kinh nghiệm về việc trồng rừng ngập mặn ven biển. Bài học rút ra là: chất lượng cây con giống không đảm bảo, hàng rào không có tác dụng chắn sóng và giữ bùn và thời gian trồng không hợp lý.

Qua nhiều cuộc họp và tham vấn, CDBRP, cơ quan chuyên môn địa phương và người dân Vàm Rầy cộng tác và làm việc với nhau để đưa ra các giải pháp khắc phục những khiếm khuyết cũng như đưa ra các giải pháp ngăn chặn xói lở bờ biển phù hợp với địa phương. Theo chương trình hợp tác này, CDBRP là cơ quan tài trợ chi phí mua vật tư xây dựng vườn ươm, làm hàng rào và trả tiền công lao động và tiền thuê đất làm vườn ươm; cơ quan chuyên môn địa phương chịu trách nhiệm nâng cấp và bê tông hóa tuyến đê đất hiện nay (428 in) làm đường giao thông nông thôn; người dân Vàm Rầy áp dụng ý tưởng và kinh nghiệm của mình trong việc đưa ra các giải pháp. Ý tưởng xuyên suốt chương trình này là cố gắng càng nhiều càng tốt sử dụng vật liệu tại địa phương, kiến thức tại địa phương để giảm giá thành và có khả năng nhân rộng, khi mô hình được triển khai thành công.

Ba giải pháp được đưa ra là sản xuất cây giống có chất lượng tốt của 5 loài cây ngập mặn đã từng phân bố trong khu vực này; cải tiến hàng rào cừ tràm chống sạt lở bờ sông tại địa phương cũng như cải thiện hàng rào Bạch đàn; và mở rộng dần dần sử dụng ô nhỏ và trồng cây giống với mật độ dày cũng như lợi dụng cây ngập mặn hiện có làm hàng rào bảo vệ tự nhiên.

Vườn ươm sản xuất 5 loại cây giống rừng ngập mặn:

Theo như hướng dẫn, vườn ươm cây ngập mặn phải được xây dựng ở các bãi triều thấp hoặc gần với khu vực có thủy triều ra vào thường xuyên. Vì khu vực Vàm Rầy đã bị xói lở nghiêm trọng và tuyến đê biển đang được nâng cấp nên không thể tìm ra khu vực xây dựng vườn ươm theo như hướng dẫn. Thay vào đó, các bên thống nhất thuê một khu vực đất (15 m x 35 m) bên trong đất liền ở xây dựng vườn ươm. Vườn ươm được xây dựng vào tháng 5 năm 2009.

Khu vực này bị ngập nước và bị nhiễm phèn nặng, đặc biệt vào mùa mưa. Người dân địa phương tin rằng đất và nước phèn sẽ ảnh hưởng không tốt đến cây giống. Do đó, trước khi đưa bầu vào vườn ươm, người dân lấy bùn từ biển đắp lên trên mặt đất với độ dày ít nhất là 50 cm. Lớp bùn này được cho là sẽ có tác dụng ngăn nước bị nhiễm phèn ảnh hưởng đến túi bầu, đặc biệt vào mùa mưa. Người dân dùng cây cừ tràm xây khung vườn ươm và dùng lưới cũ bao quanh khu vực vườn ươm để không cho gia cầm phá cây cũng như ngăn chặn sâu hại.

Mục đích của vườn ươm là sản xuất nhiều cây giống khỏe mạnh của 05 loài cây ngập mặn (*Avicennia marina, Rhizophora apiculata, Bruguiera cylindrica, Sonneratia alba và Nypa fruticans)*. Người dân địa phương lấy bùn từ biển khi triều thấp và cho vào bầu (Hình 2). Tùy theo từng loài cây khác nhau mà bầu có số lượng trái giống khác nhau. *Avicennia marina* 01 cây một bầu; *Rhizophora apiculata* 03 cây một bầu; *Rhizophora apiculata* 5 cây một bầu; *Sonneratia alba* 01 cây một bầu; *Nypa fruticans* 01 cây một bầu. Cây giống được tưới bằng nước bơm từ biển vào, 2 ngày một lần, buổi sáng sớm và chiều tối. Sử dụng bùn vô bầu và nước biển tưới cây giống giúp cho cây giống làm quen với môi trường trồng, giúp cho cây giống phát triển nhanh hơn và đặc biệt không dùng phân và thuốc trừ sâu. Sau thời gian 3 tháng, tổng số có 37.500 cây giống của 5 loại cây ngập mặn được sản xuất từ vườn ươm và sẵn sàng đem ra trồng (Hình 3).

Cải tiến hàng rào cừ tràm và hàng rào Bạch đàn:

Việc cải tiến hàng rào cừ tràm truyền thống và hàng rào Bạch đàn dựa vào sự tổng hợp kiến thức địa phương, kiến thức khoa học và kinh nghiệm cá nhân của cố vấn kỹ thuật. Hàng rào cừ tràm theo truyền thống được xây dựng ở hai bờ sông để ngăn chặn xói lở bờ sông cũng như giúp giữ đất và lấn bờ sông để xây dựng nhà ở (Hình 4 a). Hàng rào cừ tràm truyền thống được cải tiến để tích tụ bùn và giúp ổn định bãi bùn bị xói lở. 7 loại hàng rào đã được thiết kế và xây dựng, bao gồm 02 loại hàng rào đơn dọc, 01 loại hàng rào đơn ngang, 03 hàng rào đôi dọc và hàng rào đôi chắn sóng. 7 loại hàng rào này được thiết kế và xây dựng với nhiều mục đích khác nhau. Tất cả các loại hàng rào đều có được xây dựng bằng vật liệu có sẵn địa phương (cừ tràm, lưới cũ, mê bồ, đinh, dây kẽm) và chức năng chắn sóng dọc và sóng ngang, tích tụ bùn và ngăn rác (Hình 4).

Phương pháp mở rộng dần dần:

10 ô khác nhau được xây dựng để mở rộng dần diện tích rừng ngập mặn để tăng cường khả năng chống chịu và chức năng bảo vệ của rừng ngập mặn ven biển. Những ô này bắt đầu xây dựng từ đầu tháng 9 và kết thúc vào cuối tháng 10 năm 2009. Cây giống từ 03 tháng đến 4 tháng tuổi được trồng với mật độ dày. Có hai cách trồng, trồng theo hàng, hàng cách hàng 0.2 m và trồng theo cụm. Khung đỡ được làm bằng cừ tràm được chôn sâu dưới bùn có tác

dụng giúp cố định cây giống không bị sóng đánh trôi. Theo phương pháp này, cây giống được bảo vệ bằng 07 loại hàng rào và những khoảnh rừng ngập mặn tự nhiên còn lại trong khu vực (Hình 5). *Nypa fruticans* được trồng để người dân có thể thu hoạch lá, trái cây đem bán để lấy tiền khi cây trưởng thành.

Kết quả: 07 loại hàng rào và 10 ô đã có kết quả tích cực trong việc tích tụ bùn, bảo vệ cây giống, phá sóng và ngăn rác làm chết cây (Hình 6). Tỷ lệ cây sống rất cao và cây tái sinh mạnh, đặc biệt từ giữa tháng 12 năm 2009 đến tháng 8 năm 2012 (Bảng 1).

5. Kết luận chung

Bằng cách áp dụng nghiên cứu hành động có sự tham gia người dân thì việc tích hợp kiến thức địa phương và khoa học trong quản lý bãi bùn bị xói lở có thể tạo ra nhiều lợi ích. Người dân ở Vàm Rầy, Kiên Giang Việt Nam người dân địa phương được trao thêm quyền và được tạo điều kiện để họ có thể giải quyết những vấn đề khó khăn của mình. Việc áp dụng kiến thức địa phương không chỉ giúp làm giảm đáng kể chi phí mà có là điều kiện tất yếu giúp dễ dàng nhân rộng mô hình ở những nơi khác trong tỉnh Kiên Giang và ở những nơi khác.

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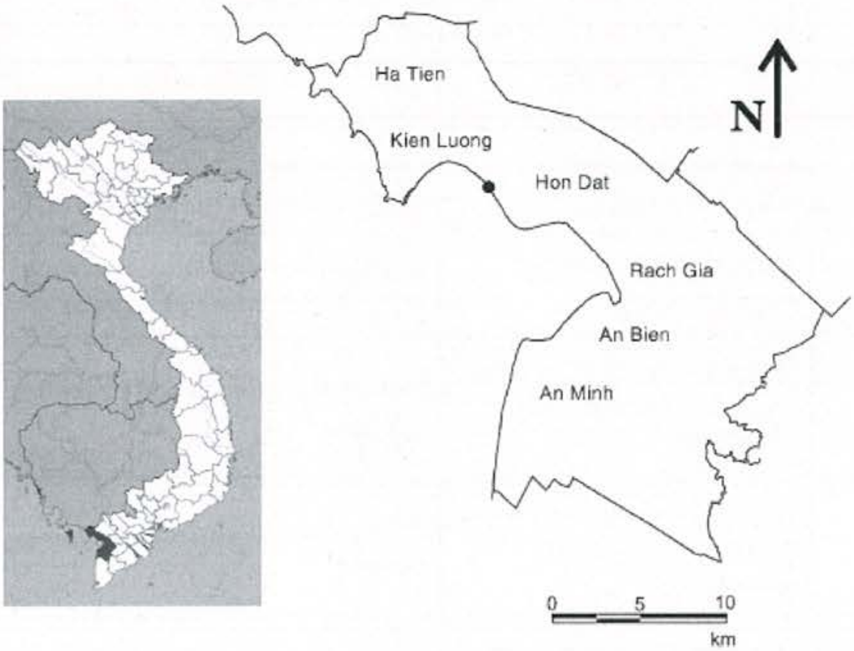
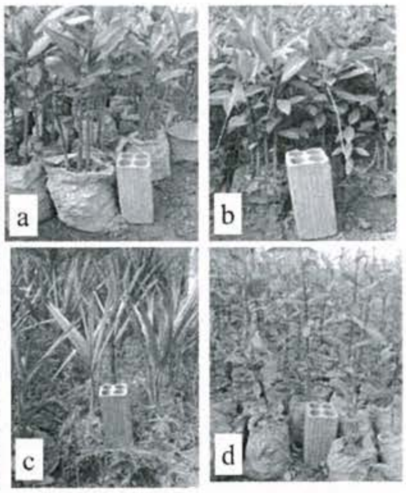
Phụ lục



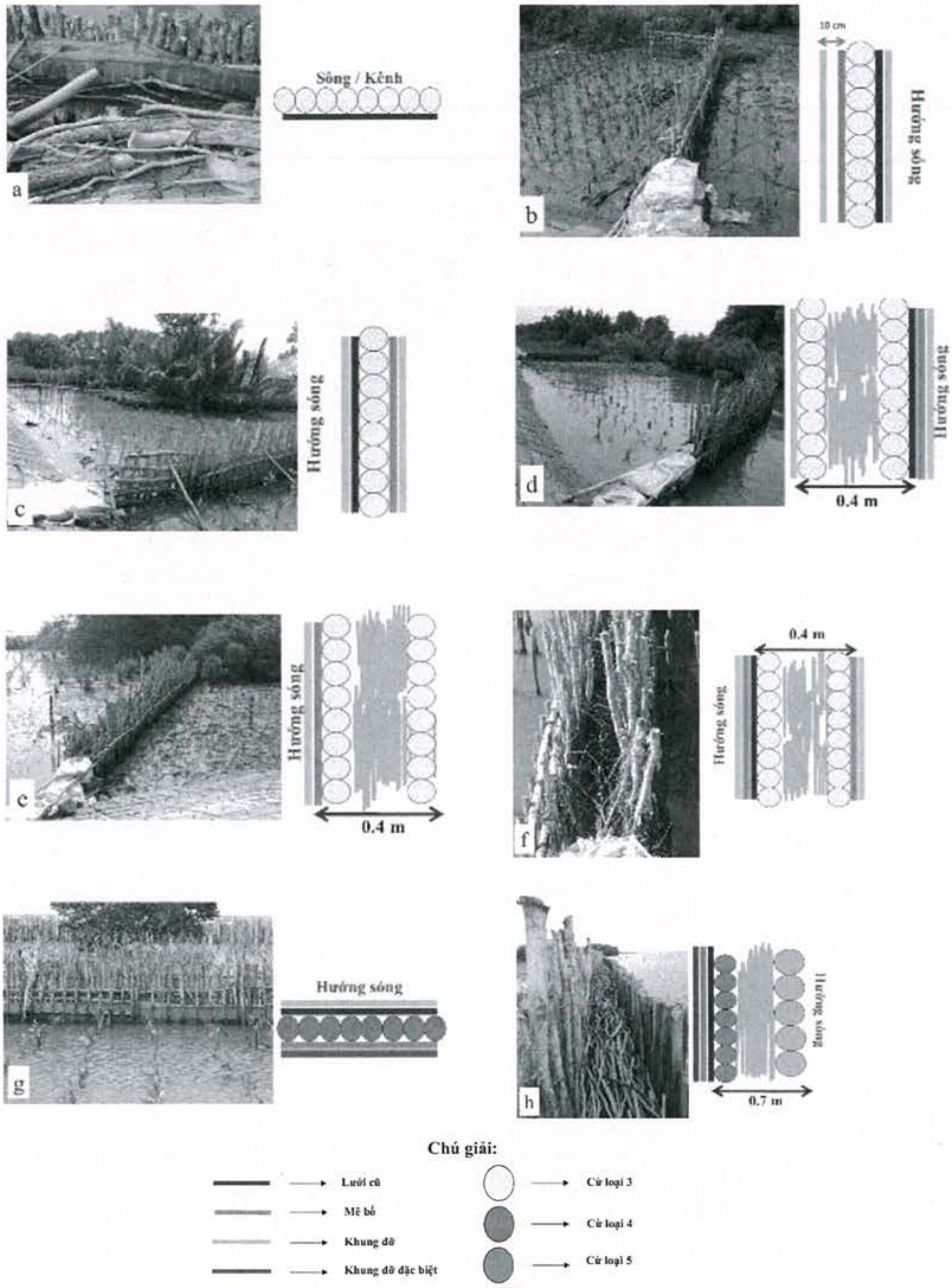
Hình 1: Vàm Rầy (chấm đen), Hòn Đất, tỉnh Kiên Giang. Nguồn: Nguyễn Tấn Phong, 2015



Hình 2: Người dân Vàm Rầy lấy bùn biển cho vào bầu. Hình 3: a) Cây giống 3 tháng tuổi *Rhizophora apiculata*, b) *Bruguiera cylindrica*, c) *Nypa fruticans* và *d) Avicennia marina*. Nguồn: Nguyen Tan Phong, 2015

Bảng 1: Danh sách các loài cây ngập mặn trồng và tái sinh cho đến (tháng 5 năm 2011)
(Nguồn: Nguyễn Tấn Phong, 2015)

Ô	Cây trồng	Cây tái sinh	Tỷ lệ sống (%)
1	*Rhizophora apiculata, Nypa fruticans*	*Rhizophora apiculata, Avicennia marina, Bruguiera cylindrica*	100
2	*Rhizophora apiculata, Nypa fruticans*	*Rhizophora apiculata, Avicennia marina, Bruguiera cylindrica*	100
3	*Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata*	*Bruguiera cylindrica, Avicennia marina,*	100
4	*Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata*	*Bruguiera cylindrica, Avicennia marina*	100
5	*Bruguiera cylindrica, Nypa fruticans, Rhizophora apiculata*	*Bruguiera cylindrica, Avicennia marina*	90
6	*Avicennia marina*	*Avicennia marina, Bruguiera cylindrica*	70
7	*Bruguiera cylindrica, Avicennia marina, Nypa fruticans, and Sonneratia alba*	*Bruguiera cylindrica, Avicennia marina, Rhizophora apiculata*	70
8	*Avicennia marina and Rhizophora apiculata*	*Avicennia marina, Bruguiera cylindrica*	30
9	*Avicennia marina and Rhizophora apiculata*	*Avicennia marina*	20
Ô đối chứng		*Avicennia marina*	1



Hình 4: a) Hàng rào cừ tràm truyền thống, b) Hàng rào đơn dọc loại 1, c) Hàng rào đơn dọc loại 2, d) Hàng đôi dọc loại 1, e) Hàng đôi dọc loại 2, f) Hàng đôi dọc loại 3, g) Hàng rào đơn ngang và h) Hàng rào đôi chắn sóng. Nguồn: Nguyen Tan Phong, 2015

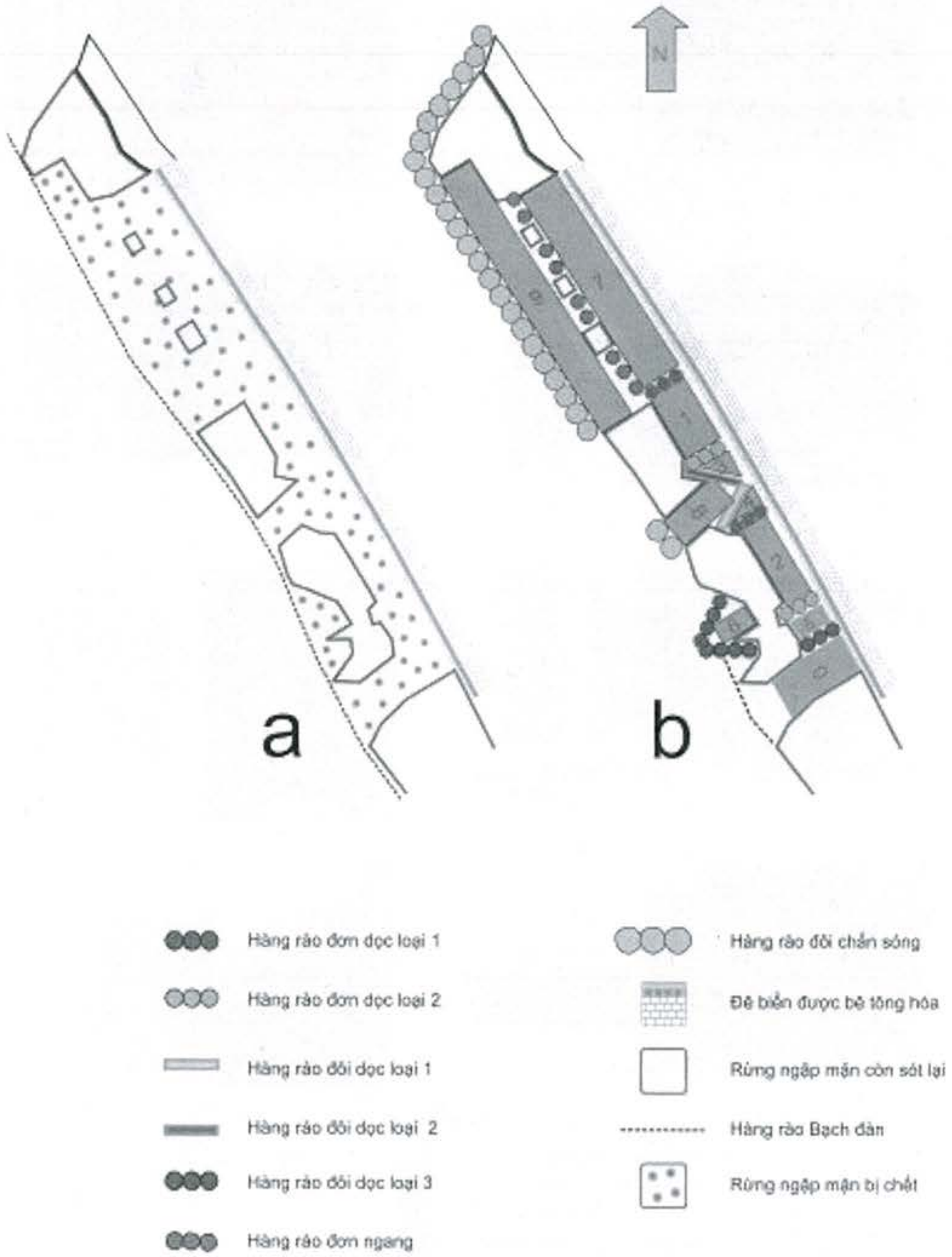
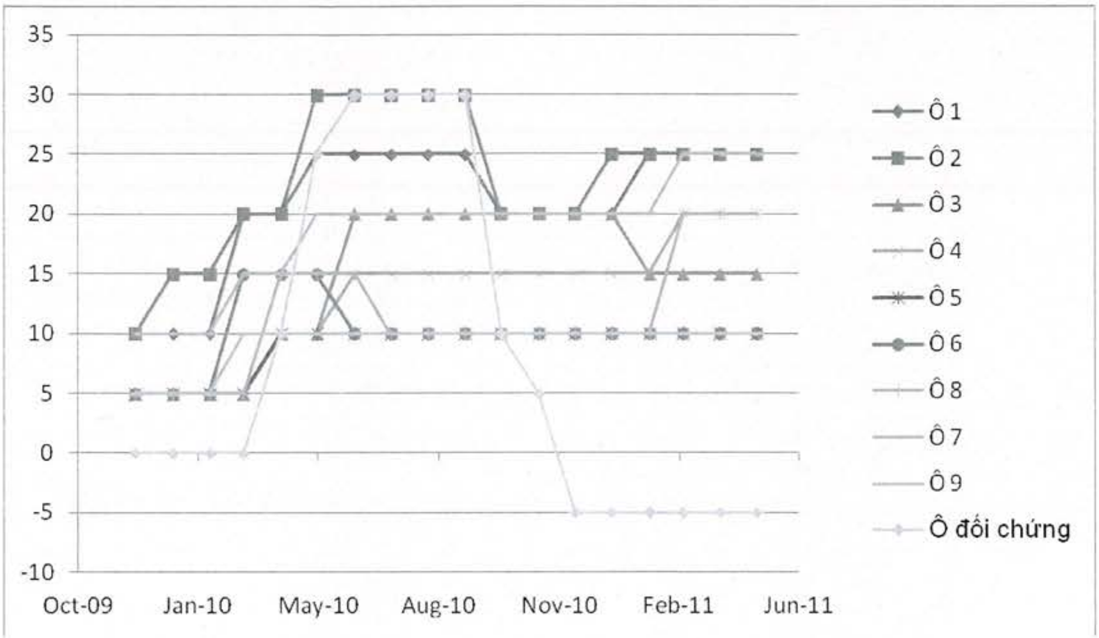


Figure 5: Sơ đồ vị trí Vàm Rầy, a) Tháng 11 năm 2008; b) Tháng 5 năm 2011. Con số chỉ thị thứ tự các ô. Nguồn: Nguyen Tan Phong, 2015



Hình 6: Lượng bùn tích tục giữa tháng 7 và tháng 8 năm 2012. Nguyễn Tấn Phong, 2015