

Natural Capital and Human Welfare: The Social Impacts of Mangrove Loss in Indonesia

Amanda Guimbeau¹, Xinde James Ji², Nidhiya Menon³ and Firman Witoelar⁴

¹ Université de Sherbrooke

² University of Florida

³ Brandeis University

⁴ Australian National University

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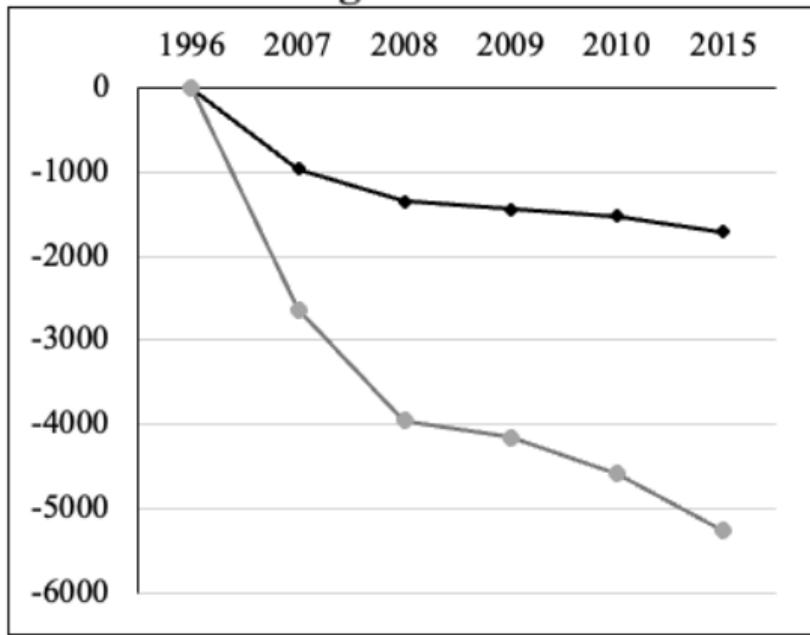
Motivation: The Value and Threat to Mangroves

- ▶ Mangroves forests: keystone species in coastal ecosystems
 - ▶ Rich biodiversity, supports fisheries
 - ▶ High potential for carbon sequestration
 - ▶ Natural barriers against storms, floods, and erosion
 - ▶ Cultural significance for coastal communities
- ▶ Indonesia: Home to world's most extensive & diverse mangroves (>20% global area)
- ▶ The Threat: Significant loss over past decades (aquaculture, oil palm, climate pressures)
 - ▶ Indonesia is a major contributor to global mangrove decline.

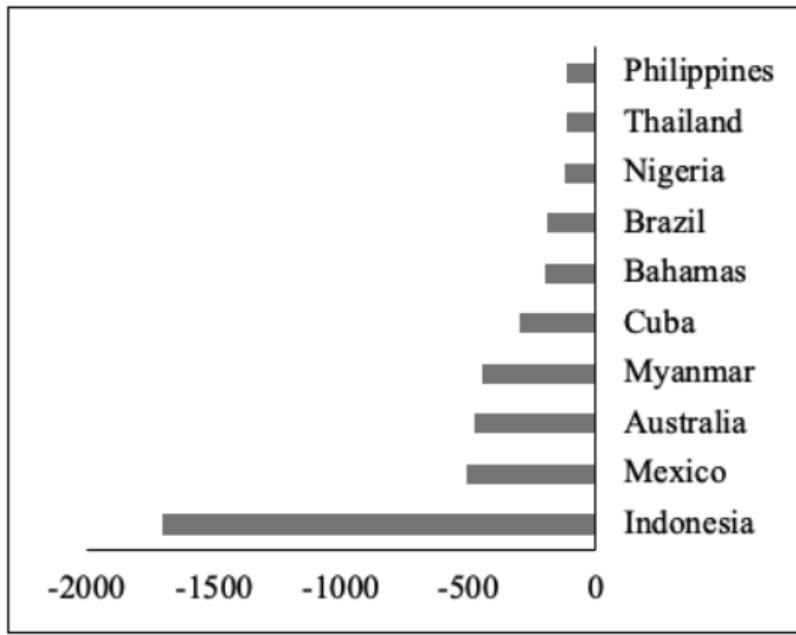


Mangrove forest in Bali. Source: the World Bank

Panel A Global and Indonesian Mangrove Trends



Panel B Mangrove Deforestation by Country



Source: Bunting et al. 2022







Motivation: social impacts of mangrove loss

What we know so far:

- ▶ In Florida, Mangrove buffers flood (Sheng et al., 2021, 2022), increase property values (Kajaria et al. 2023)
- ▶ In India, mangrove mitigates short-run cyclone impacts on economic activities (Zhu et al. 2023)
- ▶ In Indonesia, fishery households lose income (Yamamoto 2023), substitute with more labor, less food, and earlier marriage for girls (Yamamoto and Shigetomi, 2022)

What we'd like to know:

- ▶ How does mangrove loss affect human well-being?
- ▶ What are the key mechanisms driving these impacts (e.g., ecological production, **flood prevention, or cultural significance**)?
- ▶ What are ways to mitigate these impacts?

What do we do in this paper

In this paper, we study:

- ▶ How does mangrove loss affect mental health and cognitive function in Indonesian coastal communities?
- ▶ What are the key mechanisms driving these impacts
- ▶ Are there effective ways to mitigate these adverse effects?

To do so, we exploit:

- ▶ Panel variations in mental health and cognitive function from a longitudinal survey (IFLS) in Indonesia
- ▶ Satellite data on mangrove coverage

Contributions to the literature

We contribute to streams of literature on:

- ▶ The effects of ecosystem degradation, particularly deforestation, on human health and well-being (Balboni et al. 2023; Berazneva and Byker 2017, 2024; Garg 2019; Kishida et al. 2024)
 - ▶ We find that mangrove loss significantly worsens mental health and cognitive function in Indonesia.
- ▶ Social value of natural capital (Damania et al. 2023; Deustch 2003; Fenichel and Abbott 2014; Muller et al. 2025; Polasky and Daly 2021)
 - ▶ We find that the impacts of natural capital loss affects human well-being through multiple channels
- ▶ Environmental conditions and mental health (Burke et al. 2018; Carias et al. 2022; Evans et al. 2025; Hua et al. 2023; Mullins and White 2019; Rosales-Rueda 2018)
 - ▶ Most studies focus on sudden shocks (flooding, extreme heats); we focus on long-term natural capital disturbance

Data Sources

- ▶ **Welfare Data:** Indonesian Family Life Survey (IFLS) - Waves 4 (2007) & 5 (2014/15) [IFLS Coverage](#)
 - ▶ Rich individual/household panel data
 - ▶ Geocoded at the village level; tracks most migration across waves
- ▶ **Key Outcomes:** [Details on outcomes](#)
 - ▶ Mental Health: CESD-10 Depression Score
 - ▶ Cognition: Episodic Memory (word recall), Fluid Intelligence (Raven's test/numeracy test)
- ▶ **Linking:** IFLS geocodes matched to GMW data → Mangrove cover/loss within 30km radius

Measuring Mangrove Exposure

- ▶ Mangrove data: snapshots of mangrove coverage in 1996, 2007-2009, and 2015-2020 (Global Mangrove Watch)
 - ▶ Alternative metric (Richard and Friess 2016 PNAS; Yamamoto 2022 JEEM): Masking forest change Map (Hansen et al. 2013) with mangrove map (USGS) to isolate mangrove loss
- ▶ Measure 1: **Mangrove Coverage**
 - ▶ Percentage of land covered by mangroves within 30km of community c in year t
 - ▶ Measures forest endowment
- ▶ Measure 2: **Mangrove Loss**
 - ▶ Binary = 1 if net loss occurred between baseline and survey year (1996-2007 for IFLS wave 2007; 2010-2015 for IFLS wave 2014/15)
 - ▶ Measures ecosystem degradation over time

Empirical Strategy

Estimating equation:

$$y_{ihct} = \beta_1 \text{MangroveExposure}_{ct} + X'_{ihct}\gamma + \sigma_i + \eta_t + \epsilon_{ihct}$$

- ▶ y_{ihct} : Mental health or cognitive outcome (individual i , household h , community c , time t).
- ▶ $\text{MangroveExposure}_{ct}$: Mangrove coverage/loss within 30km of community c in year t .
- ▶ X'_{ihct} : Time-varying controls (age, marital status, education, etc.)

Results on Mangrove Cover

- ▶ Higher mangrove cover decreases depressive symptoms (CESD-10)
 - ▶ 1pp increase in mangrove cover = 0.16 point decrease in CESD-10 score
- ▶ No effects of mangrove cover on cognitive ability

Table 2: The effects of mangrove coverage on mental health and cognitive ability

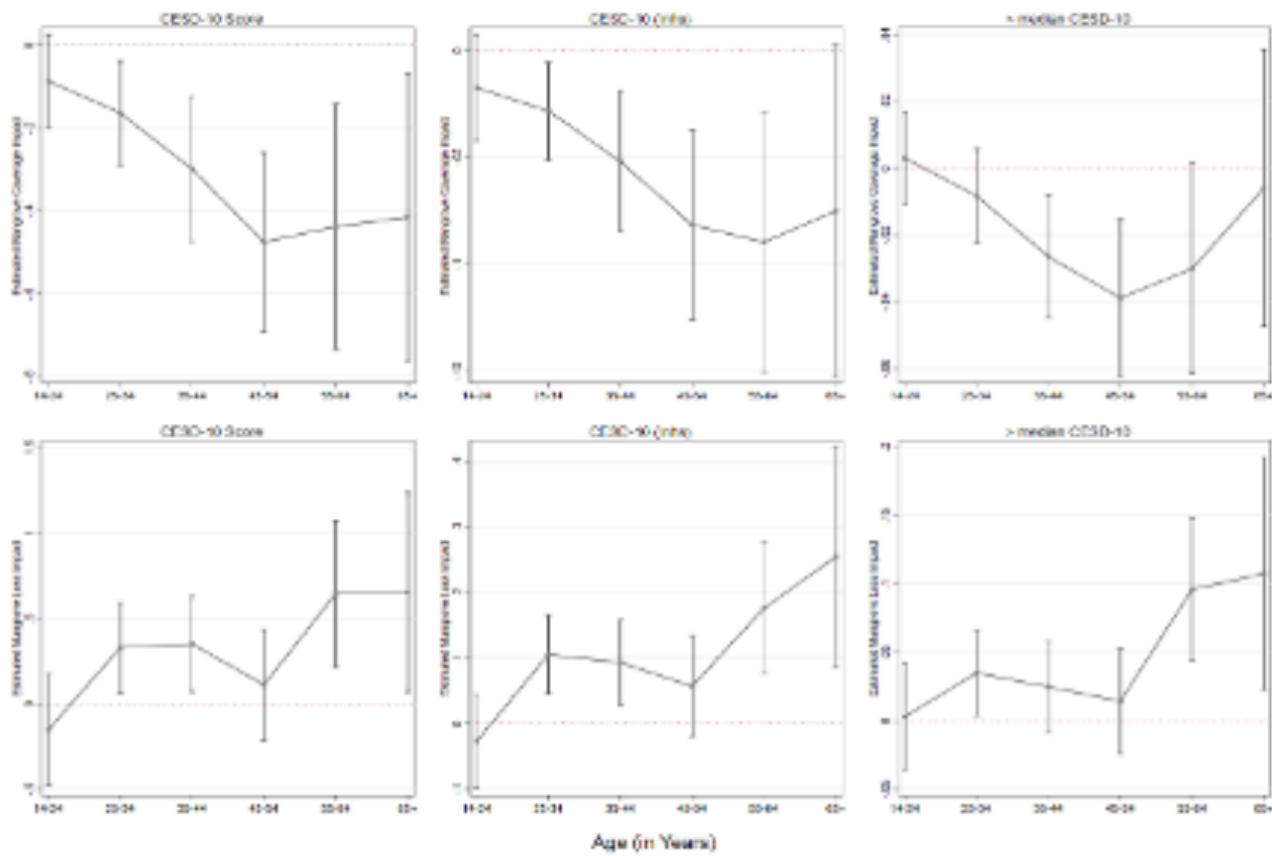
	(1)	(2)	(3)	(4)	(5)
Panel A: Mental Health					
Based on the cesd-10 score					
	cesd10	cesd10 (log)	cesd10 (inhs)	> median cesd10	>=10 cutoff
Mangrove Cover (% Mangrove coverage within 30 km buffer)	-0.161** (0.072)	-0.024** (0.011)	-0.029** (0.013)	-0.007 (0.008)	-0.013** (0.006)
Mean of dependent variable	4.680	1.458	1.862	0.396	0.128
Observations	37,198	37,198	37,198	37,198	37,198
R-squared	0.637	0.623	0.619	0.604	0.582
Panel B: Cognitive Ability					
	episodic memory		fluid intelligence		
	immediate recall	delayed recall	total recall	strong raven and numeracy skills	strong cognition
Mangrove Cover (% Mangrove coverage within 30 km buffer)	-0.013 (0.020)	0.002 (0.022)	-0.011 (0.038)	0.006 (0.006)	0.001 (0.003)
Mean of dependent variable	4.750	3.707	8.466	0.185	0.104
Observations	36,324	36,324	36,324	14,098	14,098
R-squared	0.748	0.721	0.759	0.668	0.658
Individual FE	✓	✓	✓	✓	✓
Wave FE	✓	✓	✓	✓	✓
Individual and household controls	✓	✓	✓	✓	✓

Result on Mangrove Loss

- ▶ Mangrove loss increases depressive symptoms (CESD-10)
 - ▶ Loss of mangrove = 0.24 point increase in CESD-10 score
- ▶ Mangrove loss decreases cognitive ability
 - ▶ Loss of mangrove = 0.19 point decrease in total recall, 3.1pp decrease in having strong fluid/numeracy intelligence

Table 3: The effects of mangrove loss on mental health and cognitive ability

	(1)	(2)	(3)	(4)	(5)
Panel A: Mental Health					
Based on the cesd-10 score					
	cesd10	cesd10 (log)	cesd10 (inhs)	> median cesd10	>=10 cutoff
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	0.235** (0.109)	0.063*** (0.019)	0.080*** (0.024)	0.031*** (0.012)	0.014 (0.009)
Mean of dependent variable	4.680	1.458	1.862	0.396	0.128
Observations	37,198	37,198	37,198	37,198	37,198
R-squared	0.637	0.623	0.619	0.604	0.582
Panel B: Cognitive Ability					
	episodic memory		fluid intelligence		
	immediate recall	delayed recall	total recall	strong raven and numeracy skills	strong cognition
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	-0.106*** (0.037)	-0.086** (0.042)	-0.191*** (0.071)	-0.031** (0.012)	-0.024** (0.010)
Mean of dependent variable	4.750	3.707	8.466	0.185	0.104
Observations	36,324	36,324	36,324	14,098	14,098
R-squared	0.748	0.721	0.759	0.668	0.658
Individual FE	✓	✓	✓	✓	✓
Wave FE	✓	✓	✓	✓	✓
Individual and household controls	✓	✓	✓	✓	✓



Robustness Checks

Our baseline results are robust to:

- ▶ Alternative specifications of fixed effects
- ▶ Alternative clustering methods
- ▶ Additional controls (media, amenities, childhood conditions)
- ▶ Restricting sample based on migration status

Mechanisms Overview: How Does Mangrove Loss Impact Welfare?

Potential Pathways:

① Cultural and Perceptions

- ▶ Lower perceived mobility
- ▶ Bleaker economic future
- ▶ 'Ecological grief'

② Hazard Exposure

- ▶ Reduced coastal protection
- ▶ Increased flood/storm risk

③ Livelihood and Income

- ▶ Income loss / Lower wages
- ▶ Compensating labor supply increase
- ▶ Reduced consumption
- ▶ Lower local economic activity

Mechanism 1: Perceptions

Table 4: Mangrove loss, perceived upward social mobility, and future economic outlook

	(1)	(2)	(3)
Panel A: Low Perceived Upward Social Mobility			
(Based on Subjective Social Status)			
	current and future	past and future	past, current, future
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	0.016* (0.009)	0.019** (0.008)	0.016** (0.008)
Observations	32,940	32,940	32,940
R-squared	0.581	0.580	0.582
Panel B: Standard of Living and Future Economic Outlook			
	Bleak economic outlook	Inadequate std.of living (adults and children)	Bleak economic outlook and low social mobility
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	0.012 (0.012)	0.011 (0.012)	0.018*** (0.007)
Observations	36,110	15,516	32,378
R-squared	0.614	0.596	0.571
Individual FE	✓	✓	✓
Wave FE	✓	✓	✓
Individual and household controls	✓	✓	✓

Mechanism 2: Flooding and Natural Hazards

Table 5: Mangrove loss and exposure to floods and other disasters

	Dependent Variables					
	<u>Floods only</u>		<u>Floods or windstorms</u>		<u>Floods and other disasters</u>	
	(1)	(2)	(3)	(4)	(5)	(6)
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	0.018** (0.007)	0.018*** (0.006)	0.016* (0.009)	0.016** (0.007)	0.020** (0.008)	0.023*** (0.007)
Observations	35,160	37,148	35,160	37,148	35,160	37,148
R-squared	0.639	0.617	0.628	0.606	0.652	0.630
Individual FE	✗	✓	✗	✓	✗	✓
Household FE	✓	✗	✓	✗	✓	✗
Wave FE	✓	✓	✓	✓	✓	✓
Individual and household controls	✗	✓	✗	✓	✗	✓

Mechanism 3: Income and Livelihood

Table 8: Mangrove Loss, income and employment

	Dependent Variables			
	Income (last year) (1)	Work for pay (2)	Employed last year (3)	Hours worked (4)
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	-0.070** (0.034)	-0.008 (0.010)	-0.009 (0.009)	1.138** (0.568)
Observations	15,706	37,194	37,174	22,684
R-squared	0.785	0.666	0.689	0.635
Individual FE	✓	✓	✓	✓
Wave FE	✓	✓	✓	✓
Individual and household controls	✓	✓	✓	✓

Mechanism 3: Income and Livelihood

Table 9: Mangrove loss, purchase of protein-rich foods, and consumption

	Dependent Variables				
	Purchase of	Consumption			Non-food
	Fish	Protein-rich	Healthy Food	Total Food	
	(1)	(2)	(3)	(4)	(5)
Panel A: Full Sample					
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	-0.026*	-0.017	-0.089*	-0.024	-0.065*
	(0.015)	(0.012)	(0.047)	(0.028)	(0.036)
Observations	35,050	35,050	35,050	35,050	35,050
R-squared	0.643	0.640	0.673	0.739	0.776
Panel B: Food insecure Households (Based on FCS Score)					
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	-0.059*	-0.024	-0.066	-0.087*	-0.173***
	(0.032)	(0.027)	(0.084)	(0.050)	(0.057)
Observations	16,977	16,977	16,977	16,977	16,977
R-squared	0.732	0.720	0.726	0.813	0.854
Household FE	✓	✓	✓	✓	✓
Wave FE	✓	✓	✓	✓	✓
Individual and household controls	✓	✓	✓	✓	✓

Mechanisms

Table A6: Mangrove loss and the potential transmission channels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Dependent Variables					Strong cognition				
	CESD-10 Score									
Mangrove Deforestation (30km) (1 = Mangrove loss within 30 km buffer)	0.235** (0.109)	0.208* (0.116)	0.188 (0.137)	0.142 (0.162)	-0.146 (0.213)	-0.024** (0.010)	-0.025** (0.011)	-0.012 (0.012)	-0.038** (0.015)	-0.019 (0.018)
Low perceived upward social mobility	x				x	x	x			x
Flood/windstorm exposure		x			x		x		x	x
Income and consumption			x	x				x	x	
Observations	37,198	32,940	26,546	15,676	10,034	14,098	12,908	8,714	4,386	2,348
R-squared	0.637	0.637	0.638	0.641	0.643	0.658	0.660	0.679	0.654	0.659
Individual FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wave FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual and household controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: This table shows the estimated effects of mangrove loss on mental health and cognitive ability when the regressions are gradually augmented with the three potential mechanisms. The dependent variables are defined as in Table 3 for the main results. All models include the same set of control variables and fixed effects, and all regressions are estimated via OLS, weighted according to the survey design. Standard errors are clustered at the household level. ***p<0.01, **p<0.05, *p<0.1.

Can Adverse Impacts Be Buffered?

- ▶ Question: Do certain factors moderate the negative relationship between mangrove loss and welfare?
- ▶ We test three potential buffers:
 - ① Ecological Recovery Potential
 - ② Social Safety Nets (Unconditional Cash Transfers)
 - ③ Social Capital (Community Engagement)

Appendix: Detailed Mitigation Results

Mitigation Findings: Restoration Potential Matters Most

► Ecological Recovery Potential: ✓ Significant Buffer (Mental Health)

Results

- ▶ Higher restoration potential significantly attenuates negative mental health impacts of loss.
- ▶ Interaction term suggests buffering effect can statistically offset the main negative impact.
- ▶ Mixed evidence for cognition (buffers episodic memory, less so fluid intelligence).

► Unconditional Cash Transfers (UCTs): ✗ No Significant Buffer

Results

- ▶ BLT/BLSM program presence does not significantly moderate the mangrove loss effect.
- ▶ Suggests poverty alleviation alone may not address key pathways (e.g., psychological stress, loss of services).

► Social Capital: ✗ No Significant Buffer (for loss effect)

Results

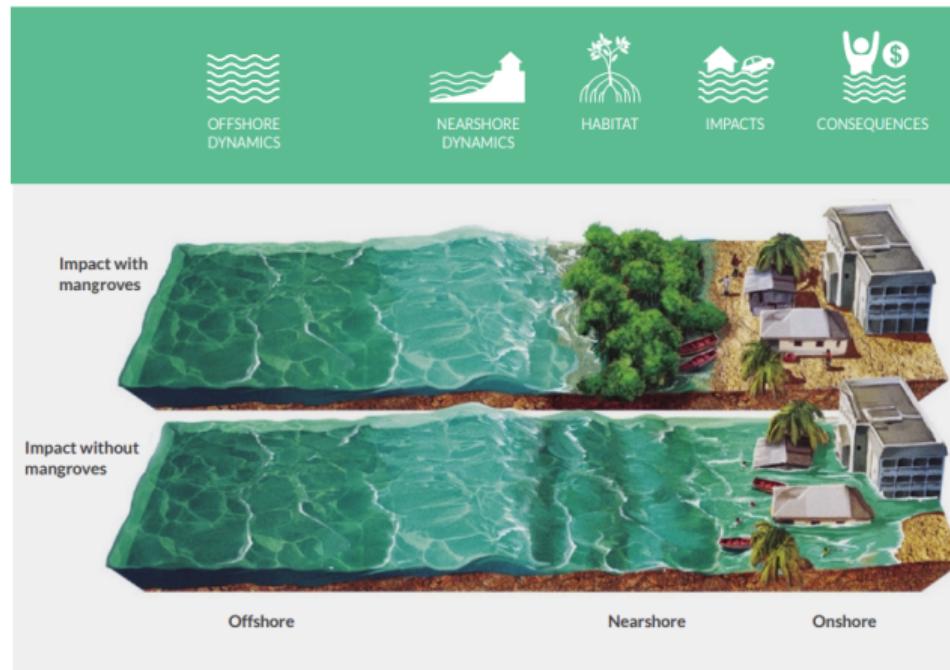
- ▶ High social capital improves mental health directly.
- ▶ But, it does not significantly moderate the negative effect *of mangrove loss* on mental health or cognition.

Conclusion Implications

- ▶ Mangrove loss in Indonesia significantly worsens mental health and cognitive function.
- ▶ Impacts operate through multiple channels: ecological anxiety, disaster risk, and income loss.
- ▶ Ecological restoration potential offers significant psychological resilience against loss impacts.
- ▶ Conservation/restoration is critical for coastal communities' well-being.

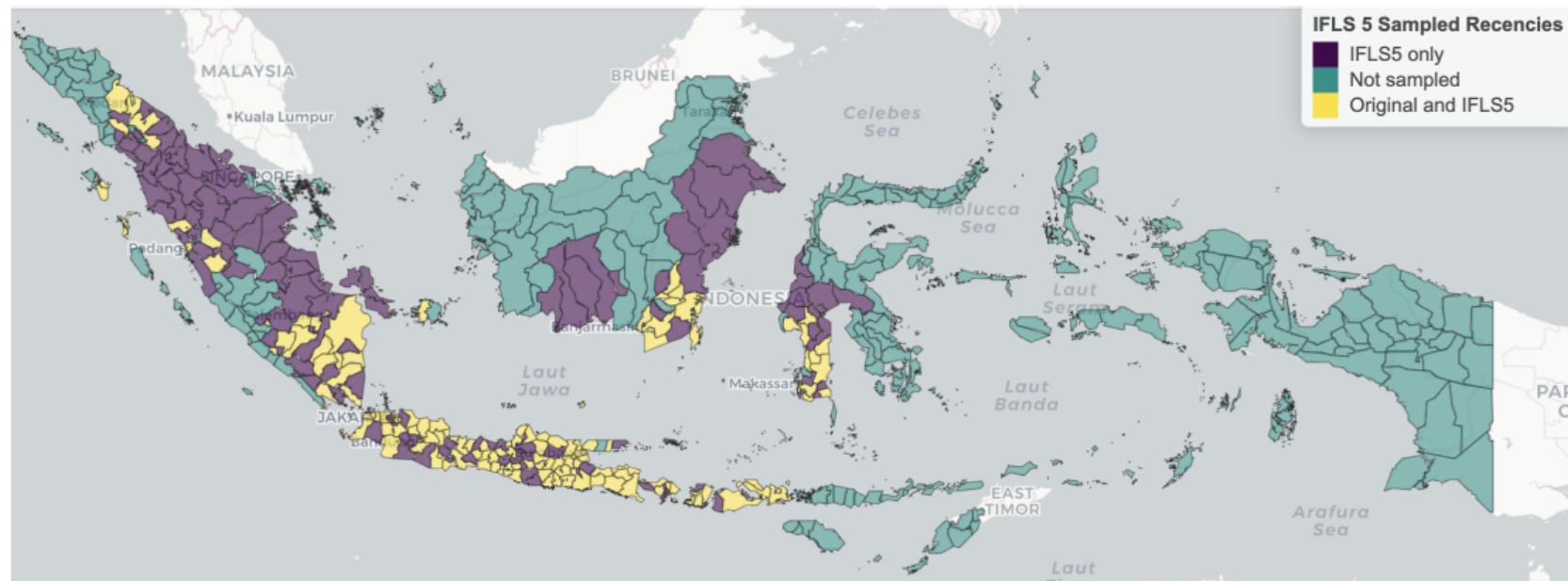
Flooding and Mangroves

FIGURE 8.1
Key steps and data for estimating the flood protection benefits provided by mangroves



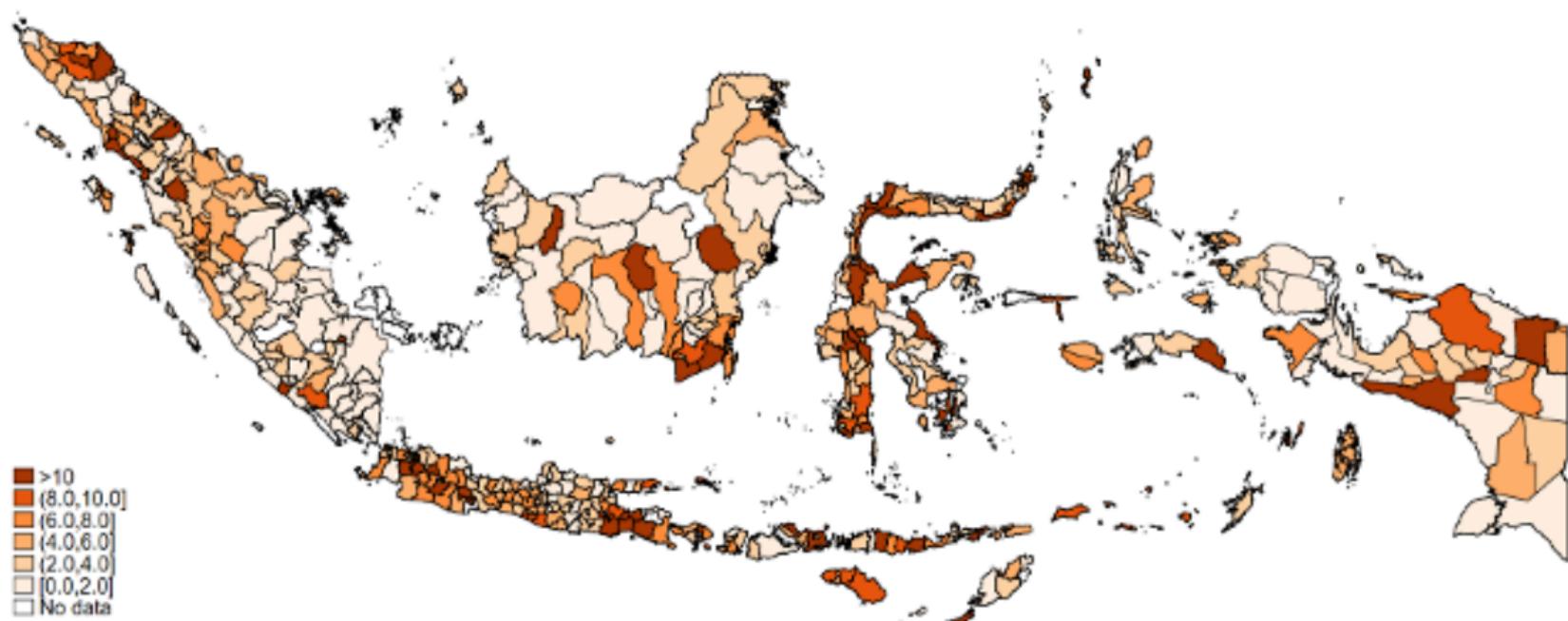
Source: Figure 2.1 in Menéndez et al. 2024.

IFLS Sampling Coverage



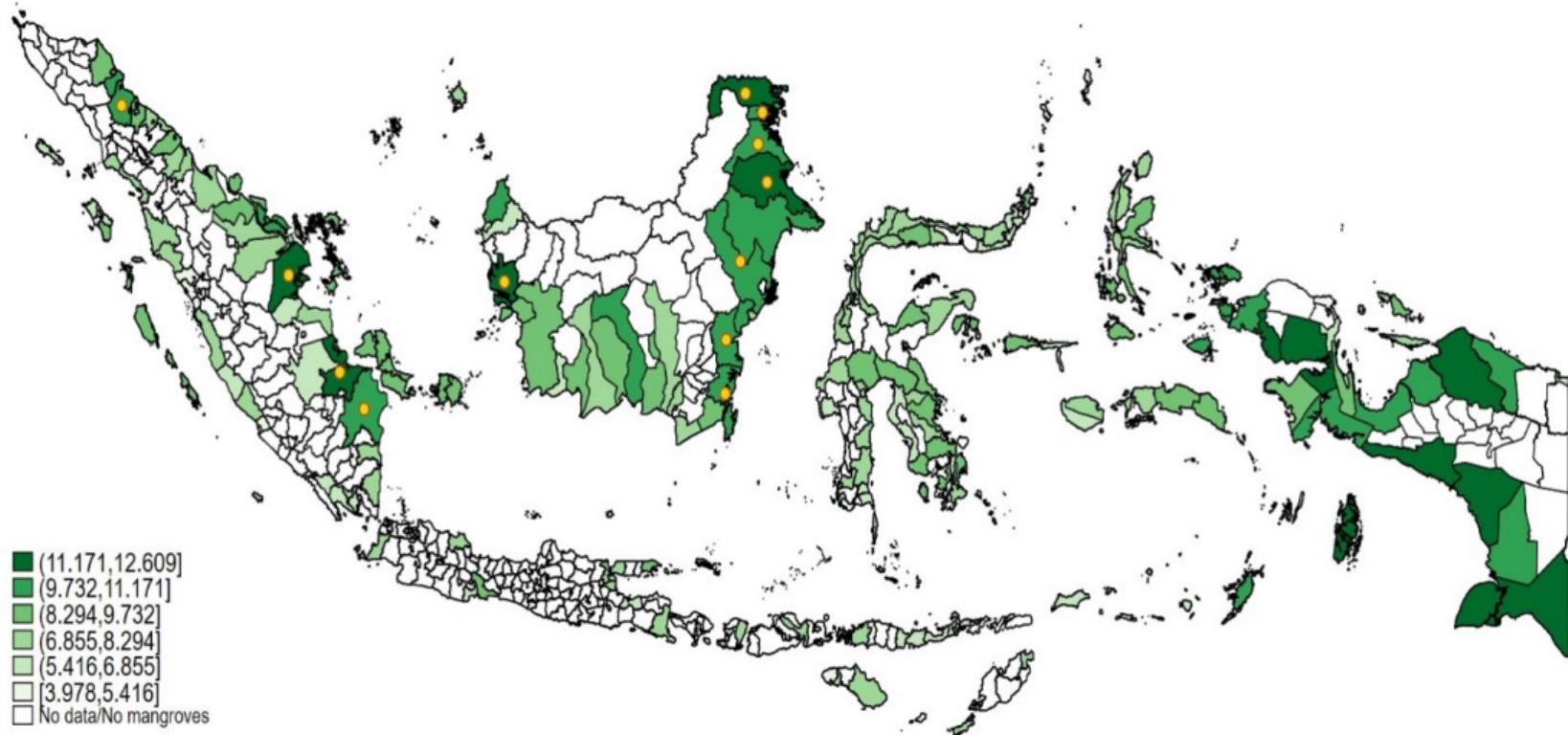
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Mental Health Conditions in Indonesia (SQR-20 score)



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Mangrove Coverage and Restoration Potential



Summary Statistics

	Mean (1)	Std. (2)	Panel D: Individual and household controls	
Panel A: Mental health outcomes (CESD-10)				
Total CESD-10 score	4.680	4.251	Age	41.517 14.982
Log of CESD-10 score	1.458	0.783	Married	0.765 0.424
Inverse hyperbolic sine of CESD-10	1.862	0.973	Rural	0.530 0.499
Binary: CESD-10 > median score	0.396	0.489	Muslim	0.938 0.242
Binary: CESD-10 ≥ 10 (clinical cutoff)	0.128	0.334	Household size	4.201 1.839
Panel B: Cognitive outcomes			Primary education	0.419 0.493
Immediate word recall	4.750	1.922	Junior high education	0.175 0.380
Delayed word recall	3.707	2.090	Senior high education	0.244 0.430
Total episodic memory (immediate + delayed)	8.466	3.761	College/university education	0.093 0.290
Binary: Top quartile in EK test	0.185	0.389	Household head is male	0.835 0.371
Binary: Strong cognition (EK + memory)	0.104	0.305		
Panel C: Mangrove variables				
Mangrove coverage (within 30km)	0.401	1.506		
Mangrove loss (within 30 km)	0.261	0.439		

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Appendix: Outcome Variable Details

► Mental Health (CESD-10):

- ▶ Standard 10-item scale measuring depressive symptoms in past week
- ▶ Score range 0-30, higher scores indicate worse mental health
- ▶ Items cover feelings like sadness, hopelessness, effort, happiness (reverse coded)
- ▶ Clinical cutoff at ≥ 10 for depression screening

► Cognition: Episodic Memory

- ▶ Immediate & delayed recall of 10-word list
- ▶ Total score range 0-20.

► Cognition: Fluid Intelligence Proxy

- ▶ Based on Raven's Progressive Matrices (pattern completion)
- ▶ Combined with numeracy test score
- ▶ Used to create binary indicators for 'top quartile' performance

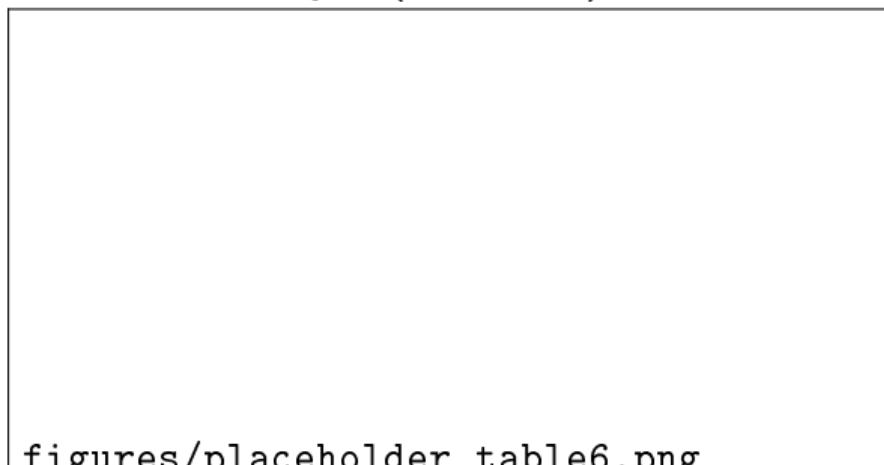
Appendix: Robustness Checks

- ▶ Results robust to alternative Fixed Effects specifications (Household, Province, Community, Sub-district, District-by-Year FE). (See Table A1)
- ▶ Results robust to alternative standard error clustering methods (Individual, Two-way clustering). (See Table A2)
- ▶ Results robust to adding more controls (media, amenities, childhood conditions). (See Table A3)
- ▶ Results robust to restricting sample based on migration status. (See Table A3)
- ▶ Results robust to controlling for drivers of mangrove loss (commodity-driven, erosion, etc.). (See Table A4)

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Appendix: Detailed Mechanism Results

- ▶ Perceived Mobility / Outlook (Table 4)
- ▶ Flood Exposure (Tables 5, 6, 7)
- ▶ Income and Labor (Table 8)
- ▶ Consumption (Table 9)
- ▶ Nighttime Lights (Table A5)
- ▶ Mediation Analysis (Table A6)



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Appendix: Mitigation - Ecological Recovery Potential

Table A7: The effects of mangrove loss with heterogeneous restoration potential

	(1)	(2)	Dependent Variables:		
	(1)	(2)	(3)	(4)	(5)
Panel A: Mental Health					
Based on the cesd-10 score					
Mangrove Deforestation (30km)	cesd10 0.801*** (0.160)	cesd10 (log) 0.130*** (0.031)	cesd10 (inhs) 0.158*** (0.038)	> median cesd10 0.104*** (0.020)	>=10 cutoff 0.045*** (0.013)
rest. opport. ratio (=1 if >median)	0.145 (0.538)	0.026 (0.090)	0.034 (0.111)	0.062 (0.068)	-0.027 (0.045)
Mangrove Deforestation (30km) x <u>rest.opport.ratio</u>	-0.973*** (0.212)	-0.114*** (0.039)	-0.132*** (0.048)	-0.126*** (0.025)	-0.055*** (0.017)
Observations	30,648	30,648	30,648	30,648	30,648
R-squared	0.632	0.617	0.612	0.604	0.583
Joint test	-0.172	0.0162	0.0265	-0.0213	-0.00997
F-statistic	1.342	0.414	0.722	1.909	0.696
p-value	[0.247]	[0.520]	[0.395]	[0.167]	[0.404]
Panel B: Cognitive Ability					
episodic memory					
Mangrove Deforestation (30km)	immediate recall -0.341*** (0.059)	delayed recall -0.323*** (0.066)	total recall -0.664*** (0.112)	strong raven and numeracy skills -0.050** (0.022)	strong cognition -0.042** (0.018)
rest. opport. ratio (=1 if >median)	-0.042 (0.148)	0.081 (0.190)	0.039 (0.309)	-0.190*** (0.060)	-0.092** (0.044)
Mangrove Deforestation (30km) x <u>rest.opport.ratio</u>	0.432*** (0.073)	0.432*** (0.084)	0.863*** (0.141)	0.036 (0.026)	0.033 (0.021)
Observations	29,926	29,926	29,926	11,672	11,672
R-squared	0.746	0.716	0.756	0.654	0.645

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Appendix: Mitigation - Unconditional Cash Transfers (UCTs)

Table A7: The effects of mangrove loss with heterogeneous restoration potential

	(1)	(2)	(3)	Dependent Variables:	(4)	(5)
Panel A: Mental Health						
Based on the cesd-10 score						
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Observations	30,648	30,648	30,648	30,648	30,648	
R-squared	0.632	0.617	0.612	0.604	0.583	
Joint test	-0.172	0.0162	0.0265	-0.0213	-0.00997	
F-statistic	1.342	0.414	0.722	1.909	0.696	
p-value	[0.247]	[0.520]	[0.395]	[0.167]	[0.404]	
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rest. opport. ratio (=1 if >median)	-0.042 (0.148)	0.081 (0.190)	0.039 (0.309)	-0.190*** (0.060)	-0.092** (0.044)	
Mangrove Deforestation (30km) x <u>rest.opport.ratio</u>	0.432*** (0.073)	0.432*** (0.084)	0.863*** (0.141)	0.036 (0.026)	0.033 (0.021)	
Observations	29,926	29,926	29,926	11,672	11,672	
R-squared	0.746	0.716	0.756	0.654	0.645	

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Appendix: Mitigation - Social Capital

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