Estimation of River Flood Damages Among Farmers and Small Business in Developing Countries: Evidence from the Kali Lamong Indonesia

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Flood Damage, Socio-Economic, Welfare Loss, Ecosystem Service, Indonesia

ABSTRACT
Flooding is a severe disaster in the Kali Lamong river basin (58 Km2). For this reason, detailed flood damage estimates are needed to design an optimal flood management strategy. This study aims to estimate flood damage in the Kali Lamong River Basin. The data collection method used cluster sampling in 15 villages with 870 respondents. We surveyed farmers' households and micro businesses from October to December 2022 to obtain information on flood damage, flood characteristics, and socio-economics characteristics based on the 27-30 September 2022 flood event. Based on those data, we used regression analysis to develop flood damage functions to know how flood characteristics are related to the damage. Our study found that the economic flood damage in the Kali Lamong river basin is estimated to be US$ 2,3 million for farmer's households and US$ 10,3 million for micro businesses. This study shows that household flood damages 5,2% more than micro business.

1. Introduction

Floods, a natural disaster projected to become more severe, frequent, and costly in the coming decades, are not just a local concern but a global one. The alarming increase in flood disasters, accounting for 47% of all disasters in Europe, 48% in Asia, and 69% in Africa in 2023, directly results from global warming and population growth. Indonesia, a country with numerous areas at high risk of natural disasters, including floods, extreme weather, earthquakes, and tsunamis, experienced a staggering 4,402 disaster events in 2023 alone. Of these, one-third were flooding in river basins (Indonesian et al. for Disaster Management – BNPB, 2022).

The Lamong River Basin, located in East Java Province, Indonesia, is one of the areas with a high risk of flooding in the country. The areas are highly vulnerable to flooding due to river overflow during the rainy season between December and February. The length of the Lamong River basin is 103 Km, and the watershed area is 720 Km2; there is a probability that flood events in this area can occur 1 to 5 in one year (Bengawan Solo Board Management, 2020). The Lamong River Basin passes through 5 cities, namely Mojokerto, Lamongan, Jombang, Gresik, and Surabaya, with 55% of the area located in Gresik cities.

Over the past two decades, The Lamong River Basin has been ravaged by major floods in Gresik cities. These floods, considered national disasters, have resulted in an estimated total loss of US$ 987 million and caused immense human suffering. The major flood in The Lamong River Basin inundated 70 villages in Gresik, affecting 15.000 houses, displacing 40.000 people, and causing the loss of 15 lives (BPBD, 2022). This area is a hub of agricultural and business activity and is densely populated. These events serve as a stark reminder of the urgent need to address the flooding in the Lamong River Basin.

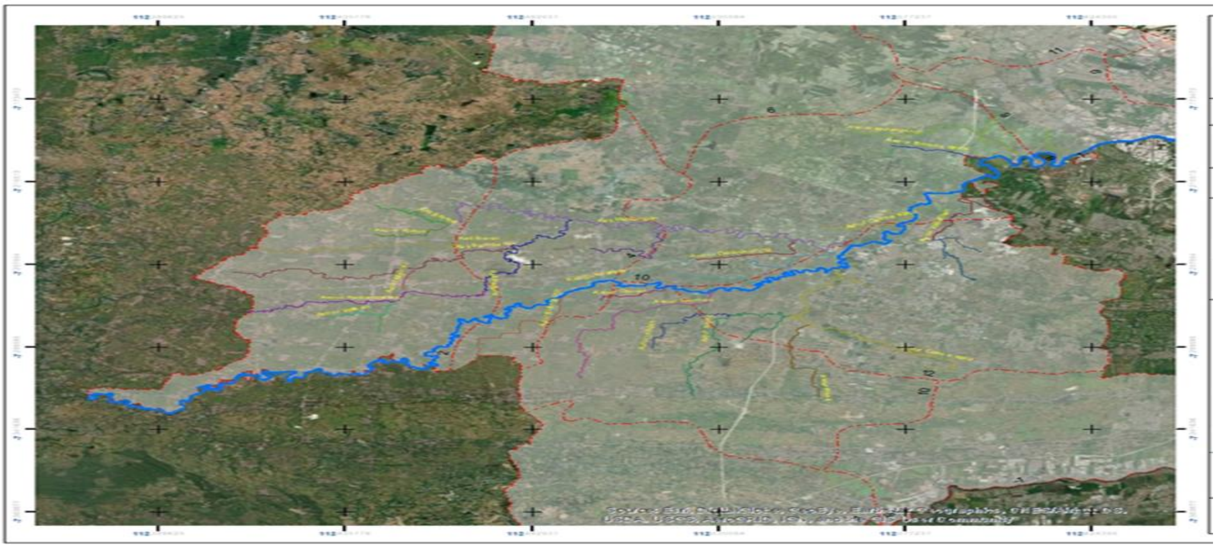

Figure 1: The Area the Lamong River Basin In Gresik

Through appropriate mitigation strategies, we can minimize the impact of flood damage. Mitigating these losses includes coordinating with relevant stakeholders (governments, residents, business operations, and others). Assessing flood damage is the key to developing effective flood policies and implementing flood protection measures to reduce expected flood damages (Fabian et al., 2023). Flood damage mitigation is the set of measures and activities that individuals, communities, and governments implement to reduce flood impacts. An accurate flood damage assessment is the key to an effective and efficient mitigation policy (Retno Dwi Siswanto &AnggraenyPuspaningtyas, 2023).

The government uses an assessment of flood damage. The Lamong River Basin covers the whole Gresik area and needs to provide detailed information that survey data of specific flooded regions offer. The assessment method of flood damage uses ex-post-flood events; this method is used in several studies that measure the impact of economic losses due to flooding (Ward, De Moel, et al., 2011; Ward, Marfai, et al., 2011). Weeknes, the technique does not provide detailed information on flood damage. In flood damage mitigation policy, detailed information is essential in presenting the local flood situation and evaluating the cost-effectiveness of flood measures for stakeholders.

This paper aims to (1) provide insight into the level of flood damage and (2) estimate the relation between flood damage and flood characteristics. It contributes to this need by documenting flood damage assessment and mitigation policy in the Lamong River Basin in Gresik, Indonesia.

2. Literature Review

A flood disaster is an event or situation where an area or land is submerged because the volume of water increases for more than 3 hours. Previous literature shows that the impact of flood disasters can be divided into direct damages, indirect damages, and secondary effects (Imamura & Van To, 1997; Ruin et al., 2008). Direct damages include all damage to fixed assets, capital, and inventory of finished and semi-finished goods, raw materials, and spare parts that co-occurs as a direct consequence. This also includes expenses for emergency assistance. Indirect damages impact the flow of goods that will not be produced and services that will not be provided after the disaster. This indirect damage can increase operational expenses due to damage to infrastructure.

Secondary effects include the impact of flood disasters, which can spread to overall economic performance as measured through macroeconomic variables. Flood disasters can reduce consumption and investment activities and increase inflation. In addition to this classification, several literatures also classify the impacts of flood disasters into tangible and intangible effects. Tangible damages mean the damages that can be valued in monetary terms, e.g., damages to buildings and contents. In contrast, intangible damages are challenging to express economically, e.g., loss of life and trauma (Jonkman et al., 2008; Merz et al., 2013). Most studies only estimate direct tangible damages because the estimation of intangible damages is difficult. In simple terms, disaster impacts can be classified as follows.

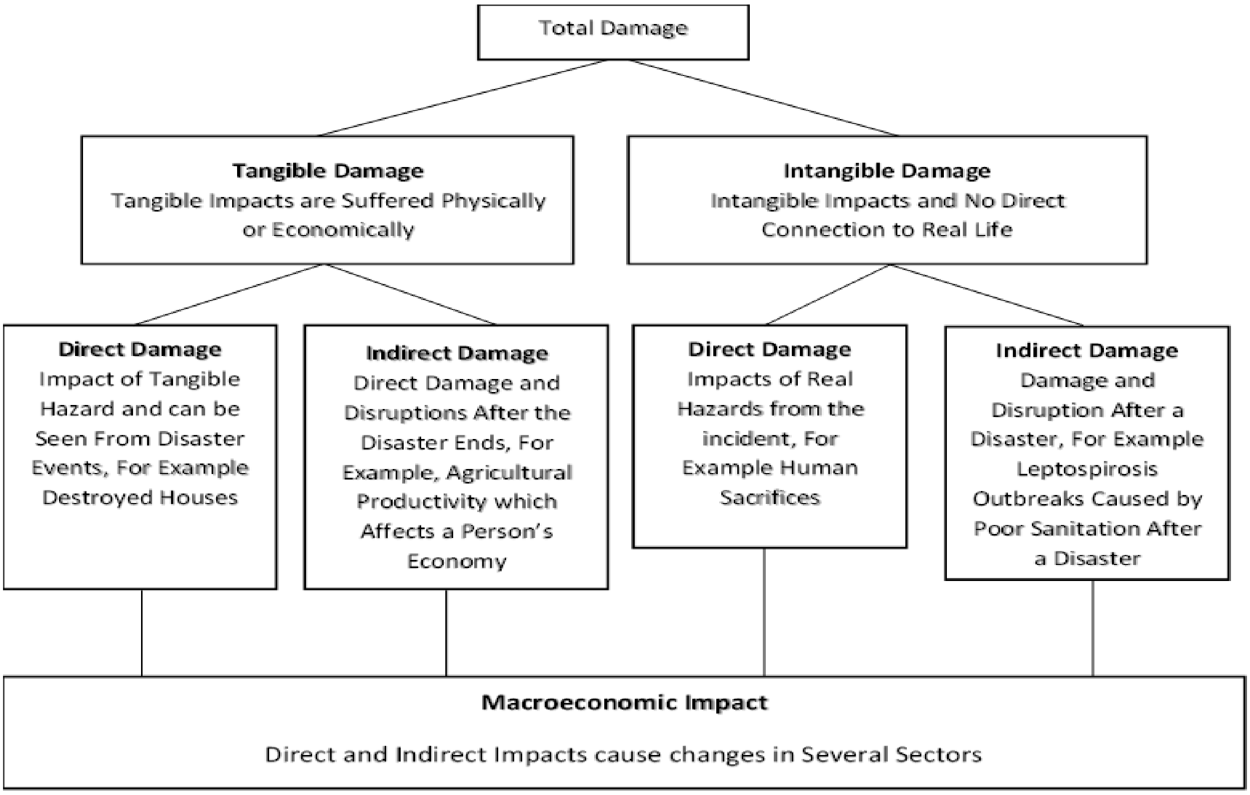

Figure 2: Recap Flood Damages

Most studies estimate flood damage using damage functions, which connect the damages to particular elements at risk with the flood characteristics (Ward, De Moel, et al., 2011). The aspect at risk represents the number of social, economic, or ecological units affected by flood hazards in a particular area, i.e., people, households, companies, and infrastructures. In contrast, the flood characteristics include depth, duration, velocity, and contamination (Ward, Marfai, et al., 2011). Thieken et al. (2005) use impact and resistance factors in determining flood damage to buildings. The impact factors are similar to flood characteristics. In contrast, resistance factors are the resistance condition of the building to flood, which can be temporary (e.g., due to flood warning and preparedness) or permanent (e.g., due to building material and preventive measures).

A flood damage function can be developed using empirical and synthetic approaches (Try et al., 2023). The empirical approach implies using data gathered following a particular flood event. In contrast, the synthetic approach uses data collected through ‘‘what-questions,’’ i.e., the amount of expected damage in case of a specific flood condition (Nguyen et al., 2021; Ward, De Moel, et al., 2011). However, a synthetic approach involves trade-offs between required time and precision because it relies on fictional scenarios from which information is derived (Mahmood et al., 2016).

Previous studies developed flood damage functions by relating direct flood damage to flood depth (Mongkonkerd et al., 2013; Oliveri & Santoro, 2000). Such a function is called a stage-damage function or depth-damage function. Meanwhile, other studies add parameters such as flood duration (Junger et al., 2023; Mobini et al., 2022), velocity (De Blois & Wind, 1995), and contamination (Mendoza-Tinoco et al., 2017). The two steps to analyze flood damage include determining the impact factors or the exposure indicators, e.g., depth and duration, and assessing the damage in monetary terms (Fabian et al., 2023; Veeravalli et al., 2022).

3. Methodology

We surveyed households and small business units from January to March 2024 to obtain information on flood damage in Kali Lamong, flood characteristics, and socio-economic characteristics based on the 17–22 January 2024 flood event. Based on those data, we used regression analysis to develop flood damage functions to understand how flood characteristics relate to damage. Finally, we compared the flood damage from the survey with the estimated flood damage obtained using Kali Lamong's damage scanner model for the relevant area.

3.1 Study Area and Sampling Method

This study was conducted in the Lamong River basin in Gresik Regency. Gresik Regency is located in the east Java region of Indonesia, far from Kali Lamong River (about 785 kilometers (km)). Figure 3 shows that Gresik has two rivers passing through it. These are the Lamong river and Bengawan Solo river. The Lamong River is approximately 103 kilometers long. It is an essential regional waterway, supporting agriculture and aquaculture for irrigation.

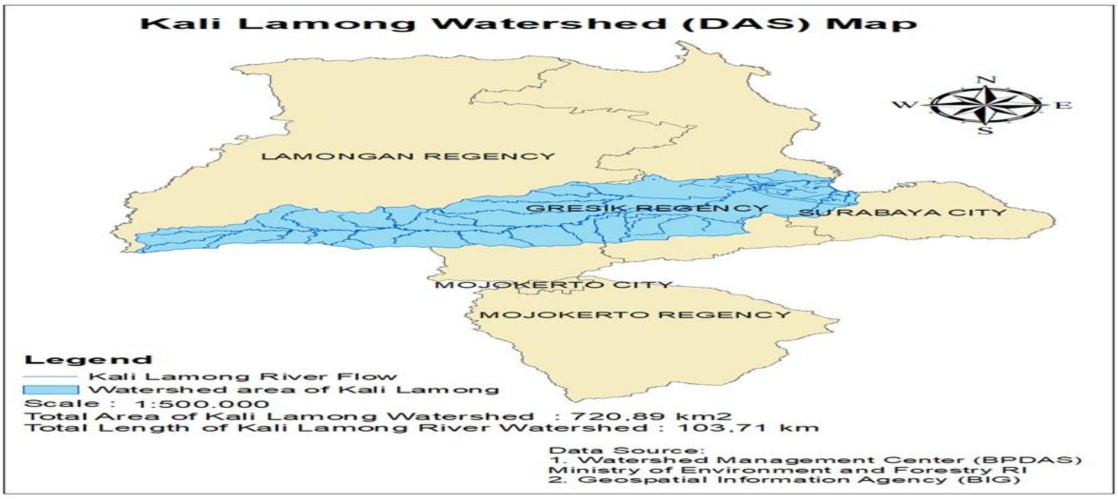

Figure 3: Area Study

Gresik is also known as the biggest city in the northeast Java region, and it has high economic activity, especially in agriculture and industry. Since Gresik has two rivers flowing through it, the agricultural areas (especially around the rivers) are fertile with sediments and nutrients. As a result, the crop yields (especially of rice and aquaculture) around the Lamong River are higher than the region's average. Our survey focused on the residential and business areas along the Lamong River.

We used cluster random sampling for twelve villages along the Lamong River as study sites. Then, we used simple random sampling to select household samples in various neighborhoods. The total number of samples was about 350 households and 175 small and medium businesses. Households and business units were eligible for the survey if they had been affected by the flood and had suffered from economic, health, and physical damages. The contact person at the household level was the head of household, while the contact person for businesses was the owner or the manager. If a contact person was not eligible or inhabited at the time of the survey, the next closest household or business unit was approached.

3.2 Model Spesification

We employed a micro-scale approach to assess damages in the residential and business sectors. The flood damage function was estimated empirically. In our model, the flood damage was explained by two factors, i.e., flood impact factors (or flood characteristics) and socio-economic factors. The first factors include depth, duration, and distance from buildings to a river. The depth is the over-floor depth of the flood, while the duration indicates the length of time that the water stays inside the buildings. The second set of factors includes the sector's income and the building's surface area. For the residential sector, income was represented by the monthly income of households, while the business sector was represented by monthly turnover. The surface area indicates how many square meters of the living area is owned by each building.

We developed the flood damage function to indicate the economic relationship between actual flood damage (FD) as a dependent variable and flood characteristics and socioeconomic factors as independent variables. Because data collected by the survey are not normally distributed, we tested several methods for regression analysis and considered several alternative combinations of variables and functional forms, e.g., linear, log-linear, double log, and quadratic, by including and excluding the constant. Finally, we applied the linear functional form, which gave the best results in terms of statistical significance:

$$FD_i = \beta_0 + \beta_1 INC_i + \beta_2 Lenght_i + \beta_3 Time_i + \beta_4 DEPTH_i + \beta_5 Wide_i + \epsilon_i \quad (1)$$

where FD_i, actual flood damage (IDR thousand) of respondent i; $DEPTH_i$, flood depth (cm) inside building of respondent i; $Time_i$, flood duration (h) inside building of respondent i; $Lenght_i$, distance from a river to the building (or housing) (m) of respondent i; INC_i, income (IDR thousand/month) of respondent i; $Wide_i$: building (or housing) area (m2) of respondent i; ei, error term.

The dependent variable FD covered the direct and indirect tangible damage. The direct damage included building structure damage and building content damage. The content meant the detailed inventories of the physical objects inside and outside the buildings. To estimate the building structure damage, we used replacement value, while to assess the building contents, we used depreciated value with a depreciation rate of 1% per year. The indirect damage in the residential sector included clean-up costs, loss of income, costs related to evacuation, and health-related costs during the flood. Meanwhile, for the business sector, the indirect damage costs were approximated by the loss of turnover during the flood because detailed information on profit loss could not be obtained as business people are unwilling to report profits.

The loss of income of households was calculated by multiplying the number of days missed at work due to flooding with the daily income. The costs of evacuation and temporary accommodation were the sum of the total costs for travel, food, and lodging due to evacuation. The cost of illness is equal to that of visiting a doctor, staying in a hospital, and buying the medicines required following a flood.

4. Result

4.1 Descriptive Statistic

Households included in the survey lived, on average, 84.8 m away from the river, with a maximum distance of 284 m. Their houses were mainly permanent constructions with an average area of less than 70 m2. Half the respondents lived in one-story houses, and half in two-story houses. The second floor was deliberately built as an adaptation mechanism to flooding. On average, their monthly income in 2024 was US$ 296, and 42% received monthly income below the standard regional minimum income of US$ 244. Most local people's livelihoods are in the informal sector, and 36% of respondents claimed they earned a living from running small and medium businesses. From January 2023 to March 2024, 53% of respondents experienced 3–5 flood events. During the January 2023 flood, there was, on average, 87 cm of water in the house for 98 hours.

Most business units were in charge of small- to medium-scale enterprises, e.g., small shops, groceries, cloth shops, and small restaurants. About 81% of respondents employed one to four workers, and about 75% had less than US$ 205 business daily turnover. Most businesses occupied small buildings to run their activities. On average, the area, including the garage, was 38 m2. Not all buildings had a basement, and 87% were permanent buildings. About 72% had an attic, and 13% had a garage or carport. Buildings were located, on average, 84.8 m away from the river, up to 123.7 m away from the river. About 51% of business activity took place in their buildings. From January 2023 to March 2024, 45% of respondents experienced 3–5 flooding events. After the January flood, three flood events occurred in the survey areas; however, the magnitude of those events was small and did not cause significant losses. During the January 2024 flood, the average inundation depth was 74 cm, and there was water in the buildings for 84 hours.

The social characteristics of the agricultural households sample have generally been divided between male and female household heads. In general, agricultural households have an average age of 48.78 years. The social characteristics of non-agricultural households have an average age of 42.15 years. Following are the social characteristics details for social characteristics:

Table 1: Descriptive Statistics Sample

Variable	Short Description	Agricultural Households		Non-Agricultural Households	
		Mean	Std.Dev	Mean	Std.Dev
Gender	Respondent's gender (1: male, 0: female)	0,52	-	0,67	-
Age	Respondent's age	48.78	13,55	42.15	9,31
Schooling	Years Of Schooling	9,73	11,72	11,87	14,71
Income	HH income in IDR Per Month	2.5873.212	16,84	4.789.361	18,73
Flood or heavy rain shock	Flood or heavy rain shock experience in the last 12 months	0,089	-	0,093	-
Flood or heavy rain shock severity	The severity of severe flood or heavy rain shock experienced in the last 12 months	0,018	-	0,016	-
Storm shock	Storm shock experience in last 12 months	0,041	-	0,052	

Source: Author own calculation based on survey flood impact kali lamong, 2024

4.2 The Actual Flood Damage

The average flood damage per household in the residential sector was US$308. Households with more property at risk, such as vehicles and electronics, experienced the highest flood damages. Direct damage was more significant for most households than indirect damage. Table 2 indicates that content damage was the major component of losses.

The content losses varied across households from zero to an estimated US$ 863. The zero value is obtained in poor households with limited household stuff. The higher losses were found in households with higher family income and larger houses. Households who owned a two-story house could safely store their assets on a higher floor; hence, they could minimize the losses. After the flooding episode, households spent, on average, 24 hours or three person days clearing their houses of mud and tidying up the contents. The average number of days missed from work was four, and the income loss per household during those days varied from zero to US$ 359.

About 70% of the respondents moved to temporary places such as family houses, mosques, or evacuation camps because they were evacuated or their homes needed repair due to the flood. On average, they stayed in temporary shelters for about five to six days and spent about US$12 per day on traveling, food, water, and lodging.

Table 2: Average actual flood damage per household for the January-March 2024

Damage	Value (US$)	Percentage (%)
1 Direct Damage		
1a Structural damage	43	14

Damage	Value (US$)	Percentage (%)
1b Content damage (inside and outside)	193	63
2 Indirect Damege		
2a Clean-up cost	25	8
2b Loss of income	30	10
2c Evacuation and temporary house	12	4
2d Cost of illnesses	5	2
Total	308	100

Source: Author own calculation based on survey flood impact kali lamong, 2024

Regarding the cost of illnesses, the number of family members who suffered from several diseases during and after the flood varied from one to three people per house, most of whom were children. They suffered from fever (34%), skin irritation (21%), and diarrhea (18%). Although 89% visited a doctor, the average cost of illnesses was low for each household (not for society) because 45% visited doctors provided by the government or social organizations, which are provided freely. Theoretically, the freely offered assistance should also be counted in the costs; however, this was impossible in practice due to untraceable information. To what extent the cost of illness is due to the flood is unclear. However, the damages related to the cost of illness are relatively low. If only a share of these damages is attributed to the flood event, the overall results will not change substantially.

For the business sector, the average flood damage per business unit was US$854. About 12% of the respondents had flood damage of less than US$154, and 10% had flood damage over US$2054. Business units with more items in their properties experienced a higher flood loss.

For most business units, the indirect damage was more significant than the direct damage. Total direct damages, including structural and contents damages, were US$216, whereas total indirect damages, including turnover loss, temporary premises cost, labor cost, and clean-up cost, were US$638.

Regarding direct costs, the structural damage was less than the content damage because most owners had small buildings. Content damage was relatively high, showing the owners had little time to evacuate their contents. Table 3 shows that the highest cost was the turnover loss, which depends on how many days the businesses had to close due to flooding. About 93% of the respondents closed their business due to flooding, with an average five-day closure. Nevertheless, only 4% of companies set up temporary headquarters at another location.

4.3 Determinant Flood Damages

Regression analysis of the survey data showed a significant relationship between flood characteristics, socioeconomic factors, and flood damage. However, only a tiny portion of the damage could be explained by the variables included in the model. This study showed that depth, duration, income, and area of rice fields positively affected the level of flood damage in the Kali Lamong watershed area. Our survey was conducted in a small area, and the reported flood damage did not show a statistically significant relationship with the distance of the house from the river.

This is explained by Pistrika and Jonkman (2010), who found no strong relationship between the location's distance to the river and flood damage. The distance factor alone cannot explain damage unless there are other factors, e.g., flood depth, flood duration, contamination, and water speed during flooding and the area of agricultural land (Middelmann-Fernandes, 2010; Pistrika& Jonkman, 2010). However, in our study, contamination and flood flow speed were outside the scope of the study because these data were complex for us to measure. The complete results can be seen in the following table:

Table 3: The Result Model Actual Flood Damages

Variable	(1)		(2)		(3)		(4)	
	Coef	**P> |t|**	**Coef**	**P> |t|**	**Coef**	**P> |t|**	**Coef**	**P> |t|**
INC	-1,782***	0,000	-1,382***	0,000	-1,632***	0,000	-1,943***	0,000
Lenght	1,654	0,173	1,866	0,253	1,814	0,167	2,001	0,173
Time	4,473*	0,081	3,876*	0,077	4,325*	0,071	4,102*	0,066
DEPTH	3,039***	0,000	2,692***	0,001	2,671***	0,000	2,912***	0,000
Wide	1,982**	0,032	2,112**	0,038	1,873**	0,036	1,536**	0,033
Age	0,0017	0,143	0,0013	0,168	0,0017	0,173	0,0012	0,166
Age^2	-0,000	0,178	-0,000	0,162	-0,000	0,156	-0,006	0,184
Health Dynamic (1 Years)								
Worse	0,084***	0,007					0,107***	0,0064
Better	- 0,012	0,213					-0,019	0,288
Educational Attainment								
Lower Secondary			-0,0348**	0,0312			-0,0347**	0,0318
Upper Tertiary			-0,0387**	0,0381			-0,377**	0,0212
Occupation								
Farming					- 1,127**	0,013	-1,372**	0,018
Non Farming					-0,793**	0,021	-0,832**	0,026

Source: Author own calculation based on survey flood impact kali lamong, 2024

Finally, although the results of this survey were conducted by taking samples in a small area (cluster sampling), at least the results are consistent with several similar studies. We realize that the Gresik Regency Government needs to assess a wider survey area in Kali Lamong. For further research, we recommend also using decision tree analysis, as used in Merz et al. (2013), and designing a survey with a wider area. We agree with Middelmann-Fernandes (2010) and Wagenaar et al. (2016), who emphasize considering various methods in assessing flood damage. Thus, the combination of damage assessment based on surveys and flood models based on expert assessment, such as damage scanners, provides a better picture of flood damage in flood-prone areas in Gresik Regency.

5. Conclusion

We can draw several conclusions from this paper. The actual flood damage approach obtains flood damage data and determines the maximum flood damage per object from the survey data. The survey directly collected the damage data from the samples affected by flooding. In detail, the survey defined the maximum damage per object as the average of total damage incurred by houses and micro- and small business units located in slump areas of Kali Lamong River. Notably, the survey might underestimate the flood damages in the business sector because it entailed difficulties in interviewing large business managers since they often refused to give detailed information. Nonetheless, the survey conducted a thorough investigation per unit sample using depreciation to assess the structure and contents exposed to the flood, including the reduction in damages due to the early flood warning and evacuation. We suggest that the survey results can be used to improve the accuracy of the damage scanner model for future research.

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