Adaptive Collaborative Management Plan
for Building Mangrove Resilience in Tanakeke Island

Restoring Coastal Livelihood Project
DRAFT REPORT

Mangrove Action Project - Indonesia
2012

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PART A - INTRODUCTION

1. Scope and Purpose of the Management Plan

Mangroves historically covered 4.2 million hectares of Indonesia's coastal areas[1], reduced to approximately 2 million hectares over the past 40 years, due predominantly to the development of coastal aquaculture, specifically intensive shrimp and milkfish farming. The model for shrimp and milkfish polyculture arguably originated in the region of South Sulawesi, facilitated by the enclosure of small estuaries to function as rearing ponds as far back as 400 years ago.

Aquaculture development in the 1990's is the sole contributing factor for the conversion of 1200 hectares of an original 1776 hectares of mangrove forest into ponds on the island of Tanakeke, just of the Southwest tip of South Sulawesi province in Takalar District. Ponds were developed both by communities (approx 800 ha) and the transmigration agency (approx 400ha) and are now largely abandoned. Community initiatives, under the Restoring Coastal Livelihoods project, are resulting in the rehabilitation of at least 400 hectares of ponds into mangroves into mangroves, necessitating the development of a management plan for both existing and restored mangrove forests. The management plan will have to take into consideration the need for extractive uses (for fuel wood and timber), fisheries values, and ecosystem services, in the backdrop of an ever rising sea, which threatens not only the position of the mangroves, but the very existence of human settlements already positions in the intertidal zone. Poverty, vulnerability, gender inequity and lack of basic government services and infrastructure make the challenge all the more difficult.

An adaptive collaborative management models is being recommended, to outlive the RCL project life by engaging all relevant stakeholders in the development of scenarios for the future, and the commitment to consider adaptation and community participation as key mechanisms for long-term management.

2. Location

Tanakeke Island is located off the Southwestern tip of South Sulawesi Province, an hour's boat ride over a choppy sea from the riverine harbour of Takalar Lama. Local boats are ill equipped to make this journey, out of the river mouth, through an often treacherous delta, across the open sea, and subsequently over the reef, sub-tidal and intertidal sections of the island. Flat boat keels are needed for these shallow sections of the journey, and do not perform well out to sea. When waves are high, and the river is swollen with rain, the crossing of the delta is exceedingly dangerous, a pair of vessels going down with loss of life in the two years since the RCL project has been operating.

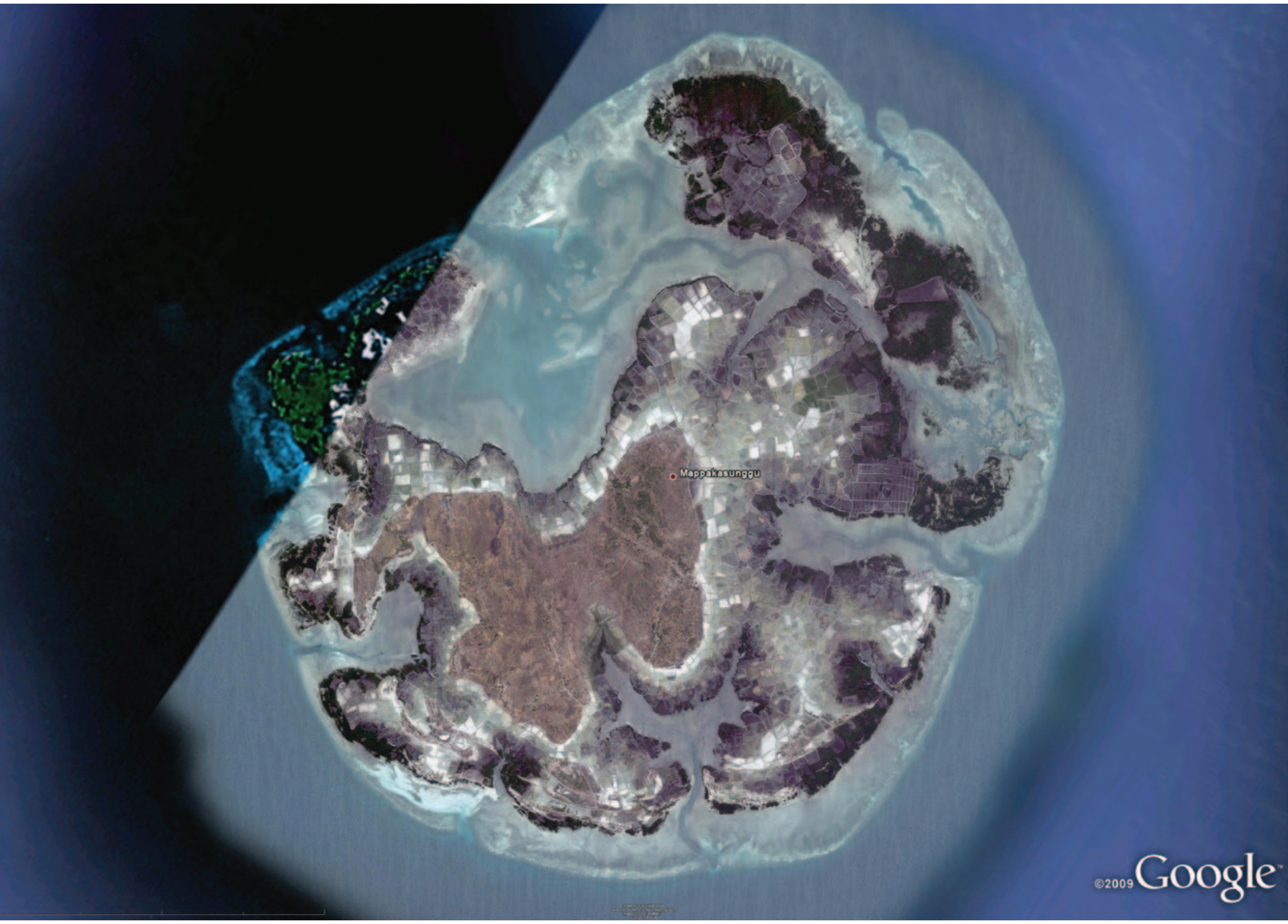
The island itself is divided into four villages (*desa*), each with a handful of sub-villages (*dusun*). The entire island consists of 23 *dusun* with 3300 people, most of whom live in the intertidal region, with traditional stilt houses constructed on foundations of driftwood, garbage and sand. Freshwater is severely limited in most villages, reliant on rainwater collection and purchased water from wells located on terrestrial sections of Tanakeke and nearby Bauluang Island during the dry season.

The island could be described as an overwash mangrove system, an atoll featuring a variety of sub-tidal and inter-tidal habitats, with upper-intertidal and hinterland systems only on a small fraction of the island. As such, mangroves are predominantly of the type found at lower tidal elevations, above mean-sea level, with very little back mangrove species.

1 Whitten


Sulawesi
Manado
Tolitoli
Gorontalo
P Togian
Donggala
Palu
Poso
P Banggai
L Poso
Map prepared by Peter Loud
Rantepao
Parepare
Kolaka
Kendari
© Peter Loud, 2007
P Buton
Baubau
P Tukangbesi


MAKASAR
CELEBES
SULAWESI SELATAN
FLORES SEA


Mappakasunggu
©2009 Google

3. Management Status of Tanakeke Island Mangroves

No mangrove forests on Tanakeke Island are currently under the jurisdiction of the Forestry Department. Rather, land where mangroves occur, as well as aquaculture ponds are owned individually by private owners with land-use planning and jurisdiction taking place at the District level by the Takalar Government. In terms of management, occasional interventions are made by the District level fisheries department, in both intertidal areas (ponds) and sub-tidal areas (seaweed mariculture).

Traditionally, mangroves have been owned by family groups, with the addition of several community owned mangrove forests (hutan pangandrian), which translates to “pantry” forests, or forests where the entire community can go to access food and medicine, but not timber.

Where mangroves continue to exist, they are managed by and large for the production of small-diameter timber, of the species *Rhizophora apiculata* and *Rhizophora stylosa*. Timber is harvested between 8-12 years of age, usually in a clear-cut area. Timber is used locally for fuelwood, housing and pier construction, fishing equipment, and as posts for floating seaweed mariculture. Timber is also sold to the mainland, for 500rp per meter ($0.04) for 4-6cm diamter pole. There are several charcoal makers scattered around the island, who produce charcoal in earthen mounds and sell the final product for 25,000 - 60,000 rp per 60kg sack, depending on whether they are able to sell directly to the mainland, or through a middle-man and transport agent.

Traditionally, once mangroves are cut, they are replanted with 5 propagules of the same species. This has driven the mangroves of the island to an ever increasing simplicity, a monoculture of Rhizophora spp., planted overly dense and resulting in low overall growth and biomass.

Non-timber forest products are accessible to all community members, who frequent tidal creeks at night in search of prawns (predominantly *Paneaus monodon*) and mangrove crabs (*Scylla serrata*), occasionally for local consumption but more frequently for sale to the mainland due to the high prices of these delicacies. Tidal creeks are highly valued ecosystem features due to this economic use. Additionally, communities collect a variety of molluscs, crustaceans, fish and even wading birds (Herons) for subsistence.

There is no formal, over-arching policy for the management of Tanakeke’s mangroves. Guidelines for mangrove management appear in documents from the Takalar Fisheries Department, but are no more than vague suggestions for the establishment of mangrove greenbelts. Occasional mangrove planting events are sponsored by District government agencies, but have not resulted in the establishment of functioning mangrove systems.

4. Definitions of the Management Area

Management of the mangroves of Tanakeke Island must be considered in connection with landscape constraints and human activities on the island which affect the intertidal zone. Although the focus of the plan will be on the mangroves, which exist at best between mean sea level and highest gravitational tide, this management plan needs to take into consideration the socioeconomic and ecological environments which are rapidly changing and have a great influence on the mangrove area. Failure to integrate mangrove management with a large context, would reduce the long-term functioning and resilience of the management system.

In taking this broad view of mangrove management, a few terms need to be described.

Landscape

This term is chosen as it refers to the totality of natural and human elements which make up a distinctive part of a region. Typically a landscape consists of a mixture of ecosystems; natural, agricultural or human settlement. The way in which these systems are arranged spatially - and the sorts of changes which they are undergoing temporally - determine the character of the landscape, and the values which human beings give to it.[1]

The properties of a landscape are the consequence of ecological, sociocultural and economic processes and their interactions with one another. The way of life of one group of people and the basis of their economy determines the relationship that they have to the physical place where they live, and to its biological properties. Lessons are being learned on Tanakeke with regard to how perceived options (aquaculture) based on manipulation of ecosystems are not always copacetic with long-term management due to environmental, social and economic constraints. Nature conservation, economic development and social equity need to be given equal consideration when developing a landscape level management plan.

Mangroves

Mangroves are tidal wetlands which occur on tropical depositional coasts between about mean sea level (MSL) and the level of the highest atmospheric tides (HAT). They are comprised of trees and shrubs of a characteristic suite of some seventy species world wide which show a varying tolerance of salinity. Below MSL perennial woody plants cannot survive and depending on the conditions of sediment type, water clarity and depositional rates, the sediment facies of the lower littoral may support associations macrophytic alga or sea-grasses or have no obvious macrophytic plant forms.

The longitudinal range which includes Sulawesi exhibits 36 true mangrove species, with a likelihood that a much smaller subset (12-18) could exist in the Tanakeke context, due to lack of significant freshwater input and transition to terrestrial habitat.

Tanakeke Island is known as an overwash system (define). There is evidence that certain ecotones (gradients of variation within the larger ecosystem) have been lost on Tanakeke, which may include foreshore mangroves (coastal pioneer species occurring at Mean Sea Level and including *Avicennia* spp., and *Sonneratia* spp.,) as well as systems which traditionally occur higher in the intertidal toward land. This loss seems anthropogenic in nature, due to community biases towards *Rhizophora* spp.

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1 GOI World Bank, 1995

***Adaptive Cycle*[1]**

The model of the adaptive cycle was derived from the comparative study of the dynamics of ecosystems. It is meant to be a tool for thought. It focuses attention upon processes of destruction and reorganization, which are often neglected in favor of growth and conservation. Including these processes provides a more complete view of system dynamics that links together system organization, resilience, and dynamics.

Traditionally ecology has focused on the concept of succession that describes the transition from a time when exploitation (i.e., the rapid colonization of recently disturbed areas) is emphasized to a time when conservation (i.e., the slow accumulation and storage of energy and material) is emphasized.

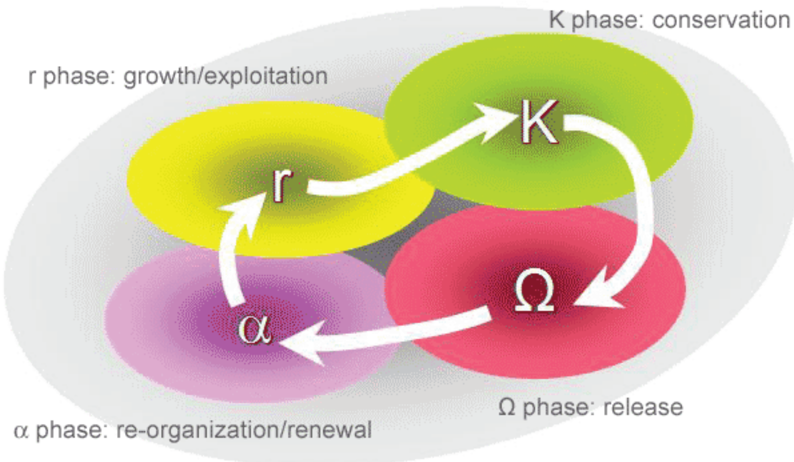
Our current understanding of ecological dynamics however indicates that two additional functions - release and reorganization - are needed.

An adaptive cycle that alternates between long periods of aggregation and transformation of resources and shorter periods that create opportunities for innovation, is proposed as a fundamental unit for understanding complex systems from cells to ecosystems to societies.

For ecosystem and social-ecological system dynamics that can be represented by an adaptive cycle, four distinct phases have been identified:

1. growth or exploitation (r)
2. conservation (K)
3. collapse or release (omega)
4. reorganization (alpha)

The adaptive cycle exhibits two major phases (or transitions). The first, often referred to as the foreloop, from r to K, is the slow, incremental phase of growth and accumulation. The second, referred to as the backloop, from Omega to Alpha, is the rapid phase of reorganization leading to renewal.



During the slow sequence from exploitation to conservation, connectedness and stability increase and a capital of nutrients and biomass (in ecosystems) is slowly accumulated and sequestered. Competitive processes lead to a few species becoming dominant, with diversity retained in residual pockets preserved in a patchy landscape. While the accumulated capital is sequestered for the growing, maturing ecosystem, it also represents a gradual increase in the potential for other kinds of ecosystems and futures. For an economic or social system, the accumulating potential could as well be from the skills, networks of human relationships, and mutual trust that are incrementally developed and tested during the progression from r to K. Those also represent a potential developed and used in one setting, that could be available in transformed ones.

Adaptive cycles are nested in a hierarchy across time and space which helps explain how adaptive systems can, for brief moments, generate novel recombinations that are tested during longer periods of capital accumulation and storage. These windows of experimentation open briefly, but the results do not trigger cascading instabilities of the whole because of the stabilizing nature of nested hierarchies. In essence, larger and slower components of the hierarchy provide the memory of the past and of the distant to allow recovery of smaller and faster adaptive cycles. A nest hierarchy of adaptive cycles represents a panarchy.

1 www.resalliance.org - Key Concepts

Adaptive Collaborative Management[1]

Adaptive collaborative management is an emerging approach for governance of social-ecological systems. Novelty of adaptive co-management comes from combining the iterative learning dimension of adaptive management and the linkage dimension of collaborative management in which rights and responsibilities are jointly shared. Complementarities among concepts of collaboration and adaptive management encourage an approach to governance that encompasses complexity and cross-scale linkages, and the process of dynamic learning. Adaptive co-management thus offers considerable appeal in light of the complex systems view. In this regard, adaptive co-management has been described as an emergent and self-organizing process facilitated by rules and incentives of higher levels, with the potential to foster more robust social-ecological systems. Key features of adaptive co-management include:

- A focus on learning-by-doing
- Synthesis of different knowledge systems
- Collaboration and power-sharing among community, regional and national levels
- Management flexibility

These features can promote an evolving, place-specific governance approach in which strategies are sensitive to feedback (both social and ecological) and oriented towards system resilience and sustainability. Such strategies include dialogue among interested groups and actors (local-national), the development of complex, redundant and layered institutions, and a combination of institutional types, designs and strategies that facilitate experimentation and learning through change. Other important themes in adaptive co-management include improving evaluation of process and outcomes, additional emphasis on power, the role of social capital, and meaningful interactions and trust building as the basis for governance in social-ecological systems.

1 www.resalliance.org - Key Concepts

5. Conservation and Development: Future Options for Tanakeke Island

The inter-relation between conservation, freedom from poverty and the consequential privilege of an educational, scientific and recreational appreciation of nature, forms the basis of an alternative philosophy of nature conservation which is embodied in the World Conservation Strategy of 1980 (IUCN). While this philosophy superficially appears to promote an ethic of conservation which is human centred, it is an honest analysis of the fundamental requirements of a physically and spiritually health existence.

There will always be pressure on the closed system of Tanakeke - to simplify and commodify its natural systems, in the name of economic progress. Compartmentalized and non-diverse systems are easier to comprehend and prescribe, but there is a fallacy that they are easy to manage and the near inevitability that systems will collapse when change comes, due to decreased resilience. The rapid development of aquaculture and subsequent total collapse of the endeavour provides one example of this. But stakeholders have not learned their lessons, a wholesale reliance on seaweed mariculture is now in operation, and future simplified ventures are surely in the cards, unless diversity and communal management of resources can begin to be valued.

Quick fixes such as eco-tourism, mangrove crab culture and grouper culture have all been proposed by individuals and agencies over the past two years that the RCL project has been inter-acting at Tanakeke, with the common denominator that no environmental, social or economic analyses have taken place to justify such developments. Processes, which do not hold communities (including the poor, vulnerable and women) as the central actors, and do not undertake holistic analyses and long-term resilience thinking, will likely meet with the same deleterious fate as aquaculture.

Even in the simplest of economic terms, the conversion of 1200 ha of mangroves to aquaculture ponds was a disaster. Supposing each hectare of converted mangroves supported a very low estimate of 25 adult (1kg) crabs per year, economic losses to the community over the 15 year period in which mangroves have been destroyed total 67,500,000,000 rupiah or about 8 million dollars. This value doesn't include any other fisheries, timber extraction or environmental services.

(RELATE THIS TO POPULATION AND ANNUAL INCOME)

In an isolated environment such as Tanakeke, a diversification of economic options, and enhancement of resources on which subsistence is based is required to ensure basic human needs and environmental health. Programs which focus on building understanding of local systems and development of critical thinking skills are essential to allow Tanakeke to develop in an appropriate fashion based on actual opportunities and constraints. Involvement of government and industry needs to hold community involvement and resilience central to its tenants, in order to avoid the pitfall of poorly planned development which has life or death consequences to humans and the environment.

Section 2.0 Status of the Bio-physical Environment

2.1 Introduction

The most significant physical processes influencing the growth and distribution of mangroves is the inundation (frequency and duration) and drainage of tidal water. These processes entirely dominate sections of the island without terrestrial components. Where there is the presence of land - tidal hydrology is still the dominant factor, as there is little terrestrial runoff of either fresh water or sediment.

Rainfall provides a periodic influence, predominantly diluting soil salinities. Overall, however, freshwater is limited, as are nutrient laden sediments. This, coupled with an underlying geology consisting of calcium carbonate (dead coral skeletons), gives rise to a low-growth scenario for mangroves, where mangroves exist due to appropriate tidal inundation duration and frequency, but pale in comparison to biomass levels found on the mainland such as alluvial mangrove forests.

Coral reefs which surround the island act to dissipate wave energy - protecting adjacent subtidal environments (seagrass beds, seaweed mariculture), intertidal environments (max forests, tidal mudflats, aquaculture ponds and settlements) and terrestrial environments (beach forests, agricultural lands and human settlements). The condition of the coral reef, however, is both structurally and biotically degraded, providing a lesser degree of environmental goods (fish) and services (protection).

2.2 Geomorphology

Get from Whitten

2.2.1 Intertidal topography

The range of soil-water conditions to be found in any location is determined by the local intertidal topography. To a large extent the intertidal topography is predictable, and are termed *tidal land units*[1] which are sub-units of a *tidal land system*.

The mangroves of Tanakeke belong to the following tidal land systems: non-estuarine island, and perhaps open coast.

To further describe this specific tidal land system, the following tidal land units may be considered;

1. eroding bank
2. prograding bank
3. apparently stable bank
4. flood levee
5. subsiding bank
6. tributary drainage
7. beach ridge

As a non-estuarine island, the majority of mangrove areas are on an apparently stable bank. They accrete sediment slowly due to deposition on high tides, but draining tides and tidal creeks act to erode these sediments back to sea. On the open coastline, accreting bank, eroding bank and beach ridge tidal land units may occur, but to a much lesser degree than open coastline on the mainland, where significant sediments are contributed to the coastal system vis-a-vis major rivers. Typically open coastlines are distinguished by soil salinities, which are at or close to the salinity of seawater (35ppt) and exposed to periodic wind and wave action. On accreting shorelines, the species which colonizes first are typically *Avicennia marina* or *A. alba,* and *Sonneratia ovata* which forms a belt of variable width. This may have been lost on Tanakeke Island (as discussed above). *Rhizophora apiculata* would then be found behind this belt, with an assemblage of other

1 GOI - World Bank, 1995

2.3 Hydrology

Tidal exchange is the dominant hydrological process on Tanakeke Island which effects the distribution and growth of mangroves. Tanakeke Island experiences a diurnal tide - with one high and one low tide per 24 hour period each day of the year. Flood tides currently occur during the day in the months between February - April, with low-tide being reached during nightfall. The opposite conditions exist in the months between July - September when low tides occur throughout the day, with peak inundation at night. This gives rise to peak dessication levels, and interstitial salinities in July-Septmber - coinciding with the dry season (low-cloud cover, low rainfall). Rainfall is monsoonal with a wet season from December until April.

Resultantly - flora and fauna in the intertidal region needs to be adapted for high variation in water and especially soil salinities, as well as associated edaphic conditions such as temperature, oxygen (and dissolved oxygen), pH, and concentration of Hydrogen Sulfide (a by-product of anaerobic respiration).

Tidal range for the island is around 1.3 meters, which allows for significant surge through tidal creeks, and drainage when there are no disturbances. The exchange of tidal waters, and patterns of sedimentation, has been significantly altered in recent years with the development of 1200 hectares of fish ponds and their associated dike walls and artificial drainage channels.

2.4 Vegetation

Patterns of vegetation have been strongly influenced by geomorphology, climate and hydrological processes. The lack of freshwater, and high range of interstitial salinity has favored mangrove species with a tolerance to salinity, however, due to the lack of a back mangrove and higher intertidal elevations, salt tolerant species which typify salt-flats in the back mangrove are largely absent, except on artificially raised surfaces (dike walls).

2.4.1 Autecology (Individual Species Ecology)

Rhizophora apiculata is by far the dominant mangrove tree species existent on Tanakeke Island, due to anthropogenic selection. This is followed by *Rhizophora stylosa*. All other species of mangroves are either tolerated, or removed and replaced with Rhizophora where possible, with no species aside from *Rhizophora* being valued by local communities. Following is a table of mangrove species, and their intertidal position on the island.

Mangrove Species	**Intertidal position on Tanakeke**
Rhizophora apiculata	mean sea level (lower mangrove) to low-high tide
Rhizophora stylosa	mean sea level (lower mangrove) to low-high tide
Ceriops tagal	mid-mangrove
Sonneratia alba	lower to mid-mangrove (absent from coastline)
Sonneratia ovata	lower to mid-mangrove (absent from coastline)
Avicennia marina	mid-mangrove
Avicennia alba	mid-mangrove
Brugueira gymnorrhiza	mid-high mangrove
Pemphis acidula	dike walls and terrestrial interface
Lumnitzera racemosa	dike walls and terrestrial interface
Exoecaria agallocha	dike walls and terrestrial interface
Acanthus ilicifolius	terrestiral interface (scarce)

Due to its position in Wallacea - Sulawesi may contain a very high diversity of mangrove species - containing both those species common to Kalimantan as well as species present in the smaller island groups of Sulawesi

Maluku and again the large land mass of Papua. Tanakeke, to be sure, should contain fewer species than mainland Sulawesi, due less so to isolation (not too far off shore) and moreso to lack of freshwater influence and therefore lack of coastal backswamp/hinterland fringe species.

However, the paucity of mangrove species expressed above is also strongly a result of mangrove conversion and environmental change implemented by the islanders themselves over time, coupled with the loss of mangrove habitat and diversity on nearby mainland Sulawesi.

2.4.2 Community Ecology

Rhizophora apiculata grows in vast monospecific stands on the island. There is clear evidence that this species is selected for by the local community. A one hectare stand of *Avicennia alba* growing adjacent to the transmigration agency's aquaculture area was cleared in 2010, and entirely replanted with *R. apiculata*.

The nearest potential reference forests in the region occur on smaller islands around Selayar island towards Take Bone Rate as well as the small islands of the Pangkep District. One most of these islands, the coastal foreshore, where it contains mangroves, contains a few members of the pioneering genus of mangroves, *Avicennia* and *Sonneratia*. These are lacking in most parts of Tanakeke Island, with the exception of the abandoned shrimp pond complex which lies between the sub-villages of Rewatayya and Kalukulang and the sea. These ponds have been abandoned for 6 years, and are growing back with 3-4 species of mangrove. Because the community is in desperate need of mangrove cover (as a bioshield to reduce the impact of seasonal storms), they are allowing Avicennia to re-colonize this lower mangrove area. On other parts of the island, these "less desireable" pioneer species would be replaced with Rhizophora given the chance.

Behind the vast *Rhizophora* stands, on slightly elevated ground, one comes across assemblages of *Bruguiera gymnorhizza,* followed by *Ceriops tagal*. These would have likely formed more robust stands without human intervention. The occasional *Sonneratia ovata, Sonneratia alba, Avicennia marina* and *Avicennia alba* can also be found in smaller pockets and as individuals around the island, not always at slightly higher elevations.

2.5 Fauna

A participatory ecology survey was undertaken in year one of the RCL program, in order to uncover a variety of vertebrate and invertebrate mangrove fauna in the forest around Lantang Peo village. In a single morning, the community went into the mangroves to collect as high a faunal biodiversity as they could find. Prizes were awarded (mask and snorkel) for the most diverse collections. One of each species was preserved by the University of Hasanuddin for a master collection of the island, while all other species were released (except for the highly edible ones).

The community collected;

Anthropods	16 (including 11 types of crab)
Aves (Birds)	27 (visual confirmation only)
Reptilia	2
Fish	9
Bivalves	14
Gastropods	19
Miscellaneous	6

This is surely not an inclusive collection, but revealed a high level of diversity for a single, large group collection, building awareness amongst community about the abundance of life in their mangroves.

2.5.1 The value of remnant forest habitat

Looking at studies by Constanza and Ronnback, in areas with underdeveloped fisheries, the annual value of natural products and ecological services generated by mangroves probably lies in the order of US$10,000 per ha mangrove. In areas where commercial and subsistence fisheries are well-developed, the value would be around $20,000/ha/yr. It should be emphasized that these economic values are ballpark estimates. From an ecological-economics perspective it can be misleading to generalize about the value of an ecosystem. Rather, site-specific studies should be done in order to account for non-linearities, thresholds and discontinuties in dynamic ecological and socioeconomic systems. It is, however, clear that considerable economic benefits can be gained by restoring mangroves, which cost approximately US$100-1000 per ha. Moreover, the significant economic value of mangroves places serious doubt on the low value paid by communities and shrimp aquaculture prospectors per hectare of pond area.

If considering additional wildlife habitat, Ronnback places a value of $140 per hectare,, but this is contingent again on use of the area, which would increase if substantial tourism were involved.

2.6 Discussion: Opportunities and constraints

2.6.1 Coastal land uses

Tanakeke is surrounded by a shallow but rough sea, and the fishing fleet is ill-equipt to make a full time living in these waters. The coral reef has undergone significant damage, as the bomb and cyanide fishing center of Indonesia is only a district away (Barrang Lompo and Barrang Cadi islands, Maros). This degraded reef can not provide significant income alone for the island community, nor can damaged coral be easily or cost effectively repaired. The sub-tidal region is nearly entirely occupied by seaweed farms, providing the islanders with their main income. Studies on the impacts of this livelihood on other sub-tidal values have been performed in the region, which show they are negligible, but there must be a decrease in seagrass productivity due to shading from seaweed farms, and potentially an impact on fisheries value.

Mangroves from the intertidal region, therefore, play an increasingly important role in subsistence fisheries production. Currently - 1200 of 1776 hectares are unproductive, therefore, it is imperative that these coastal lands be rehabilitated into functional mangroves. Improved management of existing resources, and management of healing mangrove areas must follow-suit.

What little land is available on Tanakeke island is now being considered for more intensive, organic vegetable production, to provide islanders with economic opportunities and improved nutrition.

New settlements occur both on land, as well as in the intertidal region, and could pose a future threat to natural systems. Certainly issues of trash and sewage disposal are prevalent in all settlements, as is the issue of fresh water availability. Lack of fresh water, as well as area for expansion of settlements may prove the limiting factors for the growth of human populations, who seek higher qualities of life, as well as employment on the mainland. Communities prioritize fresh water as a development need, but the carrying capacity of the island may have already been met with relation to freshwater availability. Studies on this issue should be considered for the future.

2.6.2 Sea level rise

There is anecdotal evidence of sea level rise around the island. High tides are inundating settlements which were previously dry year round. However, it is to be cautioned not to associate flooding on all parts of the island with sea level rise. For instance, the paired sub-villages (dusun) of Rewatayya and Kalukuang are experiencing increased incidence of flooding. There has been redistribution of sediment as well, and areas of higher ground, such as Tanjung Pandan (Pandan Point), previously supratidal, now occur below mean sea level. This should not immediately be associated with sea level rise, but rather change which has occurred due to conversion of hundreds of hectares of mangrove forests which once protected this village from direct wave and wind energy from the West. Sea level rise may, however, be a contributing factor, further studies of which should be considered for Tanakeke, as a low-lying and highly vulnerable island.

In the event that sea levels do rise, mangroves will have to compensate, or disappear. Mangroves can compensate in two ways. There is evidence that mangrove can trap sediment and raise themselves up vertically - to keep apace with rising seas, although there is no evidence that they can keep this up at the predicted rate of current SLR. Mangrove communities can also migrate inland, with a change in species composition at higher substrate heights, and eventually colonization of what are currently terrestrial hinterlands. However, it must be remembered that the terrestrial system on Tanakeke is minimal. As sea levels rise, there will likely be an increase in sub-tidal and intertidal habitats below mean-sea level which will not support mangrove growth. Understanding how sea-level rise will affect the island, including human settlements, and maintaining as high a biodiversity as possible - in order to effectively adapt to change are two suggested only courses of action.

2.6.3 Ecological mangrove rehabilitation

To date, over 200 hectares of abandoned shrimp ponds have been rehabilitated on Tanakeke following the principles of Ecological Mangrove Rehabilitation. Communities, including over 50% women, have been involved in assessing, planning, designing and implementing these projects.

In cases where dike walls are still in tact, the walls have been strategically breached to allow for improved tidal flows (inundation and drainage). Meandering tidal creeks have also been hand dug towards this purpose.

In cases where dike walls are already deteriorated, no hydrological amendment has been made.

Measurements both in newly abandoned ponds, as well as 5-8 year old chronoseres (ponds which were abandoned and have already experienced natural revegetation) indicate that a majority of pond bottom area is already at an appropriate height for mangrove colonization. Trials are being performed to determine rate of colonization by various species, and correlated not only with substrate height but also substrate type. Marine tolerant grasses are being transplanted for trials on propagule capture and improvement of edaphic conditions.

Mangrove planting is taking place using one of the following four methods;

1. Planting of mangrove species raised in polybags
2. Direct planting of mangrove propagules
3. Human assisted propagule distribution (distribution of propagules by hand, primarily with pioneering species)
4. Planting of marine tolerant grasses to capture mangrove propagules and improve edaphic conditions.

A major emphasis is being placed on method #3, using propagules from pioneering species of mangroves (Avicennia spp., and Sonneratia spp.)

Monitoring is being undertaken quarterly for one year after intervention, and annually in years 2, 3, 4 and 5. A multi-disciplinary monitoring team from MAP-Indonesia, UNHAS and local community undertake quantitative monitoring (methodology attached as an **appendix**) and analysis. Community groups will soon be engaged in a more simplified version of monitoring for qualitative change (methodology under development).

2.6.4 Some key values of Tanakeke's mangroves

Below are discussions on four major values of the mangrove system; a) forestry, b) fisheries, c) protection of shoreline and settlements, d) biodiversity.

2.6.4.1 The potential value of Tanakeke mangroves for forestry

Mangrove forests have a high potential to meet particular forestry needs. The hardwood, rich in tannin and resistant to decay, that characterizes species of *Rhizophora* spp. (bakau) and *Bruguiera* spp. (tongke) is highly valued for construction, fisheries equipment, fuelwood and charcoal.

On Tanakeke Island, all of these uses are evident from Rhizophora poles, including preparation and export of timber, fuelwood and charcoal to the mainland. However, this timber resource is severely undervalued, with low timber prices (500rp/m) and charcoal prices (400-1000rp/kg) being paid to producers.

Poor forestry practices, of clear-cutting, and replacement by overly dense plantings, have decreased the growth potential and overall biomass of Tanakeke's forest. When compared with algorithm's of low growth forests across Indonesia, Tanakeke's current Rhizophora resource lies on the lowest possible growth curve. Indeed, lack of fresh water, organic nutrients and a substrate consisting largely of calcium carbonate contribute to low growth potential, but poor forestry practices are also a major factor.

There is no avoidance of the need for Tanakeke Islanders to harvest and use mangrove timber, but advances in community based silviculture are essential in order to reverse the trend of forest degradation for future generations of use. Silviculture is discussed in greater detail in Part C, sections 5 and 6.

2.6.4.2 Conservation of functional linkages (coastal fisheries and fish and shrimp fry production)

The export of nutrients from mangrove communities to the marine environment at Tanakeke takes place through two pathways, tidal export of litter and the dissolved and particulate products of decay within the mangrove forest to the water column and the direct flow of energy ingested by larger organisms (fish, birds, crabs, prawns) which spend part of their life history in the mangrove environment (for food and shelter) before returning to other systems.

The range of productivity of Tanakeke mangroves, and its contribution to near-shore fisheries has not been quantified. Primary productivity by mangroves, as well as algae in the water column adjacent to mangroves certainly supports near-shore fisheries. The extent of this support should be studied, as should the extent to which restored mangroves enhance a functional fisheries equivalent.

2.6.4.3 Protection of the shoreline

The potential for mangroves to buffer erosion on shorelines is a major justification behind greenbelt legislation in Indonesia. However, mangroves ability to buffer erosion is inconsistent. When mangroves are lost, erosion may indeed be exacerbated, but there are also cases where adult mangrove systems succumb to larger scale erosive processes, such as change in current pattern, and mangroves, large or small, are claimed by the ocean.

Nonetheless, mangroves do serve a protective function on Tanakeke Island, reducing the impact of wind, waves and currents. One example is the village of Rewatayya/Kalukuang, threatened seasonally by wind and waves, and an ever eroding shoreline since the conversion of mangroves to aquaculture ponds. The cost incurred in terms of damage to the village can be calculated, and a per hectare cost ascribed to the value of mangrove forests in terms of protective function., 2.6.4.4 Conservation of Biodiversity

Biodiversity has been defined as the richness of biological species as well as the diversity of gene pools and ecosystems within which the species are found in nature.[1] Biodiversity is gaining ever-increasing recognition not only to be intrinsically valued, but ascribed with an economic value. For instance, the carbon from a carbon sequestration project can now be valued up to 10 times higher based on whether or not indicators of biodiversity are significantly enhanced due to the intervention.[2]

Floral biodiversity has been decreasing on Tanakeke Island due to human preferences for *Rhizophora* based timber products. Alternate mangrove species are actively replaced with Rhizophora, lending to a simplification of the system. A ripple effect must occur, as organisms associated with the lost mangrove species must adapt to new conditions or perish. Bio-physcial processes are also affected by the replacement, and the overall range and resilience of mangroves is decreased.

Options, in terms of utilization of floral species, are also decreased. A suggested course of action on Tanakeke is recognition of species loss, and incidence of rare species, and development of zone in which biodiversity is promoted and protected.

2.6.5 Community Based Mangrove Management

There still exists skepticism amongst government agencies about whether coastal villages can sustainably manage and protect mangroves. Indeed, the success of communities in managing their forests depends on many factors, which until recently had not been scientifically analyzed. Research from Thailand[3] presents evidence of successful mangrove conservation and management by two coastal villages in Trang province, southern Thailand. Using interdisciplinary methods including interviews, discussions, quantitative forest surveys, and institutional analysis, the history of how these two communities gained rights to manage the mangrove forests, and the subsequent positive biological outcomes associated with their management was described. Local villages developed their own governance management institutions over the forest, and as a result, stand structure was superior in community-managed mangrove forests than in the open-access state forest. In these villages, community management was successful due to the combination of the following factors;

- managing these forests was that the resource was necessary to local livelihoods and was becoming scarce;
- the communities enjoyed autonomous decision making and had a high degree of social capital;
- the forest and user groups were well defined and monitored;
- effective leadership was present in the villages to apply sanctions and resolve conflicts;
- there was substantial assistance from an external non-governmental organization, which served as a bridge between the villages and the government.

It is not suggested, in the Indonesian context, that autonomous management of mangroves take place, without significant collaboration of stakeholders. However, it needs to be recognized that local communities are the central stakeholder in determining the success of mangrove management, due to their day to day interaction with the resource, innate skills and knowledge of utilizing and managing the system, and self-interest.

It needs to be stressed that any community is comprised of at least 50% women, and that women's roles in mangrove management need to be ensured - as equal to, or more than the roles of men. This means equal involvement in planning, implementing and monitoring a mangrove resource, equal access and equal control.

1 World Bank, 1992
2 Green Development Mechanism, 2011
3 Sudtongkong, C., and E. L. Webb. 2008.

Section 3.0 Socioeconomic Conditions and Trends

3.1 Introduction

The purpose of this section is to describe the sociocultural and economic aspects of the communities living on Tanakeke Island and their impact on coastal natural resources with specific attention to the intertidal environment.

There are x dusun on Tanakeke Island, divided into 4 villages (Mattirobaji, Macinibaji, Rewatayya and v). 12,000 people live on the island. There is limited fresh water on the island, and difficult access to the mainland for basic household needs. Locally caught and collected fish and seafood are the main protein source, with very little fresh vegetables or fruit consumed. Rice is a daily staple, but is purchased at significant cost from the mainland. Living conditions are difficult on the island at best, and human activity is already the single most important critical environmental parameter to consider when developing a coastal management plan.

3.2 History of coastal settlement in Tanakeke

It is told by the inhabitants of Tanakeke themselves, that their island is one of outcasts from the mainland, exiled from their communities for a variety of reasons. To be sure, the older inhabitants were seafarers, trading turtles to Bali. Until recently turtle hunting, fishing, and sale of mangrove timber made up the majority of the livelihood opportunities on the island.

The inhabitants are nearly all of Makassarese ethnicity.

Augment with Prof Marzuki's presentation and info from RCL

In the 1990's development of aquaculture was supported both by the fisheries department as well as the transmigration department. It was in this period that large-scale conversion of mangroves took place. However, involvement in aquaculture was not long-lasting on Tanakeke, and by early 2000 the majority of the population became involved in seaweed farming as the major livelihood, supported by small scale commercial and subsistence fisheries. Inhabitants from the terrestrial portion of the island have also been involved in farming of annual crops and coconuts, with only the recent development of organic agriculture supported by the RCL farmer field school program.

3.3 Community Organizations in Tanakeke

When the RCL project started, one single community organization had members in most sub-villages from the island. This organization, known as PUKAT, was led by an individual from outside of Tanakeke. During the RCL project, PUKAT experienced a rift, with some members, including the former leader, leaving and forming their own organization. The two organizations still exist, but have much less involvement in sustainable development programs on the island.

In the paired dusun of Rewatayya and Kalukuang, a woman's group was formed by a motivated school teacher. This group is involved in mangrove restoration, livelihood development and literacy. They are currently the main partners on mangrove rehabilitation and future management with RCL.

A similar women's group was formed by the NGO partner of RCL, Yayasan Konservasi Laut, in the dusun of Tompotanah.

Small field school groups have also been formed recently around farming, and mangrove silviculture.

3.4 Land Ownership

Land ownership on Tanakeke is somewhat well defined, which belies the fact that there is very little "land" to own in the classical sense. Rather, communities and family groups have traditional claims to mangrove areas, much of which was converted to aquaculture ponds, and thus granted use rights. A number of families also have ownership titles over these intertidal areas, granted by the District level government land office. There is also the new issue of seaweed farm plots, which have been divided traditionally, over the sub-tidal areas where seaweed is raised.

Land use and ownership conflicts exist on the island, but are usually resolved, thanks in part to the strong role and authority of traditional village leaders, who regulated Makassarese society before the development of national village delineations (dusun and desa). After evolution from settlements to Dusun and Desa, the original traditional leader was usually elected to become the Kepala Dusun or Kepala Desa. Nowadays, general elections are held for these posts. In 2010, Tanakeke's two Desa were divided into a total of four desa, all of which are now governed by their own village governments. This has given rise to some new land use issues, such as the delineation of a traditional *hutan pengandrian* (community mangrove forest).

When working with communities in the RCL program on Ecological Mangrove Rehabilitation, a prime concern of communities was whether or not they would lose land title, or use rights over rehabilitated ponds. They asked for clarity, if the Department of Forestry would claim newly forested lands. Similar concerns were raised with regard to the District government and also NGO partners of the RCL program (MAP, YKL, OXFAM and RCL itself).

3.5 Community perceptions of coastal resources, use and potential (from Sonjaya, 2011)

3.5.1 Mangrove System

Communities on Tanakeke have been living amongst and using their mangroves since the beginning. Mangroves were used for firewood, medicine, construction and fishing equipment. More recently, knowledge on use for medicine has waned, while timber use has increased since the large-scale development of seaweed mariculture. Communities understand that mangrove also provide important environmental services primarily in reducing the impact of waves and as habitat for fish, crabs and prawns. In terms of mangrove management, the common Makassarese Punggawa-Sawi relationship is employed, where a mangrove area might be owned by a wealthier individual or family, who employs loggers to fell and process *his*[1] timber for sale. Mangroves are commonly clear-cut, and then replanted with 5 propagules of *Rhizophora* spp., per tree felled. Before the RCL program, communities identified only the following problems with this system;

- damage caused by a marine worm (*turutusuk*) which bores into mangrove roots and damages the tree,
- changing patterns of erosive currents, which sometimes claim areas of mangrove forests
- illegal logging

Communities do not feel that logging can be a sustainable industry, as they need to wait 10 years before harvest, and thus need alternative livelihoods between logging cycles. This final perception contributed largely to the large-scale development of fish ponds discussed below.

1 Punggawa are all male.

3.5.2 Aquaculture System

Aquaculture began on Tanakeke Island in the 1980's, by clearing mangrove areas and constructing ponds with voluntary labor - a system called "Akio." Community members learned how to fish farm on the mainland, working as seasonal laborers on aquaculture ponds until they developed enough skills and capital to manage their own ponds on Tanakeke. After a while, Akio was replaced with use of excavators, with pond bottoms dug deeper and dike walls built higher, wider and more dense. Over 800 hectares of ponds were created by the community, which were managed for shrimp and milkfish production for periods of 3-10 years. In the early 2000's, productivity fell, inputs grew more costly, and shrimp disease became endemic. At a certain point, shrimp disease became the limiting factor to pond operation, and most ponds fell into disuse. Today 95% of community ponds on the island are disused.

There also exists 400 hectares of ponds developed by the transmigration department, but data for these ponds has not yet been collected under the RCL program.

3.5.3 Seaweed Mariculture

The culture of carrageenan seaweeds began on Tanakeke in the 1980's, but remained small-scale. In these early days, communities did not know how to overcome problems of grazing by herbivorous fish, changes in water temperature and outbreaks of parasitic algae. In the 1990's, communities spent more time developing seaweed as a major livelihood, and this led to a significant increase in income generation on the island. Communities point to indicators such as a greater proportion of its members being able to make the pilgrimage to Mecca, the use of ironwood and other tropical hardwoods from mainland Sulawesi and Kalimantan for house construction, and incidence of younger brides and grooms. Children also began to attend school as parents could both afford school fees as well as the opportunity cost of lack of child labor to help in daily subsistence. To this day, mariculture of seaweed is the main livelihood base of the island, coupled with capture fisheries. The success of seaweed mariculture also contributed to the disuse of aquaculture ponds.

3.5.4 Agriculture

Only two *dusun* (sub-villages) on Tanakeke, Dande and Danre, have significant dry land and fresh water resources for agriculture. All other communities purchase agricultural products from the mainland, predominantly rice, chilli peppers, and occasional additional vegetables. Farmers on Dande and Danre have rudimentary farming skills, do not use chemical fertilizers, but also do not create adequate organic fertilizer. (this is changing with the RCL farmer field school program). The most commonly raised crops include; cassava, banana, squash, red corn and white corn.

Communities in the intertidal region also grow squash and occasionally cassava on the dike walls of fish ponds.

3.5.5 Capture Fisheries

Communities on Tanakeke have fished, in various ways, since their habitation of the island. Subsistence fishing is practiced by all families, while some families are engaged in commercial fishing. All aquatic systems are exploited, including mangroves, seagrass beds, tidal creeks, coral reefs and to a limited extent, the open ocean. A variety of techniques and tools are used, from hand-capture of crabs, prawns and molluscs, to a variety of nets and traps, and also hook and line.

3.6 Gender analysis

3.7 Economic development

Tanakeke, by nature of being an island with no safe, public transportation options to the mainland, is marginalized from mainland South Sulawesi. Services such as health, transportation, education, electricity, water, sanitation, waste management, fisheries/forestry/agriculture extension are inadequate or wholly lacking.

Boat transportation between villages is accomplished with a variety of boats, some powered by fuel with some hand paddled. Boat transportation to the mainland is risky, as boats of Tanakeke have flat keels, inadequate for crossing the open sea in rough weather, especially upon entrance to the river mouth through a dangerous waves and currents sweeping over a shallow delta. No boats are equipped with safety equipment, and many islanders can not swim. Piers on the island and on the mainland, would alleviate much of the danger. The District government commissioned a pair of fiberglass ferries to service the islands at a cost of over $200,000 US, however these have never been put into operation.

School attendance beyond primary level is low, and children must relocate to the mainland for highschool education.

More............

3.8 Discussion: Socioeconomic Pressures on Land Use and Habitat Protection

After several decades of consistent population growth, fuelled by marriage, and transmigration, there is a substantial, young and fast growing population on Tanakeke Island. Availability of fresh water and terrestrial land place limits on growth of the population, who seek nearly their entire livelihood in aquatic environments. Land use and ownership conflicts are rare, in this largely homogenous society, with traditional land ownership and conflict resolution mechanisms still strong.

With regards to utilization of the coastal zone, there are no areas on the island or adjacent to it which are not economically exploited by the islanders. All systems are in a degraded condition compared with previous states (off-shore fisheries, coral reefs, seagrass beds, mangroves), with the exception of the littoral sub-tidal which has been, and is being effectively managed for seaweed production - over the past several decades.

There is significant interest, amongst local communities, in restoring and improving management of the mangrove areas, to enhance and enjoy a variety of economic and ecological values. Charcoal production is minor component of the islands economy, which provides low economic returns to a small percentage of the population, with inordinate destruction to mangrove resources. Most of the island residents are against the production of charcoal. RCL has investigated if charcoal production can be sustainably and equitably managed on the island, by improving efficiencies and markets, the results of which are discusses under sections 5 and 6. There is also interest economic development in new sectors such as organic agriculture and eco-tourism, which are being trialed and analyzed under the RCL project.

Section 4.0 Administrative Structures and Practices

5.0 The Need to Manage for Sustainable Utilization & Conservation

The need for Tanakeke communities to continue to use mangrove timber for fuelwood needs is undeniable, as is the need for management of timber harvest to improve overall biomass production and ensure a sustainable supply of timber for future use and ecosystem service. Improved management will involve the improvement of silvicultural practices (managed felling), as well as the delineation of no-take zones (hutan pengandrian and greenbelts), which a portion of the larger task of an integrated management effort. The other side of this silvicultural management coin, is improved efficiency in the use of mangrove timber, which the RCL project is attempting by introduction of improved cookstoves to each partnering dusun, and management recommendations on the degree to which charcoal production is a viable industry on the island.

The reality of mangrove charcoal production on Tanakeke Island, is that a very small portion of the community is involved in its production. This small industry is not very lucrative (40,000rp per 60kg sack to producers, 70,000rp per 60 kg sack to wholesalers), nor is it very efficient. The practice is, however, disproportionately destructive in comparison to its benefit, resulting in the total clearing of 36 hectares of forest per year for use by only 7 producer and 2 wholesaler families.

A field school has taken place in Kampung Beru, with all seven charcoal producing families in that area (the Rewatayya Village area), to better understand the timber needs of mangrove charcoal production, opportunities for improved efficiency, and potentials for improved marketing.

This section uses case studies on mangrove silviculture and charcoal production to better understand growth requirements and mangrove coverage needed to supply a small or medium scale charcoal operation. The results of this report will be used by the RCL team to understand appropriate management interventions for Tanakeke, whether there is a feasible future for charcoal production at any scale, and if silvicultural practices as described below (taken from Malaysian and Indonesian case studies) can be applied or adapted on Tanakeke for non-charcoal, timber harvest.

5.1 On Charcoal Production

Members of the Rhizophoracea family (*Rhizophora apilculata, R. mucronata,* and *Bruguiera gymnorhizza* have good potential as raw material for charcoal. The charcoal made from these species has special qualities that are similar to those of Bincho charcoal in Japan, such as a high specific gravity, hardness and high combustibility. In Asia, Rhizophoracea charcoal has a good reputation as the third most prized charcoal, behind Japanese Oak and Chinese Onshyu.

In Aceh and Riau provinces, mangrove charcoal is produced under the Government of Indonesia's Wood and Non Wood Products Utilization Licence (HPHH); Hak Pemungutan Hasil Hutan. Traditional charcoal production is also customarily permitted in West Kalimantan province. There have been great strides in this region in terms of sustainable charcoal production based on appropriate silvaculture practices, spear-headed by Yayasan Dian Tama and the Integrated Charcoal Training Center in Toho. The traditional method of charcoal production is known as the "Panglong System" adapted from hundreds of years old practices from the Chinese. Improvements to kiln type have taken place over time in Indonesia, where four main types are now distinguished; Chinese, Malaysian, Indonesian and Japanese. A variety of new Japanese kiln types have been developed for specific use in Indonesia, for various timbers as well as bamboo, through consultation and skills trading with Charcoal Sinsei, facilitated by the Yayasan Dian Tama, the Integrated Charcoal Training Center and also Yayasan Dian Desa and the ARECOP network working out of Yogyakarta.

Indonesia export figures for the charcoal Industry are spotty and unreliable – much of the production potentially selling over the straits of Malacca (to Singapore and Malaysia) without record. Nonetheless the following figures are representative of government accounts.

Year	Production (tonnes)	Revenue (USD)
1993	330,000	$33 million
1998	83,000	$13 million

In the early turn of the millennium, Thailand outlawed production of charcoal from mangroves. This shifted much of the regional burden of production onto Indonesia, as well as Malaysia, who operate the most well known mangrove silvicultural system in the world in the 40,000 hectare Matang Forest Reserve, which is mainly geared to production of charcoal. Much of the silvaculture practices recommended in this report originate from management procedures in Matang.

On Tanakeke Island – charcoal production is mostly confined to one dusun (community) with occasional producers scattered amongst additional communities. The main producing community is called Kampung Beru, where two large extended families (made of seven smaller family units) practice traditional charcoal making using an above ground mounding system. This system was studied during a mangrove charcoal field school, where simple technological improvements to increase efficiency were also learned (addition of chimney pipe to mounding system, making and use of small kilns from used oil drums, collection of carbonization vapours to make pyroligneous acid). This field school process also provided the opportunity to understand timber use needs, women's involvement in the small charcoal industry, and current marketing practices, to help inform future recommendations.

5.2 Sustainable Forest Management for Timber Utilization

Forests in general provide renewable and valuable resources. Viable management systems can provide continuous production while maintaining various other vital functions. In the case of the Matang Mangrove management system, 75% of the area is considered production forest while 25% of the area is preserved to emphasize environmental protective functions, such as;

- protecting the river banks from excessive erosion;
- minimizing the impact of clear-felling operations on the marine ecosystem;
- preventing unnecessary loss to the most accessible productive forest areas;
- acting as a source of propagules for the immediate felled areas; and
- providing a pleasant landscape for visitors and tourists.

(Malaysian Timber Council, 2009)

Thus, in the Matang example, production coexists with conservation. The production forest, as well, is subjected to rigorous management, with plans updated routinely every 10 years. At the heart of these plans is the accurate determination of the range of the forest's fluctuating resource potential.

Although the original work of calculating volume estimates and yield predictions for mangrove timber took place in Matang, Malaysia, JICA, in their long term program in partnership with the Indonesian Forest Department, developed formulae for these predictions, as part of their studies into sustainable management models for Indonesian mangrove forests, the reports of which are the main resource for this section.

5.3 Wood Volume Calculations

The Volume Table for *Rhizophora apiculata* is based on an analysis of 104 samples. Samplings were carried out in Central Java, Bali, and West Papua. After cutting and measuring each tree, analysis of stem volume was made by using the Sumalian equation. Then, stem height, diameter at breast height and volume were analyzed by multiple-regressions. Finally, a correlation of coefficients was determined and applied to the Yamamoto-Schumacher equation (see Table A).

The Yield Prediction Table for R. apiculata is based on an analysis of data obtained from plot studies. The plot studies were carried out in mangrove forests in Bali, West-Java, Central-Java, West Papua, Riau West Kalimantan provinces.

Volumes estimated from this Volume Table (Table A) are from above the stilt root to the top of the tree. Volume is estimated by 2 factors, one being stem height and the other diameter at a point of 1.3m from the top of the stilt root.

The equation for estimating the volume of *R. apiculata* is:

Tree volume = 0.000029 x ($D^{1.934575783}$) x (StemHeight$^{1.121478932}$)

Table (A) Stem Volume Table (m2) for *R. apiculata*

	DBH: Diameter Breast Height (diameter at a point of 1.3m above the top of the stilt root)<cm>											
		4	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**	**42**
	4	0.0020	0.0077									
	8		0.0167	0.0366	0.0638							
	12			0.0576	0.1005	0.1547						
H	**16**			0.0795	0.1388	0.2137	0.3040					
(m)	**20**			0.1021	0.1782	0.2744	0.3905	0.5262				
	24					0.3367	0.4790	0.6455	0.8358			
	28						0.5695	0.7673	0.9935	1.2478	1.3854	
	32						0.6615	0.8913	1.1540	1.3987	1.6092	
	36							1.0171	1.3170	1.6540	1.8364	2.2287
	40								1.4822	1.8615	2.0667	2.5283

(Summary Table) JICA 1999

At each site, the data was analyzed and appropriate equations were applied. A Site Index was compiled consisting of five of each type of site. High Growth Sites were sub-divided into Site H-I through H-V with Low Growth Sites into Site L-I through L-V. Measurements of diameter, height, volume and effective volume were analyzed.

5.4 High Growth Sites

In general, mangroves grow well where edaphic conditions are favorable. Although edaphic factors such as soil structure, composition, aeration, the mineral contents of surface and soil water and water movement, including changes in water levels are important, probably the most important and most widely distributed are caused by an extreme water regime (Hubert). In general, in mangroves – growth will be high where mangroves experience regular tidal flooding and drainage, where regular fresh water inputs are high (and thus reduce the potential of toxic build up of salts and other compounds in soils, such as Hydrogen Sulfide, which could inhibit growth), and where adequate organic matter is available in the sediments. This takes place predominantly in deltaic mangroves and alluvial flood plains associated with larger river systems, and areas with pyritic soils.

According to the Yield Prediction Table, stands in the middle site (H-III) of high growth areas aged 30 years have an Effective Volume of 177.08 m3 per hectare. In the same site, stands aged 15 years have an effective volume of 81.23m3 per hectare while the number of trees totals 2,516 per hectare. These figures mean that the forest already has a high enough potential to allow viable commercial thinning. The highest annual forest volume increment occurs at the age of 23 years old, being 11.49m3 per hectare per year.

The estimated effective volume of 177.08m3 per hectare at an age of 30 years may be appropriate because the figure obtained in West Kalimantan is 178 m3 per hectare. In Matang Mangrove Forest Reserve, for 3 indexed sites, yields for poor forests were 128m3 per hectare, for good forests 177m3 per hectare, and for excellent forests 212 m3 per hectare.

Calculations for the derivation of the following Yield Prediction Tables for *Rhizophora apiculata* appear on pg 71 in JICA, 1999

Table B – High Growth Site
Yield Prediction Table for Rhizophora apiculata (Site H-III)

Age	10	15	20	25	30	35
Mean Height (m)	12.41	16.11	19.54	22.30	24.32	25.71
Number (trees/ha)	4,983	2,516	1,644	1,200	1,066	960
Volume (m^3/ha)	105.86	135.36	186.21	243.20	295.13	336.61
Effective Volume (m3/ha)	63.52	81.21	111.72	145.92	177.08	201.97

(Summary Table) JICA 1999

5.5 Low Growth Sites

Although the reasons why mangrove forests grow slowly has not yet been conclusively established, field observations and measurements made at the permanent plots indicate primary factors which cause stress and delay growth are overly sandy substrates and islands.

Tanakeke Island itself is an overwash mangrove system, with a scant layer (5-15cm) of organic matter overlying sand and coral rubble, and a predominant underlying geology of CaCO3. Fresh water inputs come largely from direct rainfall (due to low proportion of land mass to capture and contribute fresh water), and organic matter is limited due to distance from a contributing landward source. Although anthropogenic factors greatly contribute to low growth rates and small overall size of mangrove trees, older and undisturbed trees are also much smaller than the same species found in different habitat types on mainland Sulawesi.

According to the Yield Prediction Table, at the age of 30 years, Effective Volume in the middle site (Site L-III) of low growth area is 94.97 m3 per hectare. In such areas at the age of 15 years, the Effective Volume is 24.24 m3 per hectare.

Table C – Low Growth Site
Yield Prediction Table for Rhizophora apiculata (Site L-III)

Age	10	15	20	25	30	35
Mean Height (m)	3.84	7.10	9.63	11.23	12.12	12.59
Number (trees/ha)	6723	5565	5063	4828	2715	4659
Volume (m3/ha)	7.94	40.33	88.57	130.17	157.45	173.07
Effective Volume (m3/ha)	4.76	24.24	53.14	78.10	94.47	103.84

(Summary Table) JICA 1999

Such a low figure means that the forest is not yet viable for production purposes. The value of forests products from such areas can not be considered for industrial production of charcoal or other timber products (chip), but rather small-scale production of charcoal poles and fuelwood). Although low production of woody biomass in most scenarios would lead to management strictly for conservation values, fisheries values and other ecosystem, services, this is not a viable option on Tanakeke Island where there are no significant fuel-wood options for the local community. The paradigm of low growth coupled with increasing need for subsistence fuel-wood necessitates careful management of timber extraction, and the involvement of additional stakeholders to guide management towards multiple but sustainable uses.

Figure 1 - High Growth Site at 9 Years – Tiwoho Village, North Sulawesi

Figure 2 - Low Growth Site (Rhizophora stylosa) at 9 Years – Tanakeke Island – Lantang Peo Village, South Sulawesi

5.6 Mangrove Growth on Tanakeke Island

Data on Tanakeke Island was taken in transects for trees aged approximately 10-12 years. Communities commonly cut trees aged 8-12 years on Tanakeke Island – with 12 years being preferred. The following measurements were taken from three distinct quadrats in forests considered for felling, and are indicative of wood volumes on the island.

	Estimated Age	Mean Height	Mean DBH	Trees/Ha	Volume m3/ha
Zone 1 – Plot 1	12 yrs	3.24	4.60	4000	6.24
Zone 1 – Plot 3	12 yrs	4.09	3.90	3200	6.51
Zone 2 – Plot 3	9 yrs	2.63	3.68	8200	6.66

Tree volume = $0.000029 \times (D^{1.934575783}) \times (\text{StemHeight}^{1.121478932})$

When compared with growth rates and volumes of Low Growth Sites from the JICA study

Age	**10**	**15**	**20**	**25**	**30**	**35**
Volume (m3/ha)	7.94	40.33	88.57	130.17	157.45	173.07
Effective Volume (m3/ha)	4.76	24.24	53.14	78.10	94.47	103.84

We see that volumes are comparable – albeit slightly lower than average 10 year old forests from the study. We may then also safely assume, that silvicultural practices prescribed for Low Growth Sites, will be similar in terms of method and rotation period, to Indonesian Forestry Department practices based on the JICA study.

Charcoal production, on such a low-growth site – would need to be managed meticulously in order not to seriously degrade mangrove forests on the island. However, since mangrove timber is felled on Tanakeke for subsistence and commercial fuel-wood, regardless of conversion to charcoal, it is important to understand and promote appropriate silvicultural methods.

6.0 Management Recommendations

Based on the above data – and given the volume potential of Tanakeke Island as a low-growth rate site, management recommendations are provided in this section as follows;

- 6.1 Silvaculture Practices
  - 6.1.1 30 Year Rotation
  - 6.1.2 Adapting the System for Tanakeke Community Silviculture
    - 6.1.2.1 Rhizophora Dominant Forest Management
    - 6.1.2.2 Traditional Conservation Zone Management - Hutan Pangandrian
    - 6.1.2.3 Non-Rhizophora Dominant Forest Management

- 6.2 Extension Practices to Socialize Improved Forestry
  - 6.2.1 Field Schools
  - 6.2.2 Sustainable Livelihood Development
  - 6.2.3 Adaptive Collaborative Management

6.1 Silvaculture Practices

6.1.1 <u>30 Year Rotation</u>: Current Indonesian Forestry Department Silvaculture System – 30 Year Rotation of Selective Cutting and Reforestation

Statutory System: Decree No 60/kpts/DJ/I/1978 Pedoman Sistem Silvikultur Hutan Payau

The legal basis of forest management systems for Production Forests in mangrove areas appears in Decree No 60/kpts/DJ/I/1978.

When a company has acquired the investigation right for a certain area, it has to conduct and compile forest inventories in the allocated area. The forest should be categorized into three categories;

1) Protected areas
2) *Rhizophora* spp. areas
3) Non-*Rhizophora* species areas.

Rhizophora spp., areas are divided into the following four classes;

1) Matured forest
2) Regenerating forest (for at least 10 years)
3) Regenerating forest (for less than 10 years)
4) Damaged forest

Later on the concession holder has to establish zones and sub-zones in all forest areas. In effective production areas (*Rhizophora* spp. areas) logging zones are designated for the implementation of a 30 year rotation of selective cutting. Initially, the areas should be divided into 5-yearly logging zones, and then these are subdivided into yearly logging zones. The yearly logging zones are further divided into areas of approximately 10-50 hectares, dependent on the total size of the concession. All zones have to be mapped (scale 1:10,000). These maps have to be finished three years before logging activities commence.

The concession (HPH) holder also has to prepare and submit Work Plans. When all is approved, a HPH license is issued. The duration of a HPH is for 20 years, and it is possible to extend if the HPH holder has fulfilled all obligations.

The method of sampling adopted for the detailed forest inventory surveys that have to be submitted with the Work Plan for approval up to 2 years before logging starts, is known as "Strip Sampling." A standard sampling area 10m x 200m is chosen for every zone.

Foresters engaged by the HPH holder choose 40 mother trees per hectare with a DBH of more than 20cm. The average distance between mother trees is approximately 17m, but varies considerably depending on forest conditions. They select well-shaped trees, in order to promote efficient natural regeneration and decrease planting costs. These mother trees are identified by yellow markings around the girth. The locations of mother trees have to be shown on maps (scale 1:1000) before being marked.

Regulations permit the logging of trees with a DBH of more than 10cm. These are marked with red paint. At the same time, Green-belts (buffer zones on the edges of forests, where they interface with tidal creeks or the sea) have to be established. The trees in the Green Belts are never felled.

Up to 1 year before logging, the HPH holder has to prepare infrastructures such as camps, a factory, nurseries, accommodation, bridges, ditches, etc. Worker's huts are built in the logging yard. Wooden rails for dragging the wood on sledges to the logging yards have to be put in place.

One year after logging, remaining stands and regeneration conditions are inspected by the authorities of the Ministry of Forestry with the concessionaire. In this inspection, the concessionaire has to be able to show that more than 2500 commercial trees per hectare have regenerated. In case of insufficient regeneration, supplementary planning must be carried out within a year by direct planting or pot planting. Whether the target of 2500 trees is or is not achieved by natural regeneration depends on environmental conditions.

The HPH holder has to carry out tending activities for several years after selecting logging. If competing plants (e.g. *Acrostichum* spp., *Nypa fruticans*) outgrow planted seedlings, they have to be weeded out.

If, 15-20 years after logging, there are more than 1,100 trees per hectare with a DBH of at least 10cm growing less than 3 m apart, thinning is permitted to allow commercial trees to grow well. Thinning is only conducted once in a 30 year rotation period.

The second rotation starts 30 years after logging.

6.1.2 Adapting the System for Tanakeke Community Silviculture

Currently, islanders of Tanakeke clear-fell mangroves, mostly *Rhizophora stylosa*, at an interval anywhere from 8-12 years, with occasional felling nowadays after only 6 years. Clear-felled areas are replanted at a high density. The resulting forests average a density of 5133 stems per hectare (MAP-Indonesia monitoring data). Elsewhere in Indonesia, 20, 25, 30 and 40 year rotations have all been attempted. 30 year rotations are the current recommendation for both chip production and charcoal production in both Indonesia and Malaysia. There are some differences in the silviculture systems as they are operated in Malaysia and Indonesia which are interesting to note. These differences are summarized in the following table, alongside of information from Tanakeke Island.

Tree-Harvesting Rotation in Matang, Malaysia

In Matang, Malaysia Mangroves, productive forests are clear-felled once they reach 30 years old. This has been in practice since 1950. Silviculture practices see intermediate felling carried out twice, i.e. during years 15 and years 20. Where necessary, intensive planting is done two years after final felling. The 30-year rotation gives the highest net return on capital value.

Most of the present stands within the productive areas of Matang Mangroves consist of second rotation crop except for an approximate 15% of the total area.

Table: Difference of Mangrove Forest Management System (Inoue et Al., 1999)

	INDONESIA (since 1978)	MALAYSIA (since 1950)	Tanakeke Island
Rotation Period	30 years for charcoal 20 years for chip	30 years	8-12 years
Production Purpose	chip charcoal	charcoal (final) pole (thinning)	Fuelwood, charcoal, poles
Logging System	40 mother trees/ha remain after selective cutting	Clear cutting and with periodic thinning	Clear cutting
Width of Green Belt	50m : small rivers/tidal creeks 100m: large rivers 130 times average difference between the highest and lowest tide level, measured from the lowest tide line landward	3m: under 50 m wide river 5m: 50-60m wide river 6m : 60-70m wide river 10m: 70-100m wide river 20m: 100 m wide river and river mouths 200m: interface with strait/sea	10 meters when practiced, occasional cutting up to creek/coast. Some forest area traditionally left in tact for communal environmental services (*hutan pangandrian*)
Planting Method	2500 trees/ha (2m x 2m)	1.2m x 1.2m (*R. apiculata*) = 6,972 trees/ha 1.8 x 1.8m (*R. mucronata*) = 3,080 trees/ha	Direct planting of propagules – 5 propagules per tree felled.
Thinning	One time: only for tending purpose	Two times, for commercial purpose (sold as poles) First thinning: at 15 years using 1.2m stick method Second thinning: at 20 years using 1.8 m stick method	Occasional thinning for immediate needs - sporadic

Proposing a silviculture system for Tanakeke Island must take into account local needs, traditions and capacities, but must also be critical of recent management and logging methods, as they have resulted in an ever-degrading resource. A silvaculture plan for Tanakeke needs to take into consideration that the island is a low-growth site, but should also take into account the need for timber extraction. This need for timber can be balanced with the provision of other ecological services including remediation of wind and wave energy, adjacent coastal habitat protection, fisheries production and preservation of biodiversity.

A proposed silvaculture plan is presented here, but certainly requires input from multiple stakeholders, primarily the community themselves, before being considered as a serious implementation plan. The plan was written in the style of the Indonesian national silvaculture plan – in order to facilitate potential collaborative management with government. After coming up with a proposed silvaculture plan, tests can begin, involving local community as the main participant and stakeholder. A proposed format for a period of trialing is discussed in section 3.13 – Supporting Processes.

Communities (per village (*desa*) as occasionally sub-villages (*dusun*) have ownership issues that need to be resolved before creating a management plan) should conduct forest inventories, and divide forests into three categories;

1) *Rhizophora* spp. areas
2) Protected areas (*Hutan Pangandrian*)
3) Non-*Rhizophora* spp. areas.

6.1.2.1 *Rhizophora* Dominated Forest Management

Rhizophora spp., areas are further mapped into the following four classes;

a) Matured forest
b) Regenerating forest (for at least 10 years)
c) Regenerating forest (for less than 10 years)
d) Damaged forest

These maps will need to be overlaid onto maps of community ownership. Later on, each mangrove owner will need a map of their resource compared to the larger scheme of zonation. In effective production areas (*Rhizophora* spp. areas) logging zones are designated for the implementation of a 20 year rotation of selective cutting.

The difficult task of rotational felling in the logging zones will need to be developed per sub-village. Use of traditional felling areas known as borong (20m x 20m), will replace larger felling plots outline in national plans. Annual logging areas will likely be one or more borong, within a larger area that is zoned as a 5 year felling section (meaning felling occurs within this larger area of one or more hectares for five years before moving onto another 5 year section). The entire production forest – is then logged over a 20 year period, split into four, five year sections, each of which is sub-divided again into annual borong. The borong is thus the smallest felling unit.

A 20 year plan for each dusun, will need to be presented at a dusun level musyawarah, approved by the kepala dusun and kepala desa, and also be presented at some form of musyawarah at the village level. Village level musyawarah should be attended by multiple stakeholders including NGO, academic and government institutional representatives. These representatives, along with community representatives, will constitute the adaptive collaborative management board.

In terms of silvicultural practice, a group existing at the dusun level (comprised of women and men, and including vulnerable members of the community) will choose 40 mother trees per hectare with a DBH of more than 20cm. The average distance between mother trees is approximately 17m, but varies considerably depending on forest conditions. They select well-shaped trees, in order to promote efficient natural regeneration and decrease planting costs. These mother trees are identified by yellow markings around the girth. The locations of mother trees have to be shown on maps (scale 1:1000) before being marked.

Regulations permit the logging of trees with a DBH of more than 10cm. These are marked with red paint. At the same time, Green-belts (buffer zones on the edges of forests, where they interface with tidal creeks or the sea) have to be established. The trees in the Green Belts are never felled. Greenbelt size needs to be determined.

One year after logging, remaining stands and regeneration conditions are inspected by the community mangrove group along with the logger. In this inspection, the logger has to be able to show that more than 2500 trees per hectare have regenerated. In case of insufficient regeneration, supplementary planting must be carried out within a year by direct planting or pot planting.

If, 12-15 years after logging, there are more than 1,100 trees per hectare with a DBH of at least 10cm growing less than 3 m apart, thinning is permitted to allow commercial trees to grow well. Thinning is only conducted once in a 20 year rotation period.

The second rotation starts 20 years after initial logging.

Reparation of any damaged tidal creeks is of utmost importance. Creeks should not be allowed to sediment, and mangrove trees should not be planted to tightly along the edges of small tidal creeks, which are vulnerable to clogging.

On Thinning: The effectiveness of thinning has been studied and compared with control samples. Measurements of volume were carried out on trees with a DBH of 20-39 cm, taken 12 years after replanting, in areas that had been thinned after eight years, and yielded similar results to measurements taken 15 years after replanting in areas that had not been thinned. Therefore, it is expected that the growing stock of forest stands thinned after eight years, will have at least recovered by the final felling at 30 years.

The feasibility of management models including thinning was determined through financial analysis. With reference to the Yield Prediction Table for Site H-III, the Effective Volume at 15years is 81.21 m3 per hectare, and the number of trees 2,516 per hectare. According to the regulation, the number of trees remaining after thinning should be 1,100 per hectare. Therefore, it is reckoned that 50-60% of existing trees , or 40% of volume, can be thinned. The growing stock of the forest stand can recover 100% by the final felling at 30 years. It is unclear – however, if this holds true for earlier thinning (8-12 years) in a 20 year felling cycle.

The thinning system employed has to be easy to execute and also easy to monitor. A complicated system may get out of control and cause damage to the forest stand. The "Stick Method," which is practiced in Matang mangrove reserve in Malaysia, is one of the best and easiest ways.

In Matang, commercial thinning is carried out twice in the 30-year rotation period. The first thinning at the age of 15-20 years is carried out with the aid of a 1.2 m long stick. The second thinning, at the age of 20-24 years, is conducted using a 1.8m length stick. All of the products are sold in local markets as poles, while the final felling products are used as raw material for charcoal production. The stick method procedure involves selecting a well-shaped Rhizophoraceae tree and using the stick to describe a circle (1.2m or 1.8 m in radius) around it. Any other trees within the circle are cut down. This procedure is repeated over the whole thinning area.

Even though thinning is carried out twice, the effective volume at final felling in stands at 30 years of age amounts to 140-190 tons per hectare. Again – trials would need to be undertaken to understand the effects of thinning on a low-growth mangrove (Tanakeke) at only a 20 year cycle.

6.1.2.2 Traditional Conservation Zone Management- Hutan Pangandrian

Hutan Pangandrian are a traditional conservation zone set up on Tanakeke Island by earlier inhabitants. This system has degraded over the past decades with the large-scale development of aquaculture – and current attention to seaweed farming as the main occupation of Tanakeke Islanders. This was further put at risk – during the division of two villages into four, with resulting border conflicts. Nonetheless, it is recommended to restore this traditional conservation system, in order to meet the following needs;

- Protection of biodiversity and wildlife habitat
- Protection of fisheries production
- Provision of a variety of non-timber forest products
- Provision of island protective services against wind, waves and currents,
- Minimizing the impact of clear-felling operations on the marine ecosystem;
- Acting as a source of propagules for the immediate felled areas; and
- Providing a pleasant landscape for visitors and tourists.

A minimum of one hutan Pangandrian should be maintained in each village. This forest should span all mangrove ecotones on the island, from mean sea level up to highest possible tide and hinterland where possible. It should exhibit a wide range of natural biodiversity, and be similar in structure and composition to the most appropriate reference forest determinable (through regional comparison, historical records and modelling). Communities, along with mangrove scientists and NGO members should be engaged in a process to determine management rules and regulations for hutan pangandrian.

6.1.2.3 Non-Rhizophora Dominated Forest Management

This management zone differs slightly from hutan pangandrian in that it may not constitute and entire forest type. There has been near total loss of foreshore mangroves (Avicennia and Sonneratia) on Tanakeke due to islander's preferences for *Rhizophora*. Rehabilitation of foreshore mangroves should take place – along with subsequent protection.

The dominance of *Rhizophora* mangroves in upper part of the lower mangroves, as well as the mesozone is not completely normal – but acceptable. As tidal elevation becomes slightly higher on Tanakeke *Bruguiera gymnorhizza* (and potentially other *Bruguiera's*), *Ceriops tagal* and *Sonneratia ovata* are sometimes evident. In the past they were surely more abundant. There are also occasional stands of *Avicennia* spp. in the mesozone. Where these exist – communities feel unfortunate – as there is little market value for the timber. They are replaced by mangroves by clear-felling and replanting. Development of regulations, and also economic incentives for maintenance of non-rhizophora zones is important to maintain the resilience and functioning of the entire ecosystem.

Upper mangrove areas are limited on the island, due to small proportion of terrestrial area (the majority of the atoll currently exists as intertidal and subtidal habitats. Where upper mangrove exists, it should be maintained. Common species in the upper intertidal are *Lumnitzera racemosa* and *Pemphis acidula*, with occasional other members. Communities seldom attempt to replace these systems with *Rhizophora*, due to inappropriate substrate height (too high – tidal inundation infrequent).

Another reason to maintain upper intertidal areas, and also hinterlands, in a natural state, is in the eventuality of sea level rise – and the migration of mangrove communities to higher tidal elevations.

6.2 Supporting Processes

6.2.1 Field Schools

Coastal field schools have been developed for a variety of investigations into local natural resource potentials in South Sulawesi through the RCL program. Specifically related to mangroves, use of mangroves as non-timber forest products, and silviculture field school have been run, while mangrove rehabilitation field school curriculum is being created for year three. Augmentation of these curriculum should be considered, for provision of an overall mangrove field school packet – as a preferred means of initializing collaboration with communities. The resultant community group (women and men, at least 75% vulnerable) can then take the lead in engaging other community and stakeholders in developing silvaculture and management plans.
Improved curriculum for silvaculture field school needs to be developed, based on the above model, as well as alternate trials such as liberation forestry (practiced in Latin America), two-story mangrove silviculture (recommended by Prof Bahruddin Nurkin of UNHAS – Faculty of Forestry) and community developed trials
Additional non-mangrove based field schools, on fisheries products, sustainable agriculture (where land is available) and seaweed can be considered as well.

6.2.2 Sustainable Livelihood Development

The development of short-term economic benefits, while waiting for the benefits of mangrove rehabilitation and improved mangrove management, needs to be considered. Again, a field school process is recommended for initial organizing of communities. This needs to be met with participatory market analysis, and the development of small-business practices, cooperatives, etc. based on appropriate need. No community should be involved in long-term mangrove management planning and implementation, without equal attention to alternative short-term economic programs.

6.2.3 Adaptive Collaborative Management Board

Adaptive co-management is an emerging approach for governance of social-ecological systems. Novelty of adaptive co-management comes from combining the iterative learning dimension of adaptive management and the linkage dimension of collaborative management in which rights and responsibilities are jointly shared. Complementarities among concepts of collaboration and adaptive management encourage an approach to governance that encompasses complexity and cross-scale linkages, and the process of dynamic learning. Adaptive co-management thus offers considerable appeal in light of the complex systems view. In this regard, adaptive co-management has been described as an emergent and self-organizing process facilitated by rules and incentives of higher levels, with the potential to foster more robust social-ecological systems. Key features of adaptive co-management include:

- A focus on learning-by-doing
- Synthesis of different knowledge systems
- Collaboration and power-sharing among community, regional and national levels
- Management flexibility

These features can promote an evolving, place-specific governance approach in which strategies are sensitive to feedback (both social and ecological) and oriented towards system resilience and sustainability. Such strategies include dialogue among interested groups and actors (local-national), the development of complex, redundant and layered institutions, and a combination of institutional types, designs and strategies that facilitate experimentation and learning through change. Other important themes in adaptive co-management include improving evaluation of process and outcomes, additional emphasis on power, the role of social capital, and meaningful interactions and trust building as the basis for governance in social-ecological systems.

Potential actors on such a board for Tanakeke include:

Community — Individuals, Women's mangrove groups, Cooperatives, Field School groups, Local NGO (PUKAT)

Government

Dusun	Kepala Dusun
Desa	Officials, BPD
Kecamatan	Fisheries, Forestry Dept
Kabupaten	Fisheries, Forestry, BAPPEDA
Propinsi+	KLH, Fisheries, Forestry

Academia — UNHAS, UNISMU

NGO — YKL, MAP

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