TAKING STOCK: *Results from a carbon stock analysis of natural and rehabilitated mangroves, Tiwoho (North Sulawesi)*

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CHARLES DARWIN UNIVERSITY

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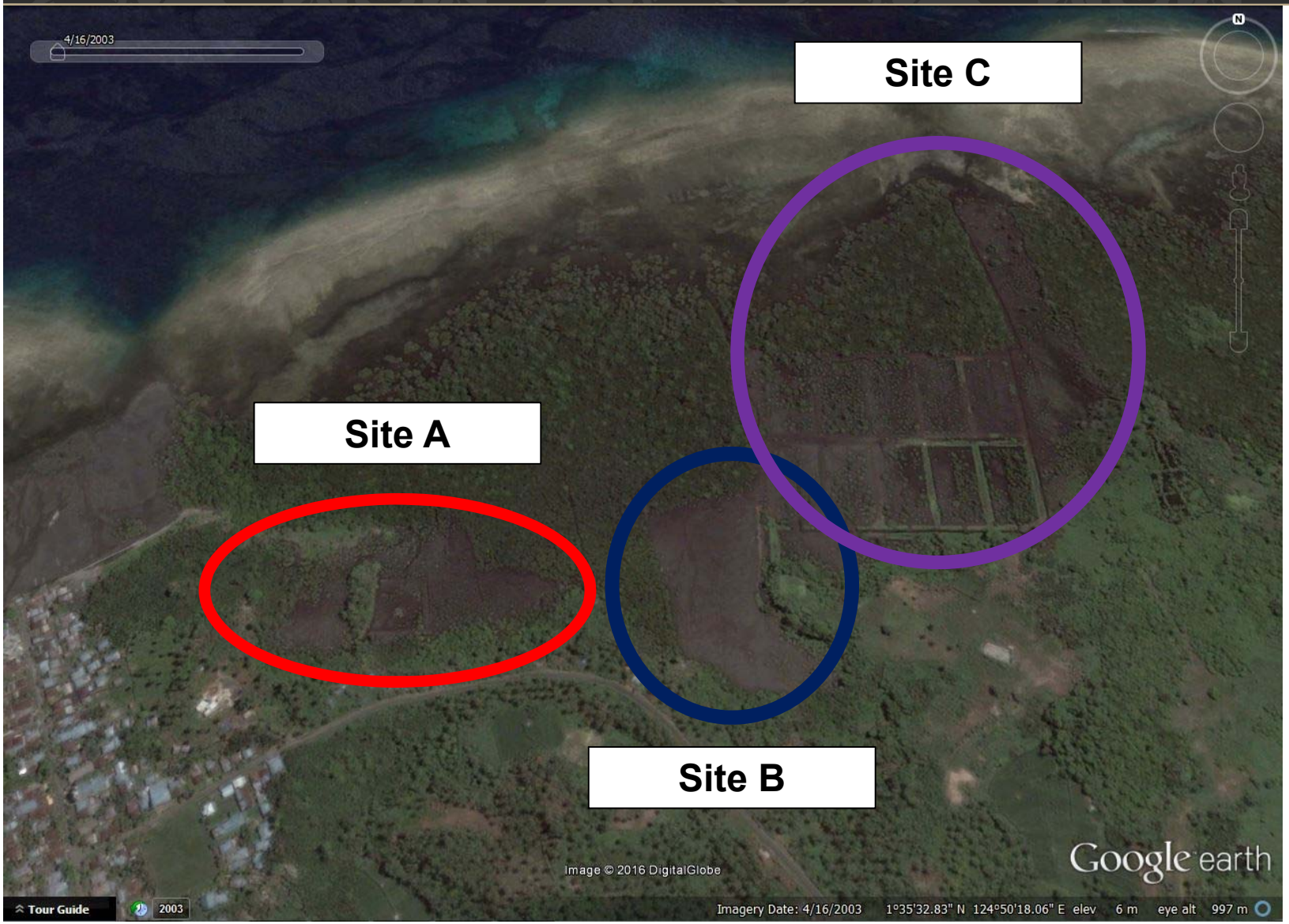
Tiwoho
Manado
GORONTALO
NORTH SULAWESI
Gorontalo
Bontang
Samarinda
Palu
Molucca Sea
Poso
CENTRAL SULAWESI
Sulawesi
Makassar Strait
Pulau Taliabu
WEST SULAWESI
Palopo
Pulau Buru
SOUTH EAST SULAWESI
SOUTH SULAWESI
Kendari
Parepare
Indonesia
Makassar
Pulau Muna
Tanete
Laos
Thailand
Vietnam
Cambodia
Philippines
Malaysia
Singapore
Indonesia
Papua New Guinea



SITE A

- Dike walls significantly diminished (in a state of disrepair) prior to EMR;
- Some mixed species plantings before EMR → poor growth;
- EMR removed hydrological barriers.

SITE B

- Higher elevation → only fully inundated at higher tides;
- 6 unsuccessful gov. plantings of *C tagal* over 9 years;
- *C tagal* finally established post – 2005;
- Still requires $ $ to develop tidal creek → flooding & drainage .

SITE C

- 5 ponds > natural recruitment prior to EMR + planting in 1998 -99;
- Remaining ponds bare.

Trees > 5 cm dbh measured in 7 m radius (A = 153.9 m^2), all subplots

Wood debris transects (4 per plot, all plots) out to 12 m, all subplots

Trees <5 cm dbh measured in 2m radius (A = 12.6m2), all subplots

Soil measurements and core extraction, all subplots

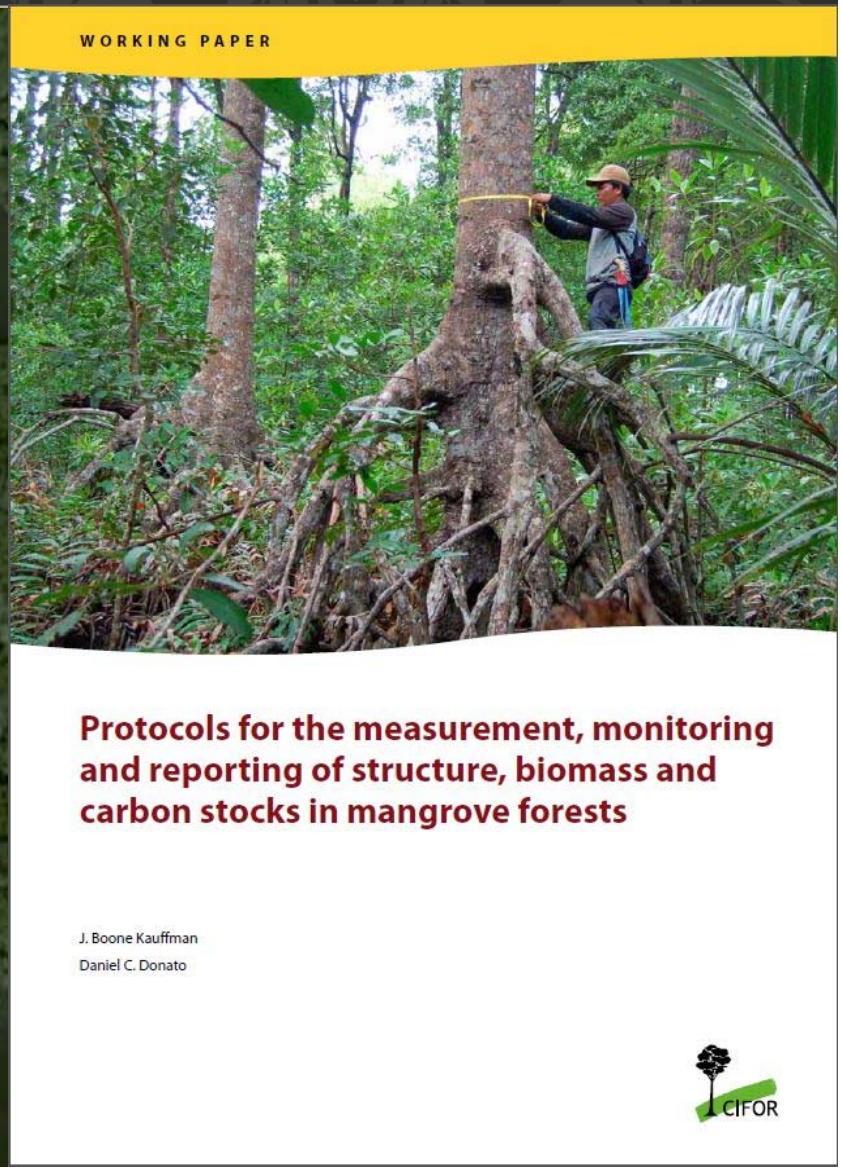
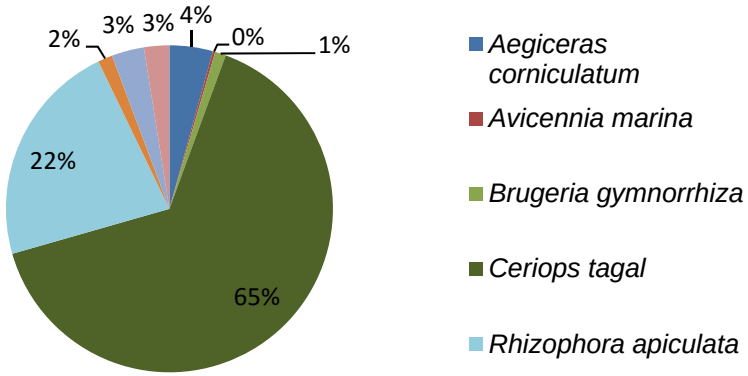


Photo credit: Dr. Aaron Burton

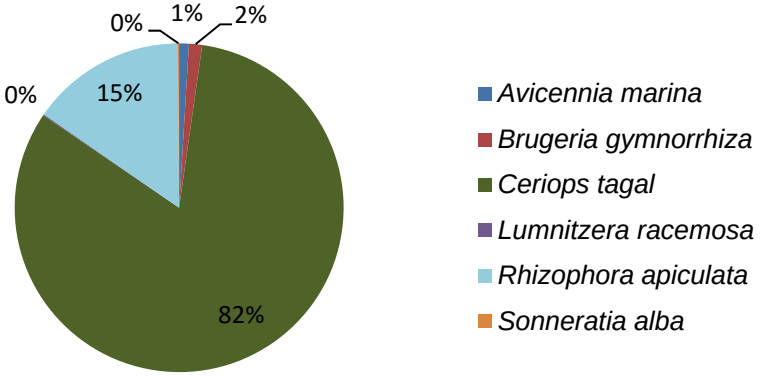
DEC 2015 TIWOHO CARBON STOCK ASSESSMENT

- Team of 12 → students from UNHAS, UNSRAT, & UNG, CDU *RIEL*, YHB (Blue Forests), Japesda Gorontalo & Mr. Compass (ex. Village head);
- 58 plots → ~5000 species & DBH measurements (trees & saplings);
- 3 EMR sites and 2 reference forests;
- 175 soil samples at 4 different depth increments (0-15 cm, 15-30, 30-50, 50 – 100 cm);
- Soil samples from a disused aquaculture site > Molas;
- Spec. specific allometric equations used to calculate biomass;
- Possible to use Nintendo 3D scanner to estimate biomass?

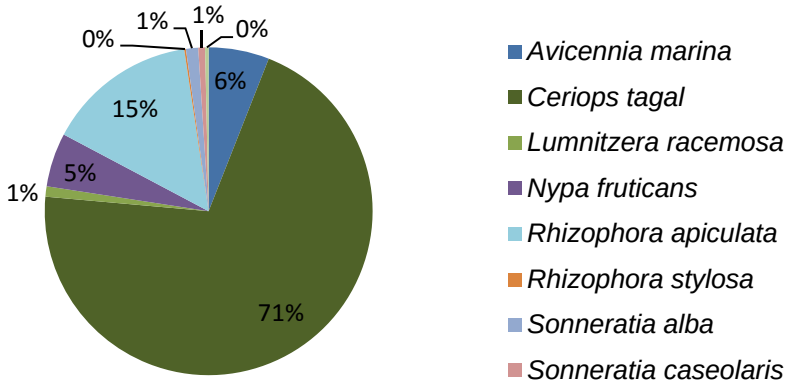
EMR Site B: Species dominance

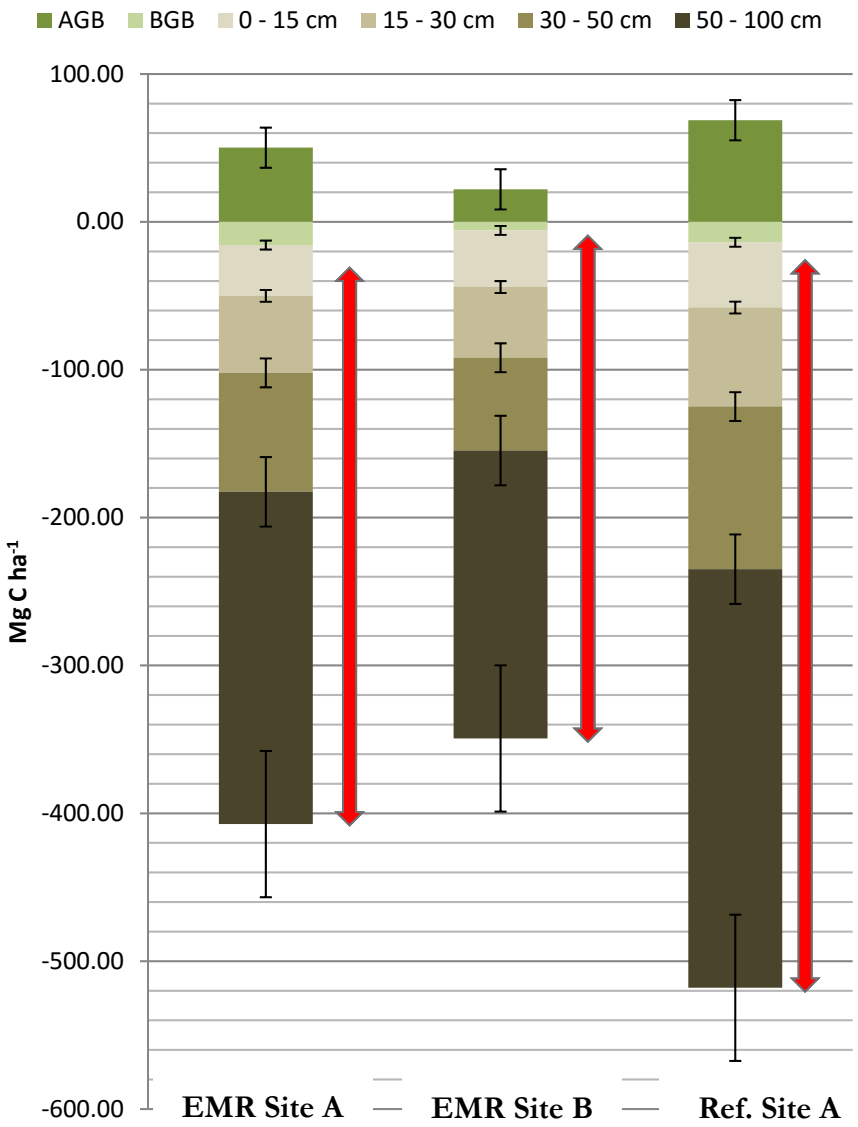


Ref Site A: Species dominance



EMR Site A: Species dominance

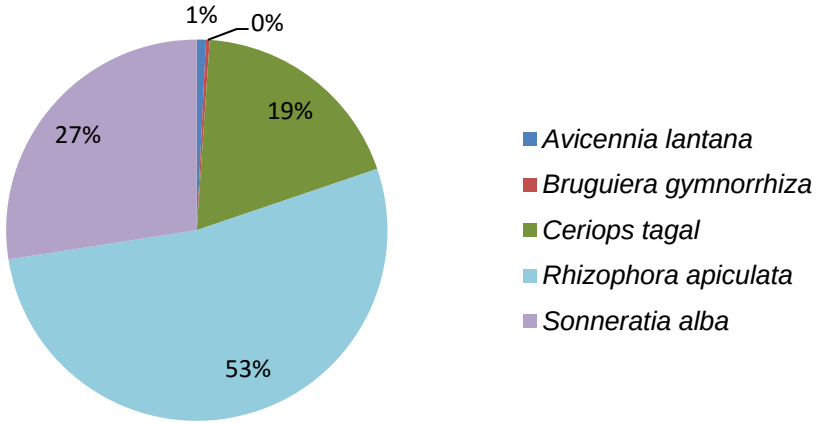




Site	EMR Site A	EMR Site B	Ref Forest A
Geomorphic position	Coastal fringing: mid - lower (landward) mangroves		
Area (ha) of EMR sites	1.97	2.17	
Species dominance	*Ceriops tagal*	*Ceriops tagal*	*Ceriops tagal*
Total trees	34.2 ± 3.1	15.4 ± 1.2	46.8 ± 3.9
Seedlings / saplings	17.1 ± 3.0	3.4 ± 0.5	1.0 ± 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 <u>but</u> > 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 to Ref Site A respectively;
- How much soil C has been gained since EMR?

EMR Site C: Species dominance



Ref Site B: Species dominance

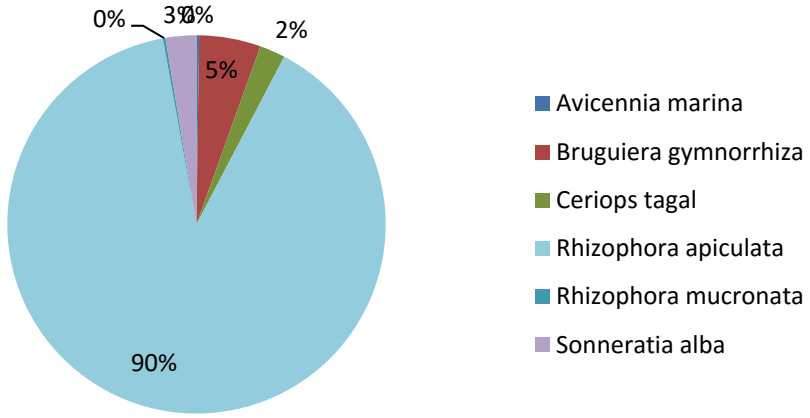
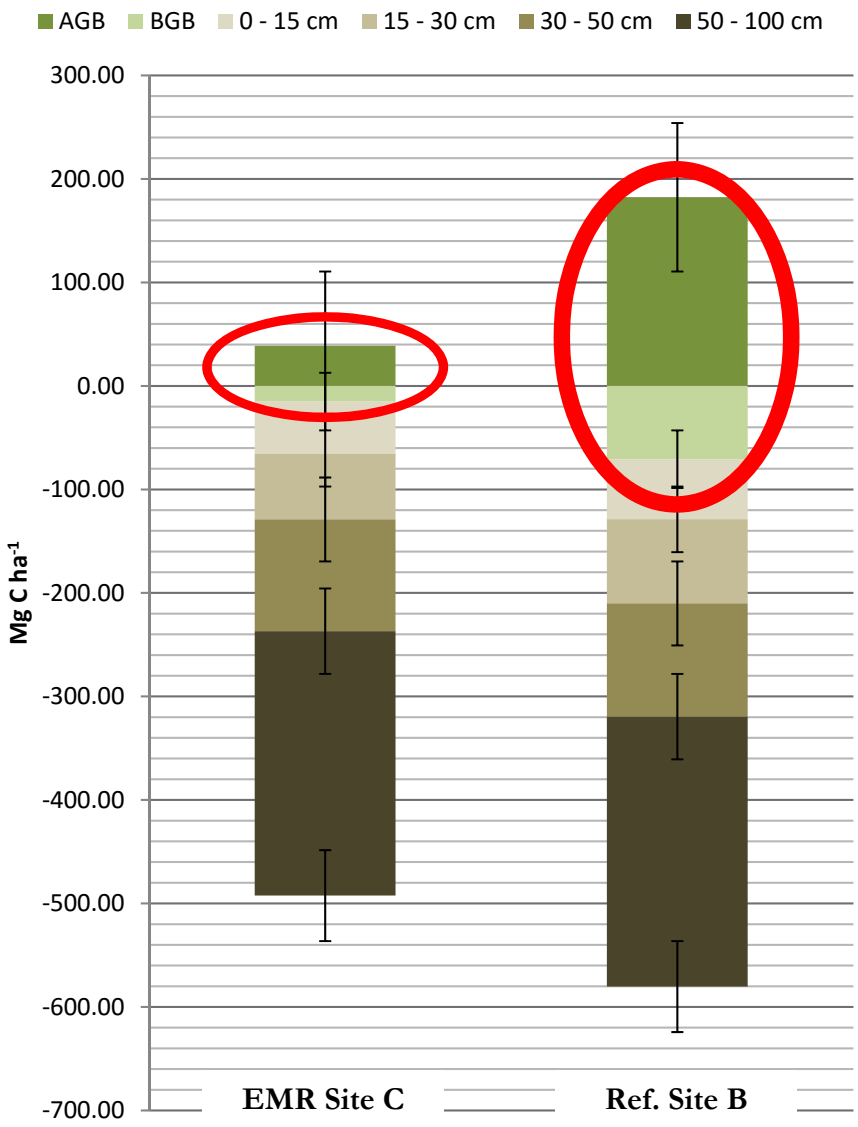


Photo credit: Dr Aaron Burton

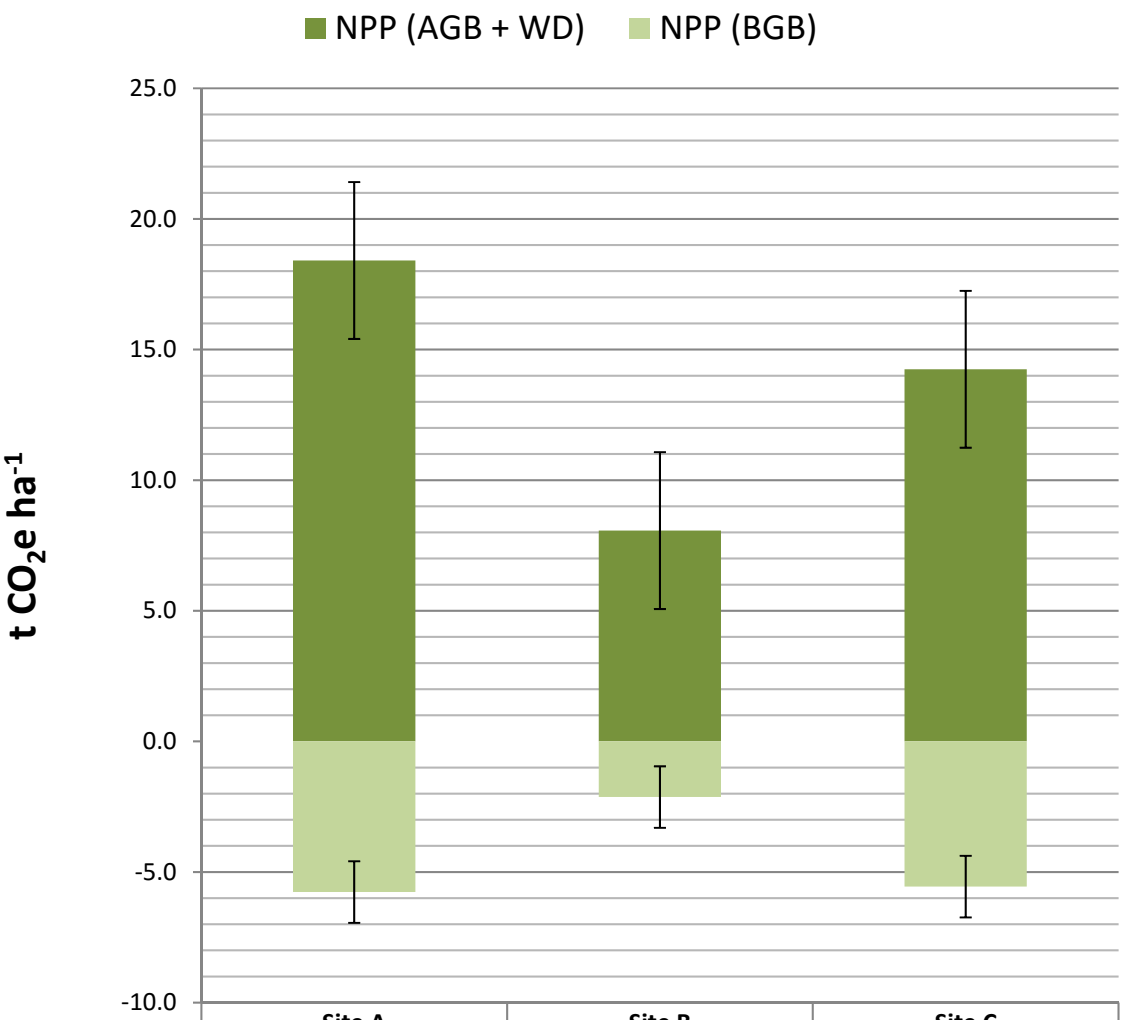


Site	EMR Site C	Ref Forest B
Geomorphic position	Coastal fringing: upper (seaward) mangroves	Coastal fringing: upper (seaward) mangroves
Area (ha) of EMR sites	9.63	
Species dominance	Rhizophora apiculata	Rhizophora apiculata
Total trees	44.1 ± 4.4	230.5 ± 16.7
Seedlings / saplings	0.9 ± 0.2	0.4 ± 0.1
Dead and downed wood total	8.7 ± 3	22.2 ± 6.5
Leaf litter / forest floor	T	T
Total biomass	53.8 ± 13.3	253.1 ± 73.4
Soils total	477.3 ± 47	509.5 ± 45.7
Total ecosystem carbon stock	**531.1 ± 211.7**	**762.6 ± 128.2**

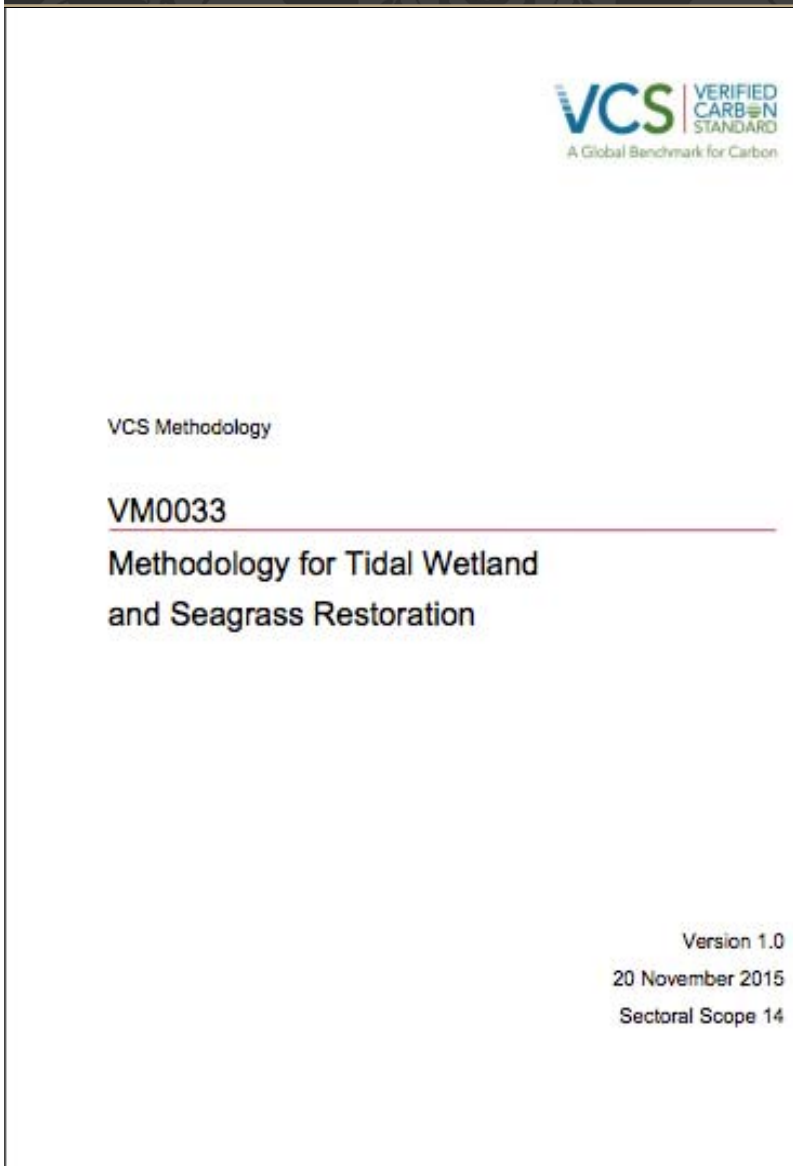
- Both sites *R. apiculata* dominated;
- EMR Site B more *S. alba* & C. tagal growth;
- Successful re-growth rates but still only ~1/5th of the way to obtaining biomass of Ref. Site B;
- Similar soil C content → lost ~32 Mg C ha^{-1} (unlike other two sites);
- Again, how much soil C has been gained post – EMR?

MOLAS RESULTS

- Huh ????
- Higher C than intact ref. forests > completely opposite of expected;
- Old lagoon / estuary > sediment accretion / deposition?
- When converted were mangrove trees (as well as stumps) left in the pond > slowly decompose > increase organic C?
- Lack of macroinvert's (e.g. crabs) and porous burrows to facilitate oxidation?
- C loss from respiration?



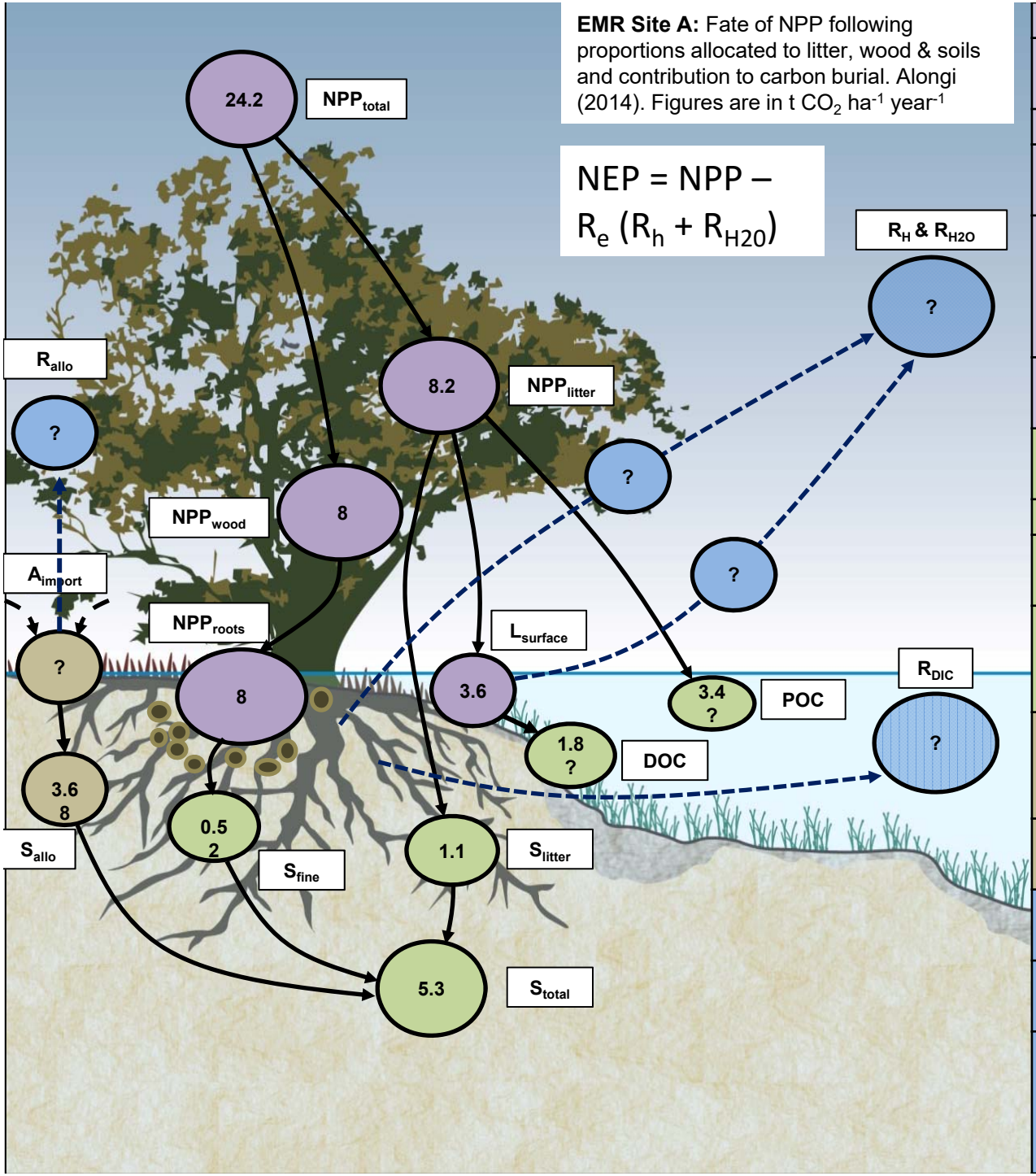
	Site A	Site B	Site C
NPP (BGB)	-5.8	-2.1	-5.6
NPP (AGB + WD)	18.4	8.1	14.2



SUMMARY / KEY MESSAGES

- Overall, EMR across 14 ha at Tiwoho has resulted in the storage of an estimated ~**708** Mg C or ~**2, 600** t CO_2e (biomass total);
- Average of ~**18** t CO_2e ha^{-1} $year^{-1}$ post rehab (NPP);
- Avg. EMR Site A & B = ~**22** t CO_2e ha^{-1} $year^{-1}$ > natural rehab works;
- How does this compare to other forest types & CER from R / A projects?
- Does not include soil C accumulation <u>but</u> possible to infer based on average rates of sediment accumulation;
- Only half the story → need to carry out GHG flux assessment:

$$NEP = NPP - R_e(R_h + R_{H20})$$



NPP_{total}	Net primary production: total
NPP_{litter}	Net primary production: foliage production and litterfall
NPP_{wood}	Net primary production: woody biomass
NPP_{roots}	Net primary production: coarse and fine roots
$L_{surface}$	Litterfall that remains at the surface. Approximately half is decomposed in-situ and respired by heterotrophs, and the other half is exported as DOC
S_{litter}	Proportion of litterfall that is buried in mangroves soils
S_{fine}	Proportion of fine root turnover that is buried
S_{total}	Total amount of soil carbon burial
DOC	Dissolved organic carbon exported to adjacent systems
POC	Particulate organic carbon derived from litterfall and exported to adjacent systems
A_{import}	Allochthonous import of sediments from adjacent systems (riverine sediments, oceanic sediments etc.)
S_{allo}	Proportion of imported allochthonous sediments that is buried
R_{allo}	Respiration of allochthonous soil carbon by heterotrophs
R_{DIC}	Respiration of dissolved inorganic carbon by heterotrophs
R_H & R_{H2O}	Respiration from soil heterotrophs when soils are exposed (R_h) and atmospheric exchange of heterotrophic respiration from mangrove waterways (R_{H2O})

NEXT STEPS: BIODIVERSITY ASSESSMENT

- Awarded *Indonesian Project Grant* 2016 -2017
- Use same approach as carbon stock assessment → researchers from Auz & Indo universities + Indo. student volunteers = ability to capture lots of high quality, quantitative data with high spatial coverage.
- Enable full suite of ecosystem service benefits (carbon + biodiversity) from rehab to be quantified → possibly first time this has been done

Questions / Comments?

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