CAPSTONE

The Impact of Mangrove Loss on Fishermen's Income in Indonesia:

A Regional Fixed-Effects Analysis

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ABSTRACT: Indonesia's mangrove ecosystems are critical to the livelihoods of millions of small-scale fishers, yet widespread degradation threatens both ecological stability and economic well-being. This study examines how regional variation in mangrove loss influences fishermen's income across Indonesian districts (*Kabupaten*), using household-level data from the Indonesian Family Life Survey (IFLS) and satellite-based land cover maps from the Global Mangrove Watch (GMW). By employing fixed-effects regression models, the research isolates the effect of localized mangrove degradation on fishermen's income while controlling for unobserved regional characteristics. The research contributes to ongoing scholarly discussions on ecosystem services, rural poverty, and coastal development, and offers policy-relevant insights for Indonesia's national mangrove restoration initiatives and blue economy strategy.

KEYWORDS: Mangrove-fishery link; Ecosystem services; Indonesia; Fishery Income; Region-fixed effect

1. Introduction

Indonesia is home to the largest mangrove forest area in the world, accounting for approximately 20% of the global total and spanning an estimated 3.86 million hectares (Marlianingrum et al., 2021). Mangroves are exceptionally productive and vital ecosystems that support many coastal communities due to the myriads of goods and ecosystem services they provide (Gretchen Daily et al., 1997). Mangroves are essential in sustaining local fisheries as crucial breeding grounds and nursery habitats for diverse marine life (Carrasquilla-Henao and Juanes, 2017). This is particularly important, considering that around 210 million people live within 10 kilometres of mangrove forests (Hutchison et al., 2014), which contribute significantly to economic value, job opportunities, and food security.

Despite their ecological importance, Indonesia has experienced extensive mangrove degradation. Between 1996 and 2020, the country lost approximately 1,739 km² of mangrove area—a 30% reduction—largely due to the expansion of aquaculture and land conversion for palm oil (Global Mangrove Watch, 2020; Evans, 2020). Although the rate of loss has slowed in recent years (Goldberg et al., 2020), projections indicate that as much as 700,000 additional hectares may be lost over the next two decades if current land-use pressures persist (Ilman et al., 2016). These ecological changes may have profound implications for coastal livelihoods, particularly among small-scale fishermen who depend directly on mangrove-linked fisheries.

Mangroves are widely recognised for their essential role as nursery habitats, making them critical to the sustainability of coastal fisheries (Carrasquilla-Henao et al., 2019). Several studies have demonstrated the significant contributions of mangroves to local fishing communities, highlighting their economic value (Bollini and Millar, 2021; Aburto-Oropeza et al., 2019; UNEP, 2014). Although these studies indicate a correlation between the extent of mangrove cover and fisheries production, they often lack a demonstration of causality and fail to uncover the mechanisms that drive this relationship. This is a key point raised by Gibson et al. in their evaluation of the evidence for the linkages between mangroves and fisheries. While the connection between mangroves and fisheries is generally accepted, identifying underlying mechanisms remains challenging since mangroves are situated within intricate social-ecological systems.

This capstone seeks to contribute to this area of inquiry by examining how variations in mangrove loss across Indonesian districts (“Kabupaten”) influence the income levels of local fishermen (“Nelaya” in Bahan Indonesian), with particular attention to controlling for regional heterogeneity through fixed effects.

The central research question driving this study is: To what extent does regional variation in mangrove loss explain differences in fishermen’s income across Kabupaten in Indonesia? By combining geospatial land cover data from the Global Mangrove Watch with microdata from the Indonesian Family Life Survey (IFLS), this research estimates the impact of mangrove degradation on fishermen's earnings while accounting for unobserved regional characteristics. In doing so, the project aims to move beyond descriptive studies and toward a better understanding of the socio-economic consequences of ecological change.

The findings are expected to have practical implications for marine resource governance, coastal land-use planning, and policies aimed at supporting small-scale fisheries in Indonesia—an economic sector that employs nearly 90% of all fishers and contributes significantly to national food security and GDP (FAOSTAT, 2018; Statista, 2023).

A better understanding of the relationship between mangrove ecosystems and fisheries is important, particularly in the context of the ongoing land-use changes, that directly affect both the economic well-being of fishing communities and national food security in Indonesia. Many people, especially small-scale fishermen, rely on mangrove forests for their livelihoods. This research focuses on that connection.

Fish and seafood are key food sources, with about 70 million people depending on them for food and income (FAO, 2025). Approximately 90% of Indonesian fishers rely on small-scale fisheries for their livelihoods and food security (FAOSTAT, 2018). The fishery sector is also important for Indonesia's economy, contributing 2.66% to the country's gross domestic product (Statista, 2023). Most of this production—95%—comes from small-scale fishers (Statistics Indonesia, 2018).

2. Research context

Mangroves form an integral part of Indonesia’s coastal socio-ecological systems. Their role in maintaining marine biodiversity (Marine Biodiversity Science Centre, 2024), stabilizing coastlines (Spalding et al., 2014) and supporting fishery productivity has been well-documented across ecological and economic literature (Alongi, 2002; Barbier et al., 2011; Hutchison et al., 2014).

Mangroves provide crucial ecosystem services (ES) through two main ecological functions: They are a source of food and nutrients for the local ecosystem through the detritus produced by mangrove litter, and at the same time provide shelter for a variety of marine species, including fish, crustaceans, and molluscs, reducing predation risk and allowing them to flourish. Furthermore, they effectively trap and retain nutrients, such as nitrates and phosphates carried by rivers and streams to the sea while removing excess nutrients and pollutants from the water (Singh et al., 2005; Lin and Dushoff, 2020).

As nursery habitats for juvenile fish and crustaceans, mangroves serve thus as a foundation for small-scale fisheries that dominate Indonesia’s coastal economy. At the same time, these ecosystems are increasingly under threat from human activities such as aquaculture expansion, illegal logging, and infrastructure development—particularly in densely populated and economically dynamic regions like Java, Sumatra, and Sulawesi.

The loss of mangrove coverage can disrupt marine trophic chains, reduce fish catch volumes, and lead to income instability among fishing households. However, the extent and consequences of these impacts are not uniform across space. Some Kabupaten have experienced rapid mangrove loss due to large-scale land-use conversion, while others have maintained or even restored mangrove cover through community-based or government-led conservation efforts (Firdaus et al., 2021).

This regional variation presents an important empirical opportunity. While previous studies (e.g., Hutchison et al., 2014; Aburto-Oropeza et al., 2008) have explored the ecological linkages between mangroves and fisheries, few have examined the socioeconomic outcomes of mangrove degradation using microeconomic data. Moreover, existing research has largely focused on national-level trends or case studies, such as India (Anneboia and Kavi Kumar, 2019), Malaysia (Chong, 2018), Bangladesh (Islam and Haque, 2004), Mexico (Barbier et al., 1998) and Colombia (Carrasquilla-Henao et al.,2021), but few have tried to account for subnational heterogeneity in environmental exposure, institutional capacity, or livelihood diversification.

This study seeks to address this gap by integrating household-level income data from the Indonesian Family Life Survey (IFLS) with satellite-derived mangrove land cover data from the Global Mangrove Watch (GMW). By using a panel of Kabupaten with varying degrees of mangrove loss, and by applying fixed-effects regression techniques, this research aims to isolate the income effects of localized ecological change, net of confounding regional characteristics. In doing so, this study contributes to broader discourses on environmental justice, rural development, and coastal resilience in the context of Indonesia’s sustainable development goals.

This research is particularly timely given Indonesia's increasing policy attention to "blue economy" initiatives and mangrove restoration targets under the National Mangrove Rehabilitation Program (2021–2024). Understanding the local-level economic implications of mangrove degradation can inform these efforts and support more equitable and data-driven coastal management.

A better understanding of this contribution would provide a more complete picture of the potential effects of mangrove deforestation and degradation on the economic and social well-being of local communities. In this paper, we focus on the importance of mangrove forests for local small-scale fisheries in supporting habitats for fish throughout Indonesia.

Scholarly research has approached this relationship between mangroves and fisheries through various disciplinary lenses. Ecologists and marine biologists have employed field experiments, tagging studies, and remote sensing to quantify habitat usage and species-specific dependency on mangrove environments (e.g., Sheridan & Hays, 2003). Meanwhile, economists and development scholars have examined the socioeconomic benefits derived from mangrove conservation or loss, using methods such as contingent valuation, cost-benefit analysis, and household surveys (e.g., Barbier, 2007).

While many studies have shown correlations between the extent of mangrove cover and fisheries production, these studies often lack causality and fail to identify the mechanisms that create this relationship, according to Gibson et al. (2005). Indeed, because of the many indirect-use values mangroves provide to economic activity through their ecosystem services, it is hard to evaluate the causal effects of mangrove degradation on fisheries. According to Ickowitz et al., there is an "absence of a consensus on the specific mechanisms linking mangroves to fisheries and through which specific ways". This absence of consensus on the pathways in which mangroves economically contribute to fisheries is the point of research this thesis is intended to fulfil. It is mainly through the reading of Yamamoto's '*Living under ecosystem degradation: Evidence from the mangrove-fishery linkage in Indonesia*' that the thesis subject arises: the paper focuses on the impacts of mangrove degradation on social and economic welfare for small-scale fisheries in Indonesia. It applies a causal research design using instrumental variables (IV) to confirm that mangrove loss reduces fishery incomes. In the context of this thesis, we would like to explore this correlation through the lens of regional variations and by focusing solely on small-scale coastal community fisheries in different regions of Indonesia.

Key Studies used to generate Thesis		Synthesis
Main Studies	(Yamamoto, 2023)	It focuses on the socioeconomic consequences of mangrove degradation, particularly for fishery-dependent communities in Indonesia.
	(Ickowitz et al., 2023)	Quantifies the contribution of mangroves to local fish consumption by coastal households in Indonesia (food security)
	(Anneboina and Kavi Kumar, 2017)	Evaluates the economic contribution of mangroves in increasing marine fish output in India.
	(Gibson et al., 2005)	Assesses the assumption that mangroves are crucial nursery habitats for fishery species and examines the underlying ecological processes supporting this link
	(Barbier et al. 2000)	Reviews recent developments in the methodology for valuing the role of wetlands in supporting economic activity

Secondary questions that may arise from the approaches taken in these specific studies include how incorporating different potential instrumental variables may vary the results. Is applying a production function approach, which is the main approach used in the different studies to estimate the effects of mangrove loss on fishery welfare, the best approach?

3. Methodology

3.1. Study Design

We perform a cross-sectional, spatial analysis in this study. We combined data on farm business characteristics for rural Indonesian coastal households from the IFLS4 and IFLS5 surveys with spatial data on mangrove forest distribution and cover from the Global Mangrove Watch to create a cross-sectional spatial dataset. Using a fixed-effects regression model, we estimated to what extent fishermen's income differs from the region (specifically from Kabupaten) and to what extent mangrove cover and loss have an impact on it.

3.2. Data

3.2.1. Fishermen Data

For this analysis, we use a dataset called the Indonesian Family Life Survey (IFLS). The IFLS is a longitudinal household and community survey with detailed information on the economic, demographic, health, and social characteristics of individuals and households in Indonesia. It is conducted by RAND Corporation in collaboration with Indonesian institutions. The IFLS survey is a well-representative dataset since it covers 13 of the 27 provinces of Indonesia, including 83% of the Indonesian population. Furthermore, it tracks the same households and individuals over time, including split-offs. The IFLS was first fielded in 1993 when it was called the IFLS1, and it initially collected a sample of almost 7000 households and 24,000 individuals. For the case of this thesis, we will be using the dataset from the IFLS4, which covers the full original sample, and IFLS5 waves which were respectively fielded in 2007/2008 and 2014/2015.

For our research, we only want to analyse the fluctuations in income of small-scale coastal fishermen; also called "*Nelayan*" in Bahasa Indonesia. *Nelayan* only applies to those who capture fish in the ocean or the open water, and not in aquaculture or the fishery processing industry. That way we specifically target individuals who are most reliable on mangroves for capturing fish. To identify households whose members are fishermen but do not work in aquaculture or the fish processing industry, we use the occupation codes provided in the survey data of the fourth and fifth wave of the IFLS survey. The occupation code we considered to identify small-scale fishermen is "64" since, according to the IFLS1 Household Codebook Appendix A, it includes "fishermen, hunters and related works". In both waves, these occupation codes can be found in Book 3A_TK2 ("Work History - Current Job"). To further constrain the population considered in this capstone research, we made sure that fish is one of the most valuable resources that households produce, including households that mainly rely on fish catch for their income. Furthermore, we made sure that the individuals are located next to the sea (coastal fishermen) since we want to measure how fishermen are reliant on mangroves for their economic well-being.

Most of the data included in this research can be found in the Household Survey Book 2 and Household Survey Book 3A dataset which encompasses data on the socio-economic status of households and individuals and their work history.

By applying these constraints to the subjects interviewed in the IFLS survey, we get a sample of 122 different households in the fourth wave of the IFLS survey and a sample of 110 households in the fifth wave of the survey. Including both the samples from IFLS4 and IFLS5, the study area includes a total of 18 regencies, or "Kabupaten" in Bahasa Indonesia (see Table 1).

3.2.2. Mangrove Data

For the geographical and temporal distribution of aggregate mangrove loss rate per Kabupaten, we used the mangrove distribution land cover maps provided by the Global Mangrove Watch (GMW), which provides one of the most accurate and comprehensive global datasets on mangrove extent, change, and condition for different time series (1996; 2007; 2008-2020) over the whole world. To construct the cumulative mangrove loss rate for the periods 2000-2007 and 2007-2014 we subtracted the mangrove coastline coverage between 1996 and 2007 (since there was no land cover map for the year 2000) and between 2007 and 2014 respectively, and calculated the percentage mangrove loss for both of these timeframes. This dataset is used to identify the geographical and temporal distribution of mangrove forests in the different kabupaten comprised in our analysis (namely where the target fishermen households are situated).

The mangrove distribution land cover maps provided by the Global Mangrove Watch have allowed us to calculate the percentage mangrove loss over the two time periods 1996-2007 and 2007-2015, but also to compute the area of mangrove per kabupaten (as a share of total national area) for all kabupatan in the studied area.

Figure 1 shows the share in percentage of total mangrove area per kapubaten in the studied area. We see how the regencies Gresik, Kota Baru and Ogan Komering Ilir are the ones with the highest percentage share of national mangroves within our study sample.

Figure 2 shows the results of compiling the mangrove loss rate at the regency level (Kabupaten) for the target areas where the specific fishermen households are situated. These are the results for the years between 1996 and 2007 and between 2007 and 2015.

Furthermore, aside from the percentage share of national mangroves a certain regency may have, we also included a qualitative ranking from 0 to 3 for the baselines for mangrove cover (indicating their original extent). This is a more informative way to show whether or not there is linearity between the dependent variable and the baseline by reporting the coefficient per baseline class.

Fig. 1 *Share of total national mangrove area that each study Kabupaten possesses, expressed as a percentage of the country's total mangrove extent*

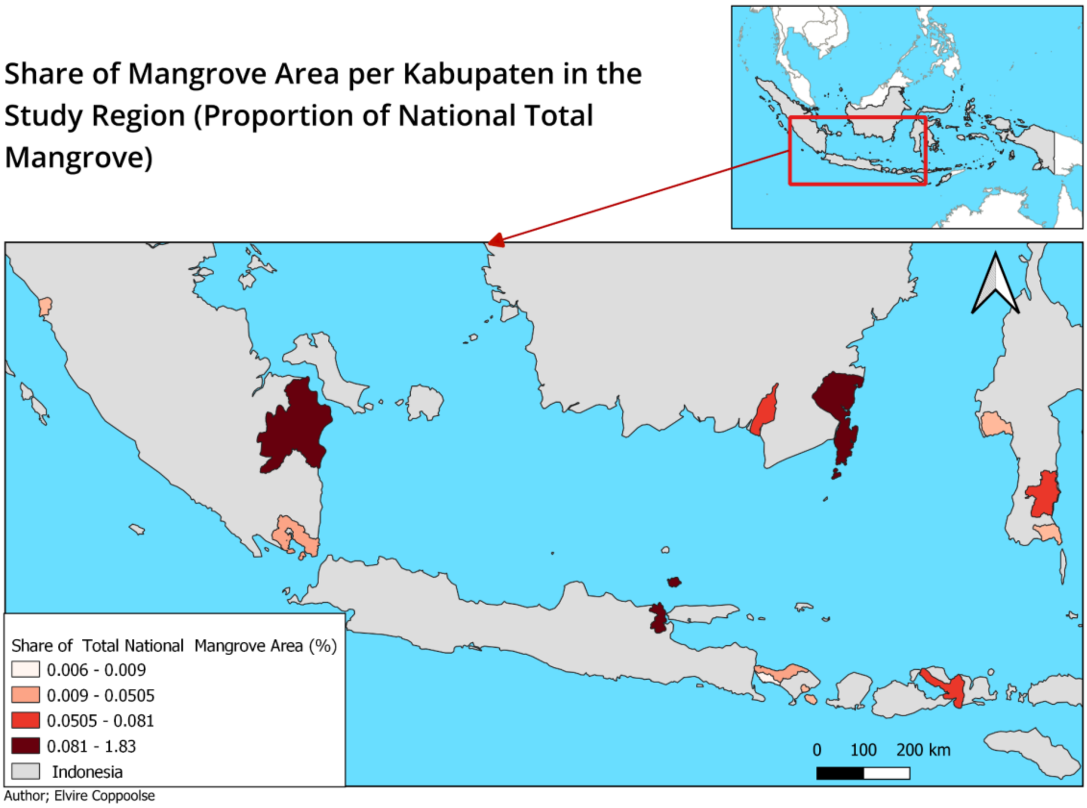


Fig. 2. *Percentage of Mangrove Loss per Kabupaten in target areas between 1996 and 2007 and between 2007 and 2015 (in percentage)*

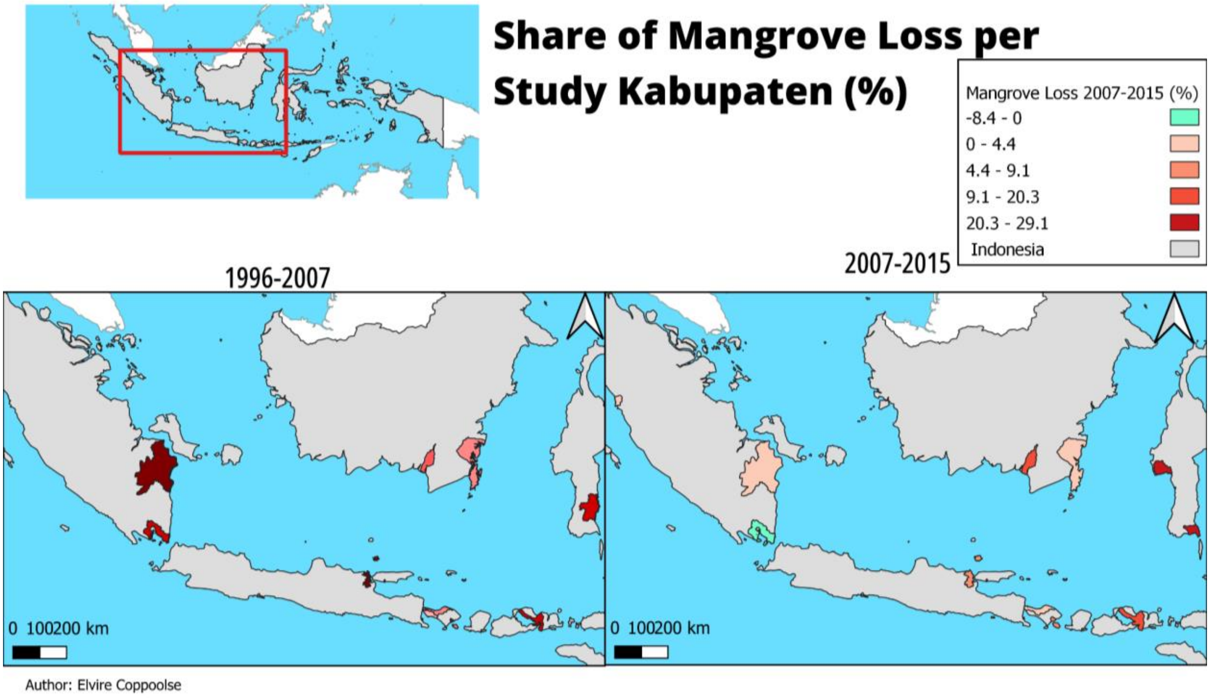
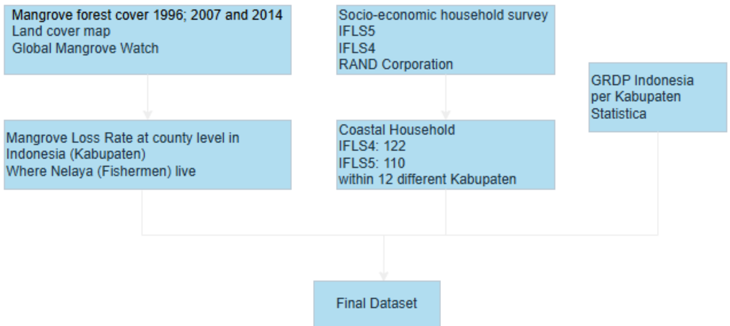


Table 1. *Kabupaten of the study area with its associated percentage share of total national Mangrove area (as for the year 1996)*

Kabupaten	**% Share of total national Mangrove area**	**Baseline**	**IFLS4**	**IFLS5**
BULUKUMBA	0.004	1		x
POLEWALI MAMASA	0.004	1		x
PADANG (KOTA)	0.002	1		x
KOTA BARU	1.830	3	x	x
KLUNGKUNG	0.009	2	x	x
BULELENG	0.02	2	x	x
BARITO KUALA	0.058	2	x	x
DOMPU	0.074	2	x	x
LAMPUNG SELATAN	0.043	2	x	x
GRESIK	0.102	3	x	x
OGAN KOMERING ILIR	1.028	3	x	x
MATARAM (KOTA)	0	0		x
KARANGASEM	0	0	x	x
TULUNGAGUNG	0	0		x
BANTUL	0	0		x
TEGAL	0	0		x
JEMBRANA	0.006	1	x	
BONE	0.059	2	x	



4. Regression analysis

We used a generalised linear fixed-effects model to investigate the association between fishermen's economic well-being, mangrove density, and its associated loss.

We use a Regional fixed-effects model at the province level to control for region-fixed effects in our regression (to account for baseline income differences across provinces). Fishermen's income may vary not only because of mangrove loss but also due to factors like local policies, regional development (GDP per capita), infrastructure…etc. By including region-fixed effects in our OLS regression when analysing income differences per kabupaten for fishermen in Indonesia, we control for unobserved heterogeneity across kabupaten that might influence fishermen's income. If we don't control for these unobservable regional characteristics, the coefficient on mangrove loss might be biased.

We used the following regression model:

$$Y_i = \beta_1 M_k + \beta_2 ML_k + \beta_3 w_j + \beta_4 e_i + \beta_5 h_i + \beta_6 m_j + \beta_7 b_j + \varepsilon$$

where the dependent variable Yi is the fishermen's approx. amount in rupiah of total income by the household from the farm business during the last 12 months for each specific household i. In our regression model, the dependent variable is expressed as the natural logarithm of the total income. M is a qualitative variable indicating the density of mangrove forest cover in Kabupaten k (representing either no mangrove forest, low, medium, or high mangrove densities), ML is a quantitative variable indicating the percentage mangrove loss for each Kabupaten where the household originates from, w represents the approximate total number of weeks worked a year per household *j*. 'e' is the total amount of years that the household member has worked as a fisherman. 'h' is the total amount of workers who help the main breadwinner of the household in the farm business. Finally, we have added for the IFLS5 fishermen sample two additional variables that were not available in the fourth wave of the RAND survey, namely whether or not the household uses a boat to fish ('*b'* in the regression model) and whether or not their boat is motorised or not ('*m*' in the regression model). And ε is a normally distributed error term with a mean of 0 and constant variance.

For each 2007 and 2015, we will first conduct a simple basic OLS regression without any fixed effects (model 1), then we will compare it to a basic model with regional fixed-effect (model 2), and lastly, we will add the complete model with regional fixed-effects (model 3).

Lastly, we will include a two-way fixed-effects regression model including both the time-fixed effects (year, either 2007 or 2014) and unit fixed effects (province). This helps isolate the effects that might not be included in the model such as time-invariant characteristics of each region and time-invariant trends across study provinces.

Furthermore, to adjust income values from 2007 to 2015 in Indonesia accounting for inflation, we used the Consumer Price Index (CPI) as a deflator/inflator. We adjusted the 2007 income values (in Rupiah) by multiplying them by 1.6662 to express them in the 2015 constant IDR since the CPI index for 2015 is 166.62 (using 2007 as a base; thus CPI index of 100) (BPS data).

5. Results

Fig 3. Scatterplot Fishermen Income and Mangrove Loss for the years 2007 and 2015

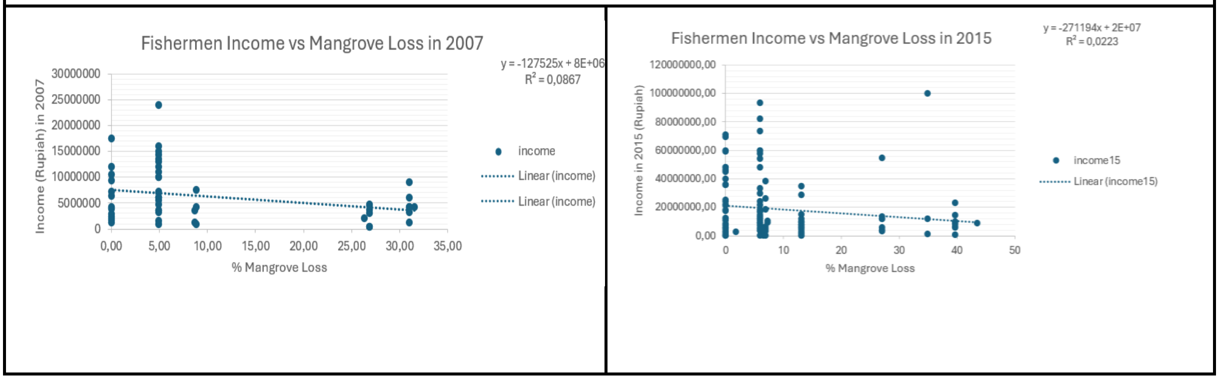


Table 1.a. Province Fixed-effects OLS for the year 2007 with dependent variable log(Income 2007)

	Dependent Variable		
		log(Income)	
	Cross-Sectional OLS (1)	*Fixed-Effect OLS (2)*	*Complete model w. Fixed-Effects (3)*
% Mangrove loss	-0.127***	-0.046	-0.045
Baseline Mangrove 1	0.283	18.15	0.265
Baseline Mangrove 2	-0.032	18.17	0.00418
Baseline Mangrove 3	-0.9172*	17.74	-0.415
Years working as a fisher	-0.0015	0.003	0.003
Appr. total nb. of weeks worked / year	0.0035	0.0859	0.17*
Amount workers	-0.017	0.018	0.084
Mangrove loss * Baseline	0.054***	0.012	
Multiple R2	0.1202	0.9974	0.07538

In Table 1.a. we get a comparative view of the three different models: model (1) which is a cross-sectional OLS with no fixed effects, model (2) which is an OLS with province fixed effects only (with no interaction or other covariates) and finally model (3) which is a complete model including province fixed effects, interaction terms and more controls.

The regression analysis reveals that mangrove loss is significantly associated with lower fishermen's income in the simple cross-sectional model, but this relationship weakens and becomes statistically insignificant once province-fixed effects are introduced. This suggests that the negative income effects of mangrove degradation may be largely explained by underlying regional differences rather than mangrove loss alone. Importantly, the interaction between mangrove loss and baseline mangrove coverage is positive and significant in the baseline model, indicating that the adverse income effects of mangrove loss are less severe in areas with higher initial mangrove extent. However, this interaction effect diminishes and loses significance when additional controls and fixed effects are included, implying that the protective role of baseline mangroves may be context dependent. Among control variables, only the number of weeks worked per year shows a consistent and significant positive association with income, underscoring the importance of labor effort in determining fishermen's earnings. Overall, the findings highlight the need to account for regional heterogeneity when assessing the economic impacts of environmental degradation on coastal livelihoods.

When controlling for province-fixed effects, we get that the negative correlation between mangrove loss and fishermen's income disappears, meaning much of the variation might be due to regional characteristics, not mangrove loss alone.

The interaction term between mangrove loss and baseline coverage is significant in simple models, suggesting that the effect of loss depends on initial mangrove extent — but loses significance with more controls.

Model (3) seems cautious but realistic since it explains less of the total variance but may better isolate the effects of interest.

This model could be improved by adding more observations, but since the IFLS4 survey doesn't include straightforward questions indicating if the household is indeed a fisherman or not (Nelaya), this makes it difficult to do without impairing the results. Furthermore, the IFLS4 wave doesn't include data about fishing effort (e.g., time, gear, boat use, motorised boats), or remoteness of the household to markets, which could have been interesting variables to include in our model.

Table 1.b. Province Fixed-effects OLS for the year 2015 with dependent variable log(Income 2015)

	Dependent Variable		
	log(Income)		
	Cross-Sectional OLS (1)	*Fixed-Effect OLS (2)*	*Complete model w. Fixed-Effects (3)*
Constant	15.164***		
% Mangrove loss	-0.048	-0.023	-0.045
Baseline Mangrove 1	0.047	14.57**	0.265
Baseline Mangrove 2	0.095	14.17**	0.00418
Baseline Mangrove 3	-0.274	10.13**	-0.415
Years working as a fisher	-0.0175.	-0.012	0.003
Appr. total nb. of weeks worked / year	0.002	0.000	0.17*
Amount workers	-0.06	-0.028	0.084
Mangrove loss * Baseline	0.0161	0.52	
Boat	1.25*	2.01*	
Motorised boat	0.823*	0.054	
Multiple R2	0.1758	0.9948	0.07538

In table 1.b. we get a comparative view of the three different models: model (1) which is a cross-sectional OLS with no fixed effects, model (2) which is an OLS with province fixed effects only (with no interaction or other covariates) and finally model (3) which is a complete model including province fixed effects, interaction terms and more controls.

This baseline model gives a general snapshot of income determinants but does not control for regional or structural differences, and its R^2 (0.1758) indicates low explanatory power. The insignificant effect of mangrove loss may reflect omitted variable bias or hidden heterogeneity.

Controlling for province fixed effects, we see that regional characteristics explain much of the income variation. The large and significant boat-related variables show how access to capital and equipment is key to income. The mangrove loss effect remains weak and insignificant, suggesting that differences between provinces, not local mangrove conditions, may be more important drivers of income levels.

Model (3) is the most reliable as it controls for both regional heterogeneity and individual-level factors. The consistent insignificance of the mangrove loss variable suggests that mangrove degradation alone does not drive income differences among fishermen once region and endowments are accounted for. Instead, productive capital (boats) and labor effort (weeks worked) emerge as the primary drivers of income. The positive, though insignificant, interaction term suggests that in areas with greater baseline mangrove coverage, the negative effects of mangrove loss may be dampened — but this effect is not strong enough to draw firm conclusions.

The regression results for 2015 show that the direct effect of mangrove loss on fishermen's income is negative across all three models, but statistically insignificant. This suggests that by 2015, mangrove loss alone does not account for variation in income, especially after controlling for province-level fixed effects. The interaction between mangrove loss and baseline mangrove coverage is positive in both fixed-effect models, but remains statistically insignificant, indicating weak evidence that the baseline extent of mangroves moderates the effect of their loss. Baseline mangrove categories become highly significant in Model (2) with large and implausible coefficients, likely reflecting multicollinearity or overfitting due to fixed effects being estimated without sufficient variation across provinces. Once additional controls are added in Model (3), these effects normalise and lose significance. Among control variables, the number of weeks worked per year is positively and significantly associated with income in the complete model, as in 2007, emphasizing the importance of labour intensity. Notably, boat ownership and motorised boats are both positively and significantly correlated with income in the fixed-effect models, suggesting that access to better fishing assets continues to play a critical role in income generation. The R^2 drops considerably in the complete model, implying that much of the income variation remains unexplained when regional effects and endowments are held constant. Together, these results indicate that while mangrove loss may not directly reduce income once regional differences are controlled for, household characteristics such as labour and capital assets are more important predictors of fishermen's income in 2015.

Table 3. Two -ways Province Fixed-effects OLS with dependent variable log(Income)

	Estimate	*Std. Error*
% Mangrove loss	-0.127*	0.029
Baseline Mangrove 1	0.283	0.432
Baseline Mangrove 2	-0.032	0.346
Baseline Mangrove 3	-0.9172*	0.454
Years working as a fisher	-0.0015	0.006
Appr. total nb. of weeks worked / year	0.0035	0.006
Amount workers	-0.017	0.029
Mangrove loss * Baseline	0.054*	0.012
Adj. R^2		0.22345

The regression model presented in Table 3 analyses the relationship between mangrove loss and fishermen's income across two time points (2007 and 2015), controlling for province-level fixed effects. The results reveal a statistically significant negative association between mangrove loss and fishermen's income. Specifically, a 1 percentage point increase in mangrove loss is associated with a 12.7% decrease in income ($p < 0.1$), underscoring the crucial economic role mangroves play in supporting coastal livelihoods.

The interaction term between mangrove loss and baseline mangrove coverage is positive and highly significant ($\beta = 0.054$, $p < 0.001$), suggesting that the negative income effects of mangrove loss are mitigated in areas with higher initial mangrove coverage. This implies that regions with more extensive baseline mangroves may possess greater ecological resilience or redundancy that cushions the economic impacts of environmental degradation.

While the main effects of baseline mangrove categories are not statistically significant—except for Baseline 3 (high initial coverage), which shows a negative and marginally significant coefficient ($\beta = -0.9172$, $p < 0.1$)—these results may reflect regional heterogeneity in dependency on mangrove ecosystems or socio-economic structure. The non-significance of labor input variables such as years of fishing experience, total weeks worked per year, and number of workers suggests that individual labor characteristics are less important determinants of income than environmental factors, once spatial heterogeneity is controlled for.

The model explains approximately 22.3% of the variance in log income (Adjusted $R^2 = 0.223$), which is reasonable for micro-level cross-sectional data with environmental covariates.

The two-way fixed-effects model (Table 3) provides a more stable and generalizable estimate across time and space. It confirms that mangrove loss significantly reduces fishermen's income, but that this effect is buffered in regions with high baseline mangrove coverage. In contrast, the individual-year regressions show some temporal variability—particularly in the 2015 estimates, where several coefficients lose significance—suggesting that single-year estimates may be more sensitive to short-term shocks or sample composition. The pooled model, therefore, offers stronger empirical support for the economic importance of mangrove ecosystems.

Interpretation Results

The results suggest that while mangrove ecosystems provide important ecological functions, their short-term loss may not immediately translate into measurable income declines for fishermen at the individual level, especially when controlling for province-level differences and individual fishing characteristics. This points to the need for longer-term or panel data to better capture the dynamic and potentially delayed effects of environmental degradation on coastal livelihoods.

6. Discussion

The regression results from 2007 and 2015 offer important insights into how mangrove degradation interacts with historical ecological conditions to influence income among coastal households in Indonesia. The significance of the interaction term (Mangrove Loss * Baseline 1996) in both years highlights an important point in environmental and development economics: the impact of ecological loss is context-dependent and shaped by the initial state of natural capital. These results align with the existing ecological and economic literature, arguing how socio-economic consequences of environmental change depend not only on the magnitude of degradation but also on the baseline stock of ecosystem assets (Barbier et al., 2011; Ostrom, 2009; Adger, 2000). This is also the case as for example Brazilian smallholder farmers who experience declining agricultural output and increased input costs (e.g. fertilizer or irrigation) following continued forest clearance, particularly in already experienced deterioration. Therefore, even little environmental changes might have a greater economic impact in places where the baseline ecosystem integrity is lower.

The regression results provide consistent evidence that mangrove loss is negatively associated with fishermen’s income in Indonesia, supporting the hypothesis that coastal ecosystems play a vital economic role in sustaining small-scale fisheries. The significant interaction between mangrove loss and baseline mangrove coverage suggests that regions with more extensive initial mangrove forests may experience a buffering effect, where the detrimental impact of mangrove degradation on income is less pronounced. Yet, according to the different models, mangrove loss alone does not uniformly predict income outcomes. Instead, in areas where mangrove coverage was initially low in 1996, the loss had a significantly negative effect on income—suggesting heightened vulnerability. Conversely, in areas with higher baseline mangrove coverage, this negative relationship is attenuated or even reversed, indicating greater ecological buffering capacity or adaptive potential. This result aligns with theoretical frameworks that link social-ecological resilience with natural capital endowments and challenges linear assumptions often made in environmental impact assessments.

However, the study also carries inherent limitations. First, the research relies on cross-sectional data from two time points (2007 and 2015), which restricts causal inference and limits the ability to fully control for unobserved time-varying shocks. While province-level fixed effects account for spatial heterogeneity, the absence of panel data at the household level prevents the use of more robust individual fixed-effects models. Additionally, measurement errors in income reporting and mangrove coverage estimates may introduce bias. The use of Global Mangrove Watch land cover data, while spatially consistent and satellite-derived, may not fully capture local-scale ecological degradation or the quality of mangrove ecosystems. Furthermore, the limited set of control variables, such as asset ownership or access to markets, may omit important socioeconomic factors influencing income. Also, the dependent variable here is treated as a singular outcome, which does not capture multidimensional economic well-being or exposure to risk. Assumptions of linearity and static effects may also oversimplify the lagged and non-linear dynamics of ecosystem degradation. Lastly, the sample for both years remains small since they include around 109-122 observations. Future studies would benefit from high-resolution panel data, disaggregated by household or village, and from incorporating additional variables to contextualize observed patterns.

The findings of this study contribute to the broader academic debate on the socio-economic impacts of environmental degradation, particularly within the context of coastal ecosystem services. Theoretically, this research engages with the environmental livelihood nexus, which posits that ecosystem health underpins rural income security, especially in natural resource-dependent communities (Barbier, 2011; Millennium Ecosystem Assessment, 2005). However, the absence of a statistically significant relationship between mangrove loss and household income in this study challenges the assumption of a direct, short-term linkage and instead supports perspectives that emphasize complex, mediated, or delayed socio-ecological feedback (Adger, 2000; Ostrom, 2009). This aligns with literature suggesting that the economic impacts of mangrove degradation are often contingent on local governance, market integration, and household-level resilience strategies (Walker et al., 2022; Barbier, 2011). This may explain why the same amount of mangrove loss doesn't affect all communities equally.

Additionally, the study raises questions about the social costs of environmental degradation, especially for marginalized fishers whose livelihoods depend on ecosystems that are often undervalued in economic planning.

Beyond academic contributions, these findings carry broader societal and policy relevance. They suggest that environmental degradation, such as mangrove deforestation, does not affect all communities equally — its economic impact depends on historical ecological conditions. This implies that targeted interventions are needed, especially in regions with low baseline ecosystem services, where livelihoods are most sensitive to ecological change. The results reinforce the importance of ecosystem-based management and conservation policies, not only for biodiversity and climate mitigation but also for sustaining local economies. In a broader context, this study calls attention to environmental justice issues, as communities with fewer ecological endowments may bear disproportionate economic burdens from environmental loss.

7. Conclusion

This capstone research set out to examine how mangrove cover and its associated loss affect small-scale fishermen households' income across selected Indonesian Kabupaten using fixed-effects OLS regression models for the years 2007 and 2015. The analysis reveals that mangrove loss has no uniform effect on income; rather, its economic impact depends on the baseline extent of mangroves in 1996.

In areas with low baseline coverage, mangrove loss significantly reduces income, while in areas with higher initial coverage, this negative effect is diminished or even offset. These findings confirm theoretical insights from ecological economics and resilience theory, which emphasize the role of baseline ecosystem health in shaping vulnerability and adaptive capacity.

This study offers both temporal insights and limitations into the socioeconomic effects of coastal ecosystem degradation, by highlighting the importance of interaction effects in modelling socio-ecological relationships, and by questioning overly simplistic narratives that assume environmental loss leads to uniform economic decline.

Overall, the comparative findings from 2007 and 2015 point to a limited direct statistical relationship between mangrove loss and household income, but a strong and consistent association between fishing productivity and income. These results imply that while mangrove degradation may influence fisheries over the long term, its economic consequences might be indirect, lagged, or conditional on other contextual factors such as initial mangrove coverage, fishing dependence, or adaptive livelihood strategies.

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