Testing Hydrological Suitability for Mangrove Restoration in Indonesia

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AIM

This study investigates the application of water level monitoring combined with a hydrological classification to improve success of mangrove rehabilitation projects of disturbed sites.

References:
- Van Loon, A.F., Te Brake, B., Van Huijgevoort, M.H.J., and Dijksma, R. (2016) Hydrological Classification, a Practical Tool for Mangrove Restoration. *PLoS ONE* 11(3): e0150302
- Van Loon, A.F., Dijksma, R., and Van Mensvoort, M.E.F. (2007). Hydrological classification in mangrove areas: A case study in Can Gio, Vietnam. *Aquatic Botany*, Volume 87, Issue 1: 80 – 82
- Watson, J.G. (1928). Mangrove forests of the Malay Peninsula. Malayan Forest Records 6, Forest Department, Federated Malay States, Kuala Lumpur

Figure 2. *Natural (left) and disturbed (right) conditions.*

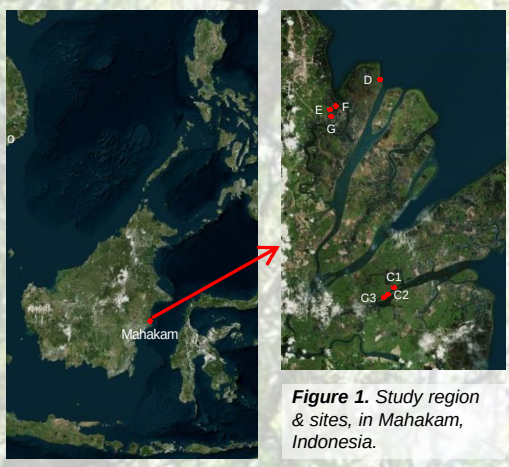

Figure 1. *Study region & sites, in Mahakam, Indonesia.*

Data and approach

- Field campaigns (2010, 2011-12) in Mahakam, Indonesia (Fig. 1).
- Measurements of water levels in open water and forest sites, with pressure transducers.
- Natural sites (C, D) and hydrologically disturbed sites (E–G): former shrimp ponds, dikes intact (E, G) or not (F), replanted (F, G) or not (E) (Fig. 2).
- Qualitative vegetation inventory for each site.
- Hydrological classification (Table 1) for each site, class determined separately based on elevation, duration of inundation (locally and based on open water site) & vegetation.

Table 1. *Adapted hydrological classification including the southeast Asian mangrove species, developed from mangrove sites in Vietnam (Van Loon et al., 2007; 2016), based on Watson (1928).*

Inundation	Tidal regime	Elevation	Duration of inundation		Vegetation
Class		cm + MSL	min per day	min per inundation	species
1	all high tides	< 0	> 800	> 600	none
2	lower medium high tides	0 - 50	400 - 800	450 - 600	Avicennia alba, Sonneratia
2*	higher medium high tides	50 - 100	250 - 400	200 - 450	Avicennia spp., Rhizophora spp, Bruguiera parviflora
3	normal high tides	100 - 150	150 - 250	100 - 200	Rhizophora spp., Ceriops, Bruguiera
4	spring high tides	150 - 210	10 - 150	50 - 100	Lumnitzera, Bruguiera, Acrostichum aureum
5	equinoctial tides	> 210	< 10	< 50	Ceriops spp., Phoenix paludosa

TAKE HOME MESSAGES

1) failure of mangrove planting can be prevented by considering hydrological conditions
2) hydrological classification can guide making suitable hydrological conditions for natural regeneration or planting

Classification

- **Natural sites** (C, D): classes based on inundation similar to class based on observed vegetation.
- **Disturbed sites** (E-G): classes different, due to stagnant water after high tide (tailing, Fig. 3) and barriers to natural regeneration.

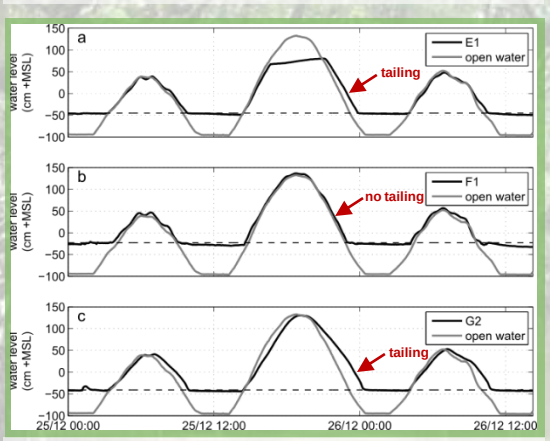

Figure 3. *Time series of water levels at disturbed sites (**E1, F1, G2**) and open water site E0. Dashed line = surface level.*

Assessing hydrological conditions for restoration

- **Classification based on elevation** (Table 2 – column 2): classes lower than based on inundation or vegetation (column 3 & 4). Only using elevation in restoration projects would lead to planting wrong species. Monitoring water level is needed.
- **Classification using open water site** (column 5 & 6): same class for F1 (column 3), higher class for E1 & G2 due to tailing (Fig. 3). Intact shrimp pond dikes make conditions too wet for mangrove species (E1: no natural regeneration, G2: failure of plantation). The comparison quantifies effect of obstructions on restoration potential.
- **Classification using matching natural sites** based on elevation (column 7): good match between estimated (column 8) and observed (column 4) vegetation class for some sites (F1, F2, G1, G3), but not for sites with tailing (E1, G2; Fig. 3). Using this approach in restoration projects would only be successful if the topography of the natural site is also mimicked by removing obstructions.

Table 2. *Hydrological classification based on elevation, inundation, and vegetation. Disturbed sites (E–G) compared to open water site E0 and matching natural sites (C–D; matching based on elevation). NB: sites in **red** visualised in Fig. 3.*

site	class based on elevation	class based on inundation	class based on vegetation	open water site (change in inundation)	class based on open water site	paired natural site	vegetation class of paired site
E1	**1**	**1**	**-**	**E0 (-10 %)**	**2**	**D1**	**2**
E2	1	2-2*	-			C3	2*
E3	2	2-2*	-			D3	2*/3
F1	**1**	**2**	**2***	**E0 (-0.2 %)**	**2**	**C3**	**2***
F2	2	2-2*	3			D3	2*/3
G1	2	2-2*	2*			D3	2*/3
G2	**1**	**1**	**-**	**E0 (-8.5 %)**	**2**	**D1**	**2**
G3	2	2-2*	3			D3	2*/3

Management implications

These results can be used to determine **management strategies for disturbed sites**, after measuring water levels at the site:
- hydro-conditions suitable & vegetation present (F1, F2, G1, G3) >> no action needed (only monitoring).
- hydro-conditions suitable but no vegetation, obstruction to natural regeneration (E2, E3) >> solution: remove obstruction to allow for natural regeneration or plant correct species using classification based on inundation (Table 1).
- hydro-conditions unsuitable & no vegetation, too wet for natural regeneration or survival after planting (E1, G2) >> solution: first restore hydro-conditions, then allow for natural regeneration or plant correct species according to new class (Van Loon et al., 2016).

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