A site history & field guide for

Ecological Mangrove Rehabilitation in Tiwoho Village, Bunaken National Marine Park, North Sulawesi, Indonesia

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Preface

In 1991, 20 hectares of pristine and biodiverse mangroves were cleared in Tiwoho Village, part of Bunaken National Marine Park, as part of a nation-wide program of aquaculture development known as the Blue Revolution, which has resulted in the loss of over 1,000,000 hectares of mangroves nation-wide.
The aquaculture venture operated only for a period of 6 months, and the land lay fallow for the next decade. Six attempts to plant mangroves took place over the intervening years, but none of these attempts succeeded, as a result of failure to restore a functional hydrology to the system, which is the limiting factor for successful mangrove rehabilitation.

In 2004, the principles of Ecological Mangrove Rehabilitation were applied to the site in a collaboration between villagers, local universities and NGOs, and international ecologists. The following pages bring to life this pivotal rehabilitation effort, the first of its kind in Indonesia where communities were enjoined to repair the hydrology of an abandoned shrimp pond complex to promote natural regeneration of mangroves. This pilot project has led to the successful rehabilitation of over 2000 hectares of mangroves in other parts of Indonesia, and serves as an example of collaboration and adaptive management that is changing the way Indonesian practitioners address mangrove restoration.

The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) – a collaborative effort between the Center for International Forestry Research (CIFOR) and the United States Department of Agriculture Forest Service (USFS) supported by the United States Agency for International Development (USAID) – welcomed the invitation from the Blue Carbon Initiatives to host its Fifth Blue Carbon Scientific Working Group Meeting held on 26–29 September 2016 in Manado, North Sulawesi, Indonesia.

During the meeting a field trip was organized and led by Blue Forests under the leadership of Ben Brown and Rignolda Djamaluddin, who also prepared this Field Guide; their contributions are gratefully acknowledged. SWAMP/CIFOR would also like to thank the David & Lucile Packard Foundation for its financial support that made the entire meeting a success.

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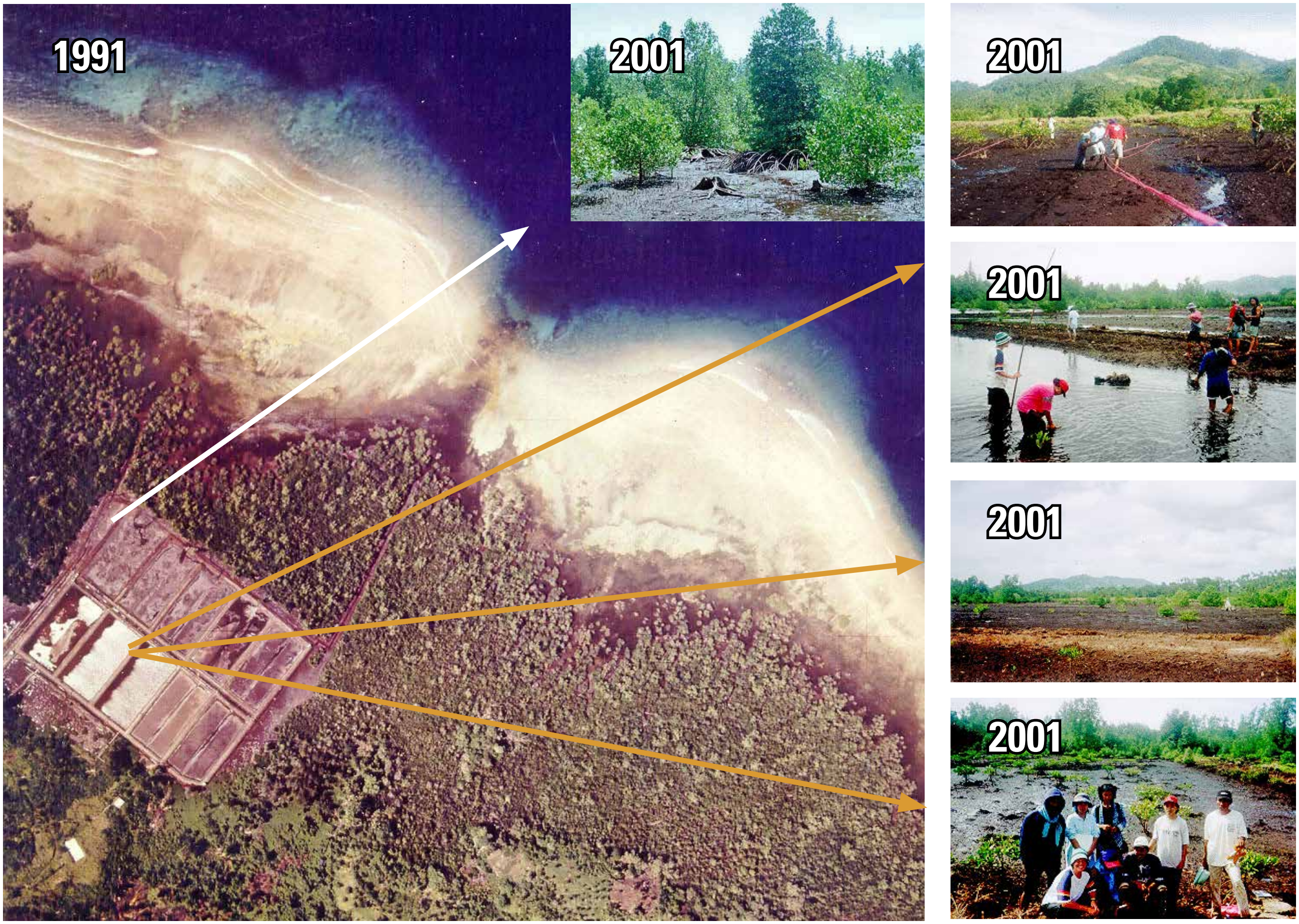


The aerial photo: JICA and BKSDA I, Sulawesi Utara. Photo of ponds: Ben Brown

In 1991, before the declaration of Bunaken National Marine Park, approximately 20 hectares of mangrove area were cleared for shrimp pond development, facilitated at the time by the Bureau of Land Reclamation (BRLKT), under the Ministry of Forestry. The aerial photo above depicts the operational ponds, which comprise roughly one-third of the total cleared area. These ponds operated for only 6 months before the 'owner,' without previous aquaculture experience, went bankrupt. The entire venture was simply an ill-conceived government development project pursued in line with the policy of the day.

Transects of the area were undertaken as part of a pre-restoration assessment in 2001, showing significant natural revegetation in the seaward five ponds, and near zero grow-back in the landward set of ponds, as well as all other cleared sections.

Failed planting attempts (1995–2004)

Photos: Ben Brown

Unvegetated areas were planted a total of seven times during the period 1995–2004. These planting events were facilitated by various agencies in the Forestry Department, and undertaken by a small subset of paid local community members (usually around eight individuals) all family members of the long-term village head. Only cuttings of the Rhizophoracea family (mostly *Ceriops tagal*, and all three local *Rhizophora* spp.) were planted. The initial six plantings experienced near total mortality. The seventh planting, which took place 2 months prior to hydrological rehabilitation in 2003, resulted in some survivorship, which appears today as neat rows of *Ceriops tagal* in an area that still has hydrological drainage issues.

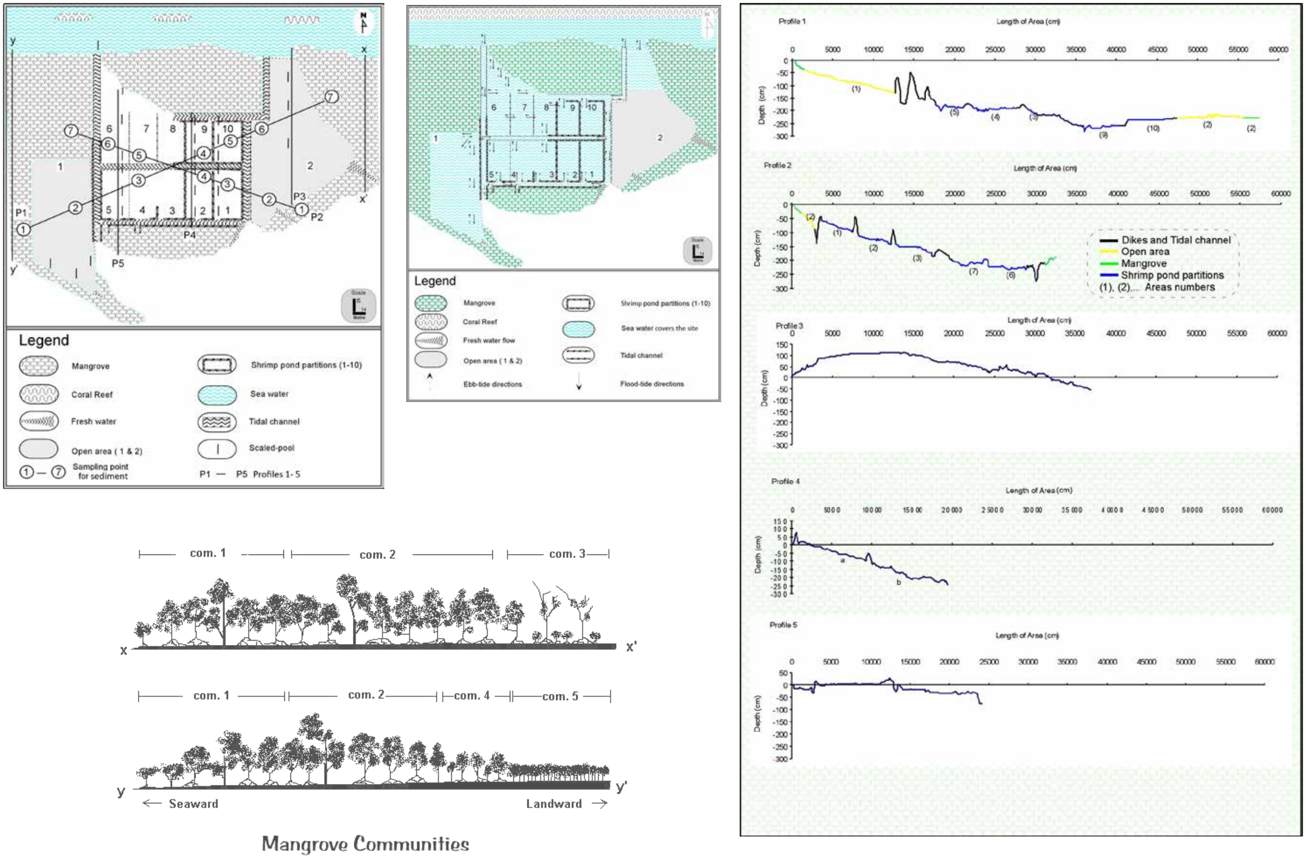


Figure: Rignolda Djamaluddin. 2005. Cost-effective mangrove rehabilitation focusing on restoration of hydrology. A report to Rufford Foundation (for Nature Conservation). Manado, Sulawesi Utara.

In 2003, with financial support from Seacology Foundation, Rufford Foundation and Cottonwood Foundation, a low-cost, ecological mangrove rehabilitation program was initiated by Mangrove Action Project – Indonesia and Yayasan Kelola. The lead practitioner on the project was Rignolda Djamalluddin, Ph.D., of Yayasan Kelola and UNSRAT, whose assessment findings (pictured) assisted in the development of a hydrological rehabilitation design.

Photos: Rignolda Djamaluddin

During this project, strategic breaching of dike walls, filling of artificial channels and creation of small tidal channels were undertaken by the local community with the use of hand tools. Hydrological restoration began in October, 2003, which is considered time zero for this project.

Photos: Rignolda Djamaluddin (upper left), Ben Brown (lower left and right)

Some limited amount of planting, of over 14 mangrove species was subsequently carried out by schoolchildren, university students and the local community as an educational opportunity.

Photo: Ben Brown

Early in the project – schoolchildren were involved in monitoring both planted mangroves and natural recruitment.

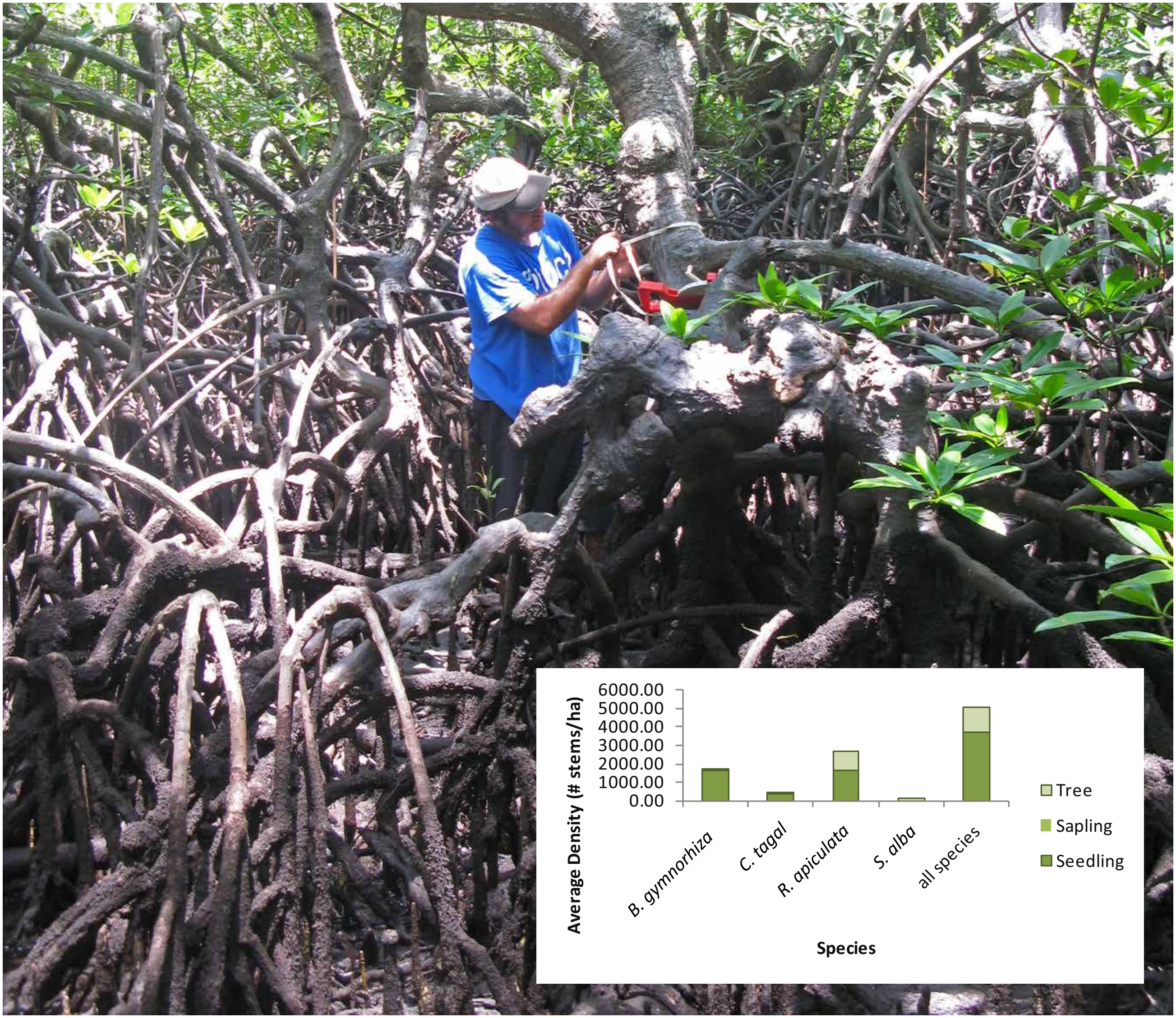
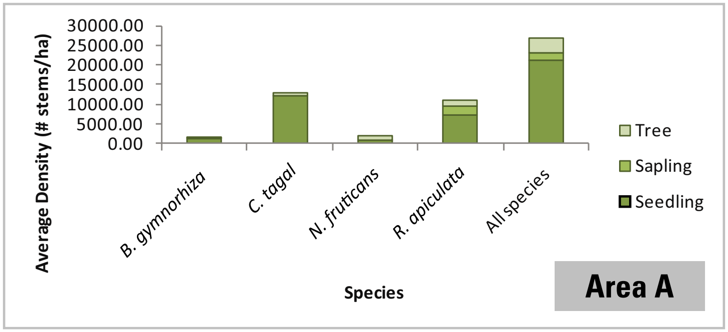
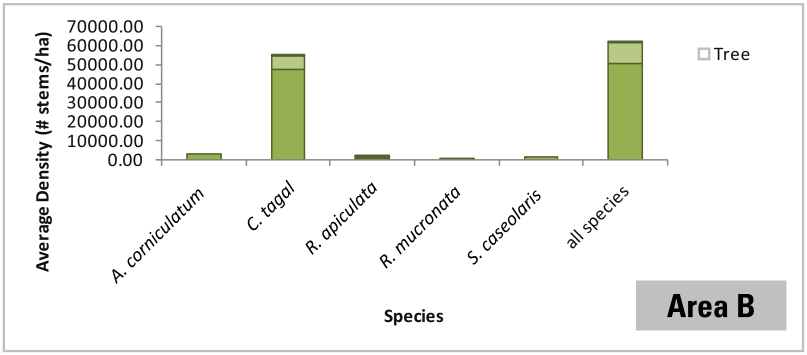


Photo: Ulva Takke

Measurement of the reference forest at Tiwoho in 2010 revealed 5050 stems per hectare across all species.



Rehab Area	Avg. Stem Density All Species (TZ + 8 yrs.)
A	27,093
B	61,900
C	9467
R = Reference Site	5050



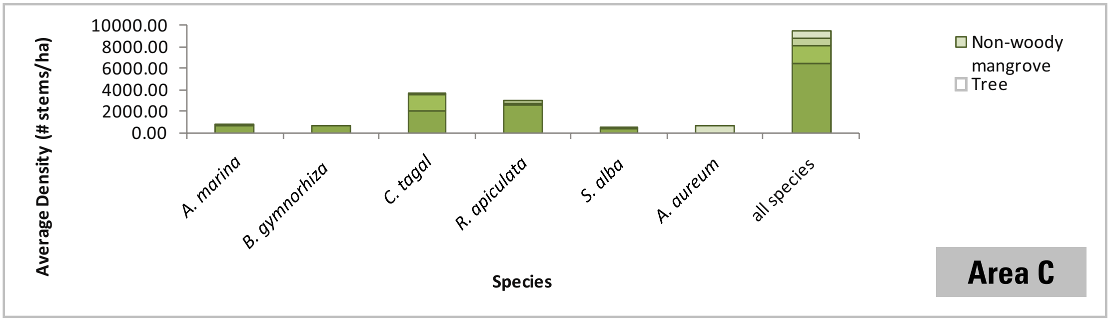


Figure: Ben Brown

Time Zero + 8-year monitoring in 2012 revealed stem densities in the range of 9,467–61,900 per hectare across rehabilitation areas A, B and C. High stem densities during the early growth phase (*r*-phase) of rehabilitation is normal. As the site matures, natural thinning will take place, with mangrove forest structure eventually approximating the reference forest by Time Zero + 25 years.

The following slides will depict the development of the site – both from long-term photo stations and through available Google Earth imagery.

2003 – Pre-rehabilitation.

2012 – Time Zero + 8 years.

2015 – Time Zero + 11 years.

Photo: Rignolda Djamaluddin

Time Zero (October, 2003).

Photo: Ben Brown

Depicting natural recruitment of mesozone mangroves 7 years after hydrological restoration.

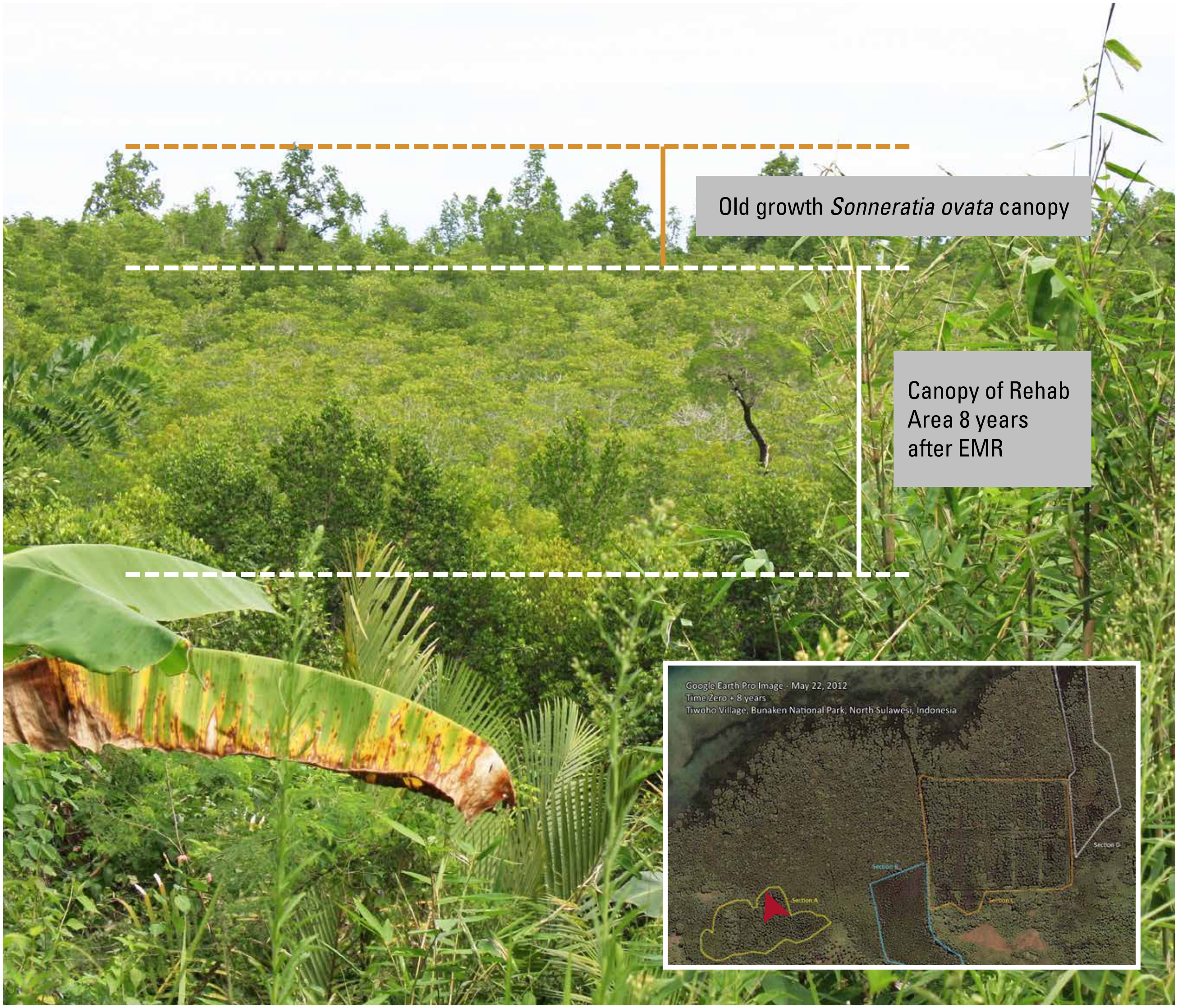


Photo: Ben Brown

View of 8-year-old canopy – from hillock above Site A (see insert). Photo from hilltop looking at canopy of mangrove restoration area (foreground) with undisturbed mangrove forest (taller trees) in background.

Photo: Ben Brown

Upper mangrove: freshwater swamp dominated by *Nypa fruticans.*

Photo: Ben Brown

Natural regeneration of *Heritiera littoralis.*

Photo: Rio Ahmad

Scyphiphora hydrophyllacea in the upper mangrove.

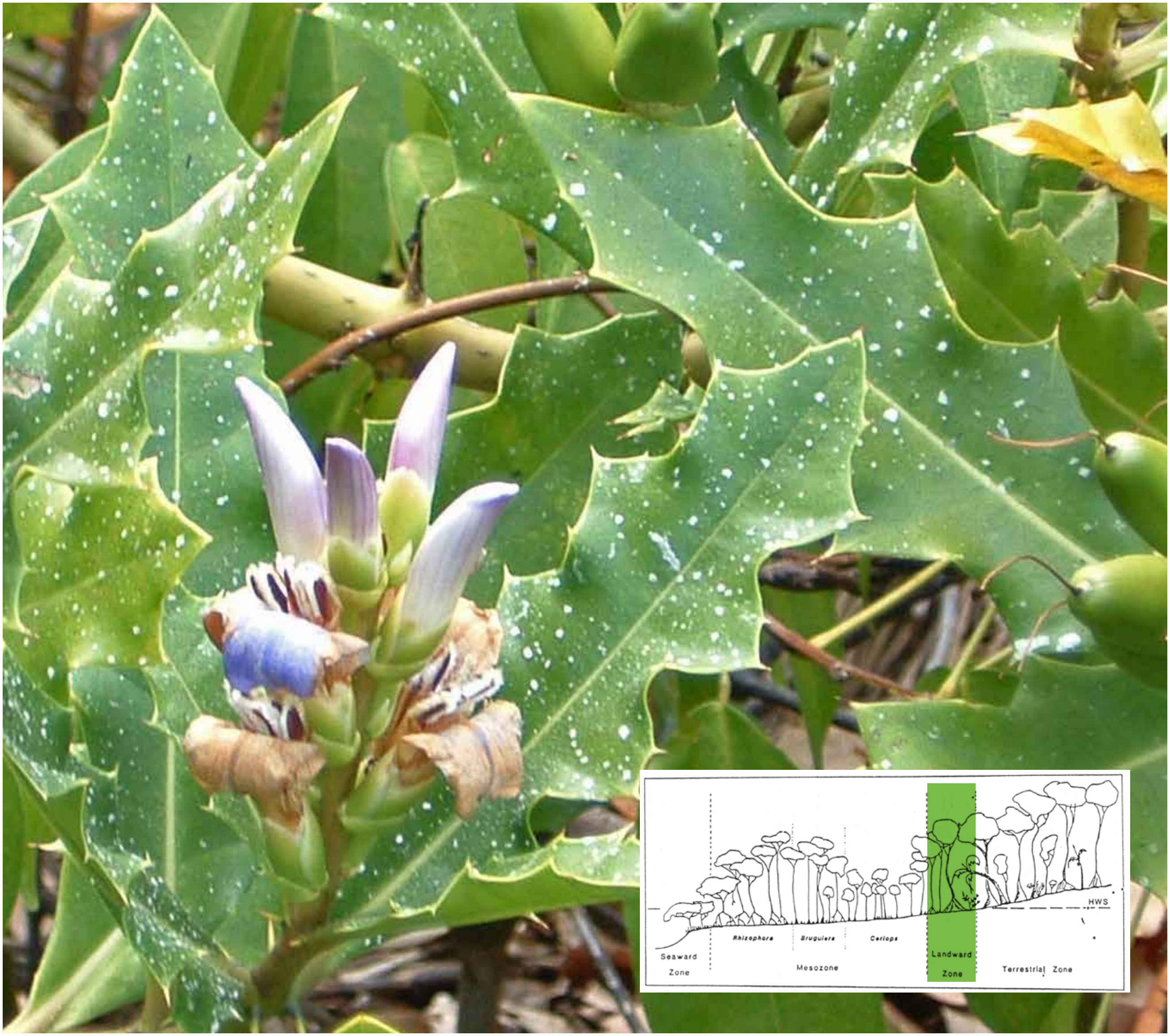


Photo: Rio Ahmad

Acanthus ilicifolius, with prominent salt exclusion in the upper mangrove.

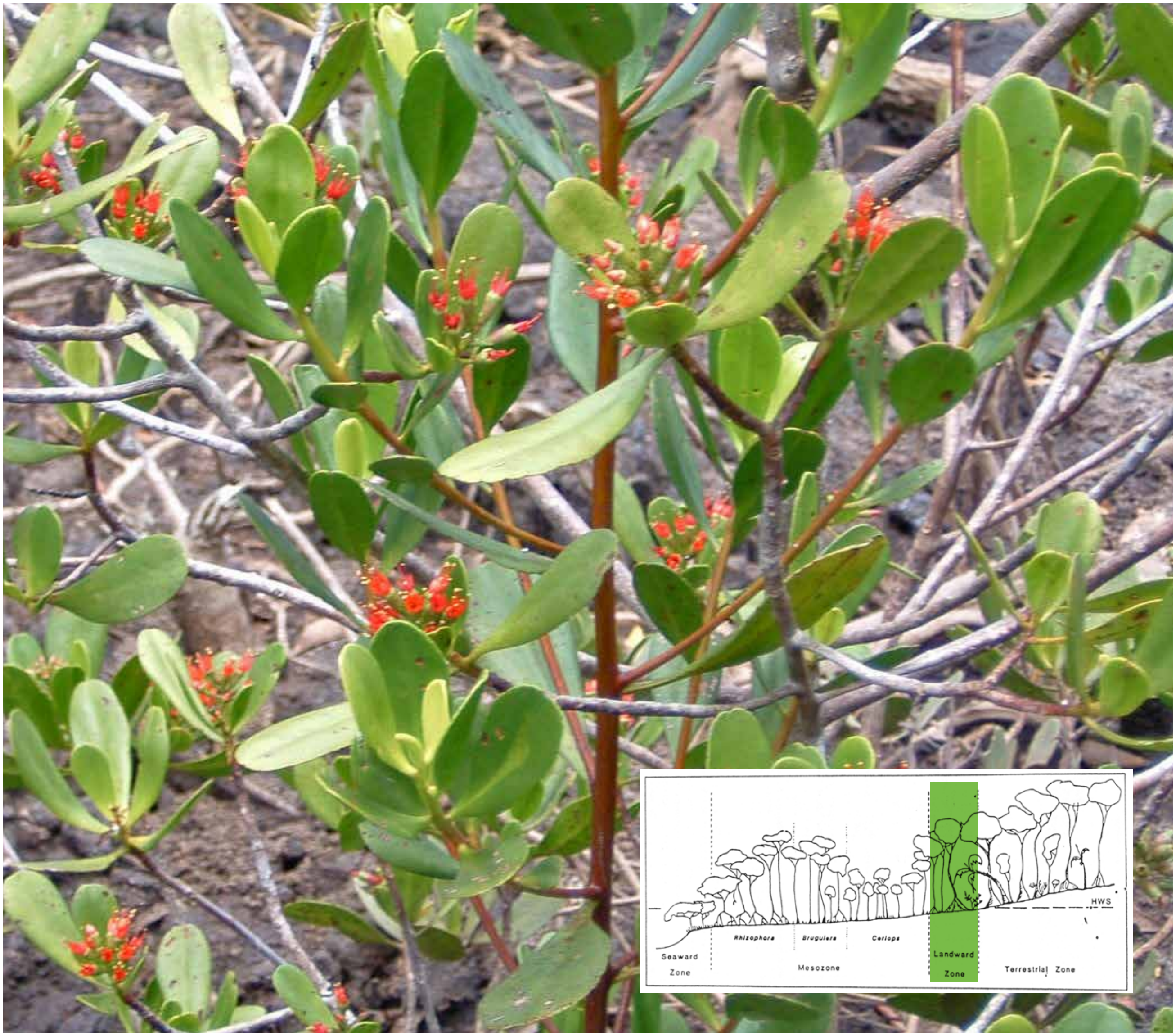


Photo: Rio Ahmad

Lumnitzera littorea naturally colonizing the upper mangrove.

Photo: Ben Brown

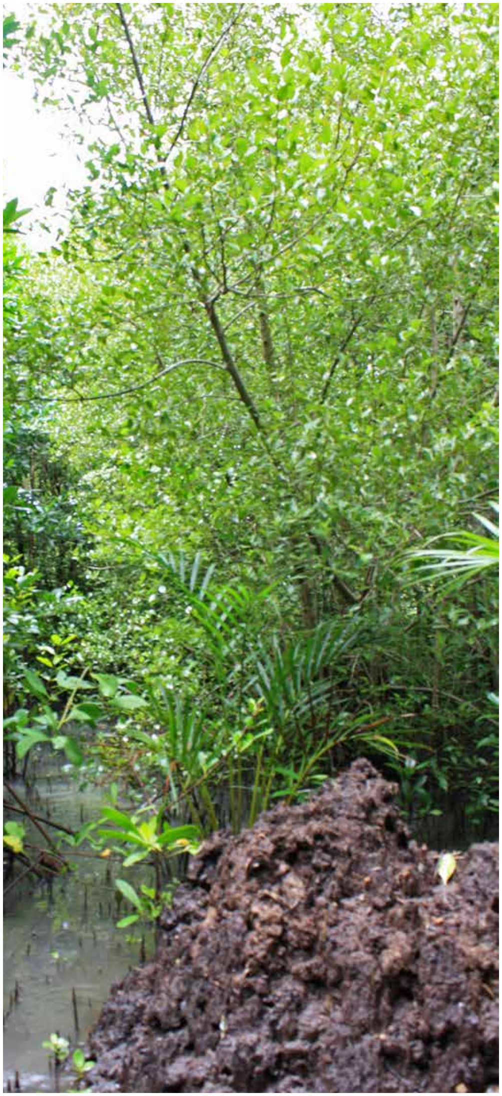
Ceriops tagal is abundant in the transition zone between upper and mid-mangrove zones, and is especially adapted to colonize hypersaline substrate. Numerous *C. tagal* were planted by the government immediately prior to hydrological rehabilitation, and survive in straight rows. Thinning of these stands, and mid-course corrections to continue to improve hydrological functioning is a recommended follow-up action.

Photo: Ben Brown

Rhizophora stylosa and *R. apiculata* dominate the mesozone. The presence of large woody debris provides habitat variation and some degree of disturbance to maintain the vigor of the site.

Photo: Ben Brown

Fecund, arboreal sesarmid crab as evidence of ecosystem health in the rehabilitated mesozone.



Photos: Ben Brown

Mesozone – mixed planting and natural revegetation. *Nypa fruticans* losing out in competition with typical mid and lower mangrove zonational species – *Rhizophora* spp., *Sonneratia ovata, Bruguiera gymnorhiza, Avicennia* spp. (left); *B. gymnorhiza* and *S. ovata* growing in association (right).

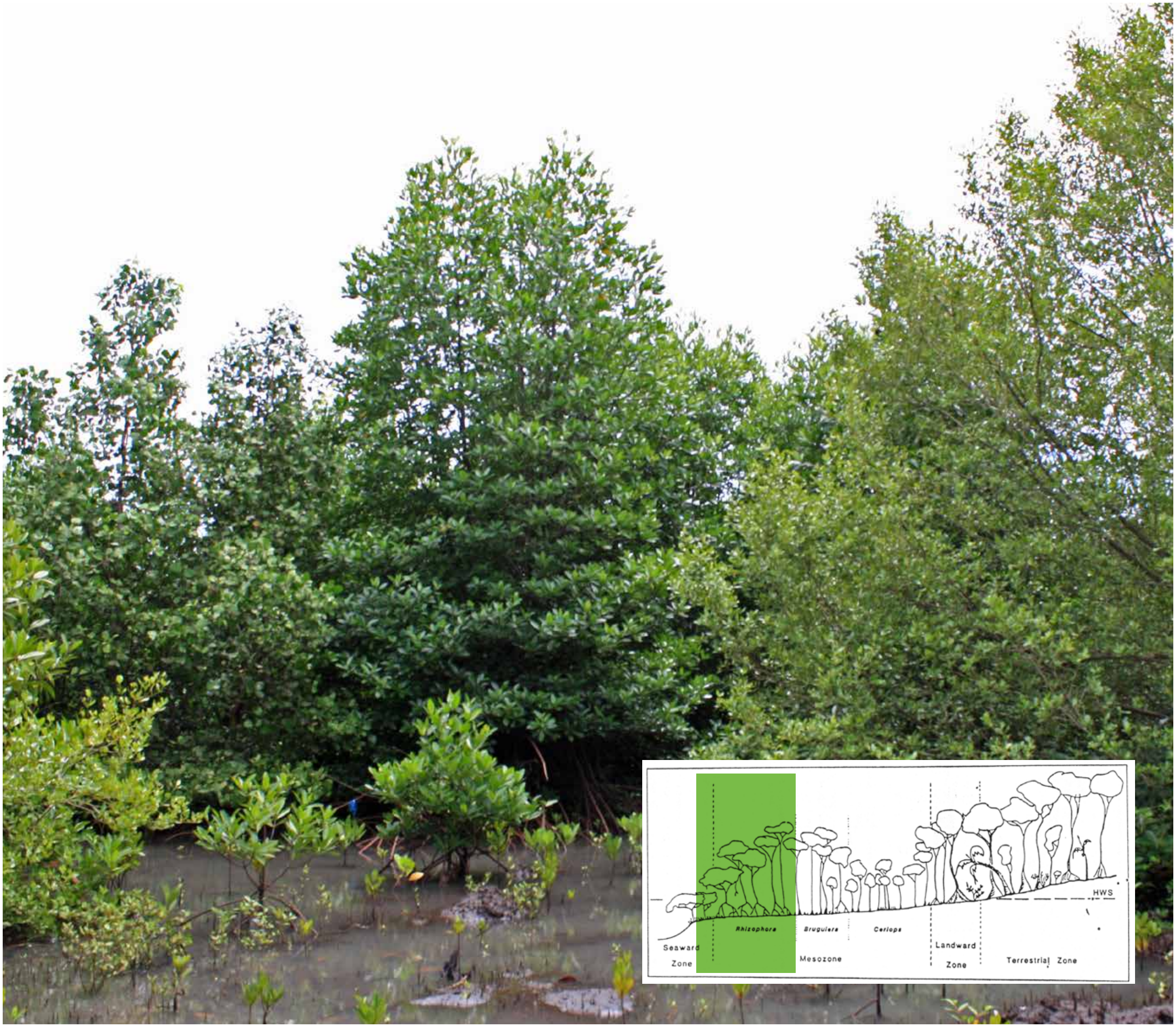


Photo: Ben Brown

Multiple species exhibiting continual natural recruitment in the lower mangrove.

Photo: Rio Ahmad

Sonneratia ovata – bearing fruit within 8 years of natural regeneration.

Photo: Rio Ahmad

Aegiceras corniculatum in the lower mangrove indicates the presence of freshwater runoff.

Photo: Ben Brown

The foreshore of Tiwoho – once clear-cut to improve the view of Manado Tua and Bunaken Island is growing back due to increased human awareness of the importance of mangroves for storm protection.

Photo: Ben Brown

Healthy regrowth along the foreshore.

Photo: Aaron Burton

CDU researcher Clint Cameron (Ph.D. Candidate, Charles Darwin University) assembles a team to undertake a comprehensive assessment of soil-derived greenhouse gas (GHG) emissions, as well as CO_2 and non-CO_2 (methane CH_4, and nitrous oxide N_2O) fluxes from the substrate. These fluxes will be scaled to provide annual estimates of GHG as a function of land use (intact mangrove versus abandoned aquaculture pond vs site undergoing restoration) at high and low productivity systems.

Photo: Aaron Burton

Subsequent monitoring events have taken place in 2012, 2015 and 2016, undertaken by Blue Forests, Charles Darwin University and Eckerd College in collaboration with local NGOs and three local universities from Sulawesi (UNSRAT, UNHAS and Gorontalo Univ).

Photo: Aaron Burton

Studies such as that of Clint Cameron (Ph.D. Candidate, Charles Darwin University) are critical to providing comprehensive and transparent estimates of the rate of carbon accumulation over time following restoration. This knowledge is essential for the assessment of long-term viability of REDD+ schemes to be implemented by coastal communities in developing countries such as Indonesia.

1 Site locations | **2** Tiwoho background | **3** Materials & methods | **4** Tiwoho results | **5** Summary / next steps

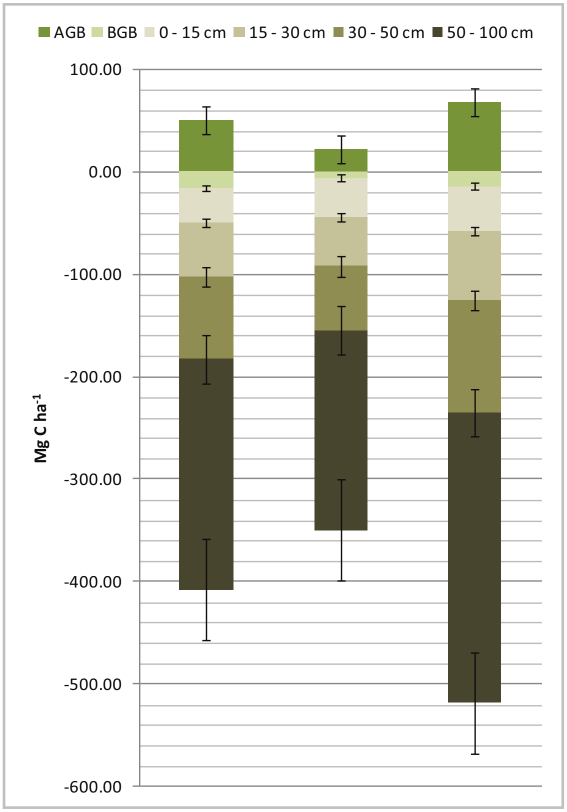


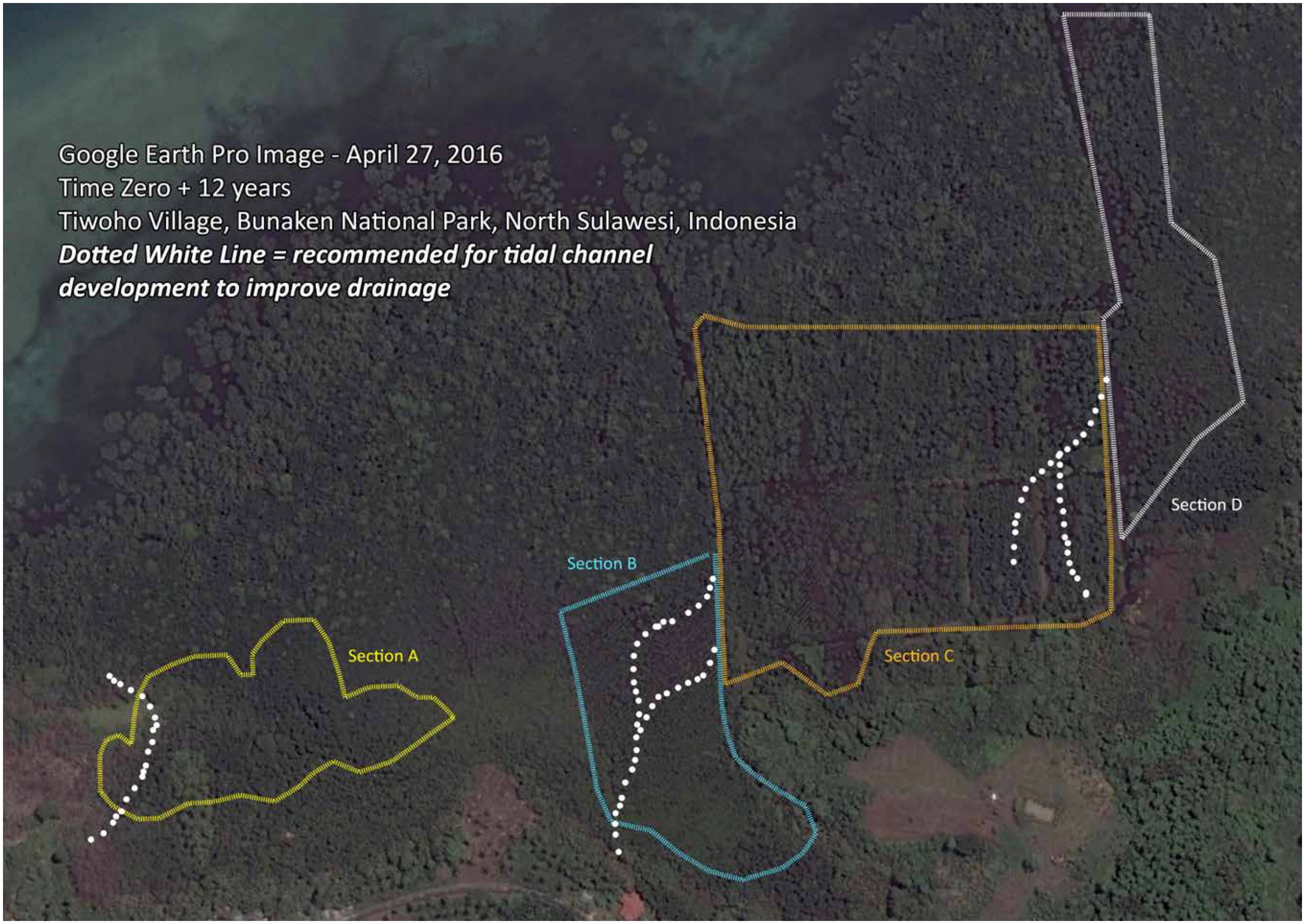
Figure: Clint Cameron

Site	EMR Site A	EMR Site B	Ref Forest A
Geomorphic position	Coastal fringing: mid - lower (landward) mangroves		
Area (ha) of EMR sites	1.97	2.17	
Species dominance	*Ceriops tagal*	*Ceriops tagal*	*Ceriops tagal*
Total trees	34.2 ± 3.1	15.4 ± 1.2	46.8 ± 3.9
Seedlings / saplings	17.1 ± 3.0	3.4 ± 0.5	1.0 ± 0.3
Downed wood total	14.5 ± 4.3	8.8 ± 6.2	34.6 ± 12.5
Leaf litter / forest floor	T	T	T
Total biomass	65.8 ± 6.2	27.8 ± 3.5	82.5 ± 13.7
Soils total	391.6 ± 43.3	343.6 ± 36.6	504.2 ± 54.1
Total ecosystem carbon stock	457.5 ± 162.9	371.4 ± 157.9	586.7 ± 210.9

- All sites *C. tagal* dominated
- EMR Site A biomass close to Ref Site A but > more seedlings / saplings
- EMR Site B » poor growth / stunted
- High prop. biomass downed wood
- Post conversion Site A & Site B ~ lost 113–161 Mg C ha^{-1} soil C in comparison with Ref Site A respectively
- How much soil C has been gained since EMR?

Photo: Aaron Burton

Images from a 2016 aerial (Phantom 3 drone) survey reveal mangrove stress and die-off of mature trees. Although natural thinning is expected in this forest, mid-course corrections in the form of hydrological enhancement are likely required at the site to facilitate drainage and reduce instances of water logging. Placement of water-level loggers will be required to more accurately determine areas of waterlog stress.



Hydrological maintenance is recommended in three significant areas to improve the long-term health and adaptive capacity of the system.

Photo: Helda Rapar

Local elementary school children from Tiwoho, being mobilized to plant 14 species of mangroves in study plots comparing natural regeneration with planted mangroves. The students learned how to raise a wide array of mangrove species as part of an educational unit on biodiversity.

Nature has an amazing ability to heal itself, but sometimes requires the assistance of humans to set it on track. Such is the case in Tiwoho Village, where a whole community dived into the mud, armed with only hand tools, to restore the way water flows in and out of their beloved mangroves. The results have manifested themselves as 400,000 true mangrove trees representing more than 25 species, growing tall and healthy in a free-flowing coastal forest. The community of Tiwoho is proud of their restored mangrove forest, receiving visitors from Indonesia and across the world every year to learn from their handiwork. Numerous families enter the mangroves every day, in search of crabs, snails, clams and natural medicines, or simply for some time away from busy village life.

Strategic breaching of dike walls and creation of tidal creeks can be achieved with manual labor as well as heavy machinery. Indonesia currently maintains over 660,000 hectares of shrimp ponds in former mangrove systems, many of which are abandoned or disused. Rehabilitating a portion of these ponds back to mangroves costs only around USD 1000 per hectare, but the long-term value they have for local communities has been calculated at over USD 20,000 per year, EVERY YEAR! If your community is interested in restoring disused or abandoned shrimp ponds to become productive mangrove forests again, simply Google "Ecological Mangrove Rehabilitation," or reach out to CIFOR and Blue Forests for technical advice.

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This research is carried out by CIFOR as part of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA). This collaborative program aims to enhance the management and use of forests, agroforestry and tree genetic resources across the landscape from forests to farms. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, INBAR, Tropenbos International and the World Agroforestry Centre.

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