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Towards sustainable community: Effort to reduce flood risk and increase well-being in a densely populated flood-prone area

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Abstract. Dealing with flooding in a densely populated flood-prone area poses complex challenges. Almost all residents realize that living in the area is hazardous. However, they choose to stay there. Therefore, flood risk management should be applied in the area. This study aims to: 1) develop facts of the local community in a flood-prone area in decreasing the flood risk while improving well-being through modifying drainage channels used for fish and vegetable farming; 2) evaluate all benefits of drainage investments include the social and economic benefits. The research method consists of a quantitative approach through the distribution of questionnaires and a qualitative approach through in-depth interviews and field surveys. In this study, a concerted community effort was developed as a design parameter. At the same time, the observation parameters include knowledge of the causes of flooding, knowledge of flood risk, community involvement, and government flood control programs. The results showed that the strength of concerted community effort was significantly influenced by the knowledge of flood risk and the local community involvement. This effort can decrease the flood risk by up to 30% and serve direct financial benefits of IDR 48 million in a year.

Keywords: flood-prone area, flood risk

1. Introduction

Currently, almost all urban areas experience flooding and inundation in every rainy season. Due to uncontrolled urban development, the reduced area of open land can produce high runoff discharges, especially on the city's main roads [1]. Many studies have examined urban flooding problems and their solutions, including permeable pavements [2]–[5]. However, the mean yearly flood occurrences and losses data during 2000-2015 show that the global flood risk was not significantly reduced by the presence of flood control infrastructure [6]. A flood risk valuation in urban areas is required in the occurrence of extreme rainfall [7], especially due to climate change [8], [9]. Currently, the solution to the flood problem is more of a countermeasure after a flood occurs than prevention, such as flood emergency response and recovery. [10]; more structural efforts are made than non-structural [11]; the role and authority of the community are still low [12], and the development of urban flood resilience systems is not based on the specificity of each different area [13]. It should be noted that the effectiveness of non-structural actions is significantly determined by the socio-economic conditions of the community and the behavior of the Government. However, these actions have advantages such as being environmentally friendly and cost-effective [14].

Significant changes in efforts to reduce flood risk, which initially used a structural approach, are now shifting to a more "soft" or non-structural approach. The non-structural approach focuses on optimizing local community involvement. These approaches include the concept of integrated flood management, sustainable drainage systems, flood resilience systems [11], and managing green open space [15], [16]. Flood solutions should be directed at prevention efforts to more effective flood risk management in reducing casualties and property. The active participation of stakeholders such as related agencies, businesses, academicians, and communities will determine the success of proactive or preventive actions.

For this reason, an integrated short-term and long-term flood disaster management program is needed to accommodate the greater need for human resources, operational costs, equipment, and facilities [10], [17]. An urban system that applies a protection system involving the community separately can prevent greater losses and even increase the net social benefit [18]. Problems and losses that occur in an area will determine the form of the system. The level of losses that occur during and after flooding reflects the resilience of the area to flooding. The resilience of each area is determined by the urban system, such as community characteristics, economic conditions, community habits in managing risk, and the level of urbanization [19]. A study found limitations to community-based flood risk management related to lack of financial resources, leading to a syndrome of aid dependency on the local community. It is feared that the lack of adequate funding facilities could obstruct the success of the program. In addition, the lack of local ownership is also a challenge to the sustainability of the program. Therefore, early identification of challenges can reveal limitations clearly so that the best solutions can be built, which are also expected to contribute to the development of science [20].

The city of Malang, Indonesia, with hilly topography conditions, should not experience significant flooding problems. However, in the last few decades, floods and inundation always occur every rainy season. It is triggered by climate change, which causes an increase in rain intensity and acceleration in the duration of rain and significant land use changes. The Government has made efforts to overcome flooding but has not provided optimal results. Flood control projects can provide direct economic benefits, especially for people affected by floods. The above information must be conveyed to the community and other parties in flood risk management programs. It can also increase the interest of related parties, such as the Government, private sector, and other sponsors to invest in flood control projects. Several advantages can be calculated as cost-effectiveness in any given investment.

The objectives of this study are 1) to develop facts of community concerted effort to decrease the flood risk while improving well-being through modifying drainage channels used for fish and vegetable farming; 2) evaluate all benefits of drainage investments include the social and economic benefits. The study focuses on the efforts of the local community for the sustainability of flood control programs and improving well-being.

2. Description of the study area

The study area is located on a flood-prone in Malang City, namely Glintung Kampong. This kampong is also known as Glintung Water Street (GWS). The name GWS is motivated by the function of the road, which turns into a channel during heavy rains, especially on roads located approximately a hundred m from the river. With an area of 8.2 ha and a population of 810 people, this area is classified as a high-density settlement, which is around 9900 people/km^2. Since the beginning of 2000, about fifty percent of the area is always inundated in every rainy season with an average flood depth of 0.7 m and a maximum of 1.5 m. This kampong is bordered by the main sewer about 12 meters wide in the south, a highway in the west, a densely populated neighboring kampong in the north, and a railroad track in the east. The inundation that occurred was partly due to the position of Glintung Kampong, which was lower than the three bordering areas. The situation worsens due to backwater when the water level in the main sewer rises and water overflows into the kampong. The map of the study area is shown in Figure 1.

Figure 1. Study location map (taken from Google Maps).

To reduce the inundation depth that occurred in the study location, the Malang City Government, through the Public Works and Spatial Planning Department (DPUPR) in 2018, made a drainage channel with a total length of 40 meters. The channel consists of two canal segments: the northern section with a length of 24 meters and the western section with 16 meters. At the initiative and collective action of the local community, the drainage channel was modified to be used for fish and vegetable cultivation using the concept of *urban farming*. At first, the channel was only used to cultivate catfish and vegetables such as eggplant, chili pepper, tomatoes. The capital for catfish seeds was obtained from the collaboration with the community service team of the Civil Engineering Study Program, University of Merdeka Malang, while the vegetable seeds were a donation from the Public Works Service. Currently, the cultivated fish types are also increasingly diverse, including tilapia, tombro, catfish.

The cultivated types of vegetables include mustard greens, pumpkin, lettuce, kale, and spinach. The types of fish and vegetables are chosen, which are commonly consumed by the community daily. It is hoped that the results of fish and vegetable cultivation can meet the community's nutritional needs. In the end, this hope came true with the award that GWS Kampong received as a Food Security Kampong.

Figure 2. Transformation of the study site, starting before the drainage channel improvement project, the construction phase, modification of the channel for fish and vegetable cultivation.

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3. Materials and Method

3.1. Data collection and analysis
This study used a mixed-method that combines quantitative data obtained from the results of questionnaire distribution of 43 purposive respondents and qualitative data using in-depth interviews from 10 informants and direct observations. Quantitative data is used to determine the influential factors in building the concerted community effort. The identified factors include knowledge of flood causes, flood risk, local community involvement, flood control programs from the Government. Questionnaires were also used to determine the level of community knowledge of flood risk and community resilience in dealing with floods. In-depth interviews were conducted to determine why the informants remain in flood-prone areas, the estimated flood losses that occurred during the last ten years, and other factors that may influence building the existing flood resilience system in the community. Direct observations of people's daily lives were carried out to find out community habits related to risk management and flood resilience, community interactions with local governments and related agencies, and developing creative ideas and local community skills in optimizing the function of drainage channels.

The questionnaire consists of five categories of questions as follows: 1) Community concerted effort; 2) Knowledge of the causes of flooding; 3) Knowledge of flood risk; 4) Local community involvement; 5) Flood control program from the Government. Respondents' answers to questions on the questionnaire were directed to four alternative answers according to the Likert Scale. The four alternative answers are: very good, score 4; good, score 3; poor, score 2; very poor, score 1. The results of the Likert Scale were then interpreted using interval analysis to determine the index. The data were also analyzed using reliability and validity tests. The process of filling out the questionnaire was done through direct interaction with the respondents. The answers were then filled in the appropriate field and analyzed using correlation, determination, and regression analysis.

In-depth interviews were conducted with ten community leaders as informants: head of the kampong, chair of woman organization of kampong, head of sub-kampong (five people), religious leader, chair of the youth organization kampong, elders, and relevant local government agencies. The interviews were also used to investigate the involvement of concerned parties, such as the Government, non-government, and academicians, in developing concerted community efforts towards food security, environmental sustainability, and the provision of facilities.

3.2. Hydrological and hydraulic analysis
Hydrological analysis was carried out to determine the runoff discharge that caused inundation at the study site. The runoff discharge is calculated using the Rational Method with rainfall data obtained from the Meteorology, Climatology, and Geophysics Agency of Malang City with a data length of 10 years, namely 2009-2018. The catchment area was measured using Google Maps and field surveys. The runoff coefficient was determined based on the type of land use in the drainage area. Hydraulics analysis is used to determine the capacity of the drainage channel built by the Government as an investment in flood control at the study site. The channel capacity was calculated using the Manning formula with technical data according to the channel specifications. The decrease in runoff discharge due to the construction of drainage channels resulted from a reduction in runoff and capacity discharge. It was also referred to as uncontrolled discharge. The inundation depth was then estimated using the ratio of inundation volume and inundation area. At the same time, the inundation volume was calculated by multiplying the runoff discharge and the duration of the rain.

3.3. Cost-effectiveness analysis
Decision making based on several alternatives can use a tool known as cost-effectiveness analysis (CEA) [21]. In recent years the use of CEA has grown widely. This concept is quite simple because it only combines the net costs and the effectiveness of several alternative interventions given. Furthermore, a comparison of the cost-effectiveness ratio of each alternative intervention with the same achievement target was carried out. Changes in behavior resulting from the intervention can be either an increase in

the good or a decrease in the bad. The difference in the calculation of the cost-effectiveness ratio depends on the selection of alternatives separately or is the result of a combination of several alternatives.

4. Results

4.1. Designed and observed parameters

The designed parameter of this study is the strength of concerted community effort. The factors that influenced the parameter were determined based on the qualitative data (interviews and field observations), and qualitative data (questionnaire). The observed parameters consist of four parameters formulated as research variables. This research used five variables, one dependent variable, and four independent variables. The variables are as follows: 1) community concerted effort (Y); 2) knowledge of the flood causes (X1); 3) knowledge of the flood risk (X2); 4) local community involvement (X3); 5) flood control program from the Government (X4). Then, by using correlation tests and regression analysis, we determined the correlation between variables. Data analysis was based on three clusters of respondents: 1) community leaders, with ten respondents; 2) male respondents, with 26 people; female respondents, with 17 people. The results of the Likert Scale were then interpreted using interval analysis to determine the index. The respondents' answers were given a weighted value or Likert score as mentioned above to quantify the results. The index calculation of each parameter is shown in Table 1.

Table 1. Recapitulation of questionnaire data and index calculation of each parameter

Level	Score	X1	X2	X3	X4	Y	Interval
Very good	4	0	7	0	13	0	75%-100%
Good	3	25	11	10	24	21	50% - 74.99%
Poor	2	18	17	24	4	18	25% - 49.99%
Very poor	1	0	8	9	2	4	0% - 24,99%
Total score		111	103	87	134	103	
Max. score		172	172	172	172	172	
Min. score		43	43	43	43	43	
Index		64.53	59.88	50.58	77.91	59.88	
Level		Good	Good	Good	Very good	Good	

Table 1 shows that the respondents understand the causes of flooding, its risk, and the importance of their collective involvement and action in flood control programs. In addition, respondents also have a very good understanding of the programs implemented by the Government. This quantitative data supported the result of qualitative data from the depth interviews. Several informants, especially those who have lived in the area for a long time, said that they understood that the area formerly was an open space located within the borderline of the main drainage channel. They also understand that the development of the area into an illegal residential area will result in flooding. However, the strategic location of the kampong makes them stay in the area.

4.2. Validity and reliability test

Based on the questionnaire analysis resulting from 43 respondents, the most influential factors in building community effort can be properly determined. The factors consist of four parameters as described above. Simultaneously questionnaire reliability test for all variables gained a Cronbach Alpha value of 0.72. The test results of each variable reliably indicate that the questionnaire instrument used ranges from 0.62 to 0.72; all results are greater than 0.6 (Guilford, 1956). The complete test results are shown in Table 2.

Furthermore, the relationship between the independent variable and the dependent variable can be analyzed using regression analysis. The validity of the question categories in the questionnaire was analyzed simultaneously and resulted in a validity coefficient of 0.75. The results of the calculation of the P-value at a significance level of 0.00 are lower than 0.05, as shown in Table 3.

Table 2. Reliability test results.

Code	Parameters	Cronbach Alpha	Standard Value	Significance
X1	Knowledge of the flood causes	0.66	0.6	reliable
X2	Knowledge the flood risk	0.72	0.6	reliable
X3	Local community involvement	0.64	0.6	reliable
X4	Government flood control program	0.62	0.6	reliable

Table 3. Validity test results.

Code	Parameters	r	P-value	Significance
X1	Knowledge of the flood causes	0.31	0.16	not valid
X2	Knowledge of the flood risk	0.76	0.00	valid
X3	Local community involvement	0.37	0.05	valid
X4	Government flood control program	0.46	0.11	not valid

Table 2 shows that the questionnaire instrument is reliable for all parameters. However, only two parameters are valid: knowledge of the flood risk and local community involvement. The respondents already have a good and even very good knowledge of the causes of floods and the importance of government programs. Therefore, it does not affect their collective actions in controlling floods.

4.3. Correlation and determination coefficient

The correlation coefficient was used to determine the relationship strength between variables, while the determination coefficient was used to determine the effect of each independent variable on the dependent variable. The correlation coefficient and the coefficient of determination are shown in Table 4 and Table 5 below.

Table 4. The correlation coefficient between variables

Code	Parameters	Y	X1	X2	X3	X4
Y	Community concerted effort	1.00				
X1	Knowledge of the causes of flooding	0.22	1.00			
X2	Knowledge of the flood risk	0.66	0.15	1.00		
X3	Local community involvement	0.28	0.16	0.33	1.00	
X4	Government flood control program	0.38	0.23	0.40	0.29	1.00

Table 5. Determination coefficient (r^2)

Code	Parameters	r^2	P-value	Significance
X1	Knowledge of the causes of flooding	0.05	0.16	no
X2	Knowledge of the flood risk	0.43	0.00	yes
X3	Local community involvement	0.08	0.05	yes
X4	Government flood control program	0.15	0.11	no

4.4. Multiple regression analysis (Effect of the observed parameters on the designed parameters)

The reliability and validity test results showed that only two independent variables were valid: knowledge of flood risk (X2) and local community involvement (X3), as indicated by Cronbach Alpha greater than 0.6 and P-value less than 0 05. Multiple regression analysis was performed using these two variables, resulting in a formula with an intercept coefficient of 0.66, X2 coefficient of 0.9, and X3 coefficient of 0.32.

It means that community action is influenced by the knowledge of flood risk with a coefficient of 0.19 and local community involvement in flood control programs with a coefficient of 0.32. Suppose the community does not have knowledge of flood risk, and there is no active involvement. In that case, concerted community effort will still exist with a coefficient of 0.66, which other parameters may influence. The equation was also tested using root means square error (RMSE), mean absolute error (MAE), and Nash-Sutcliffe efficiency NSE). The test results were respectively 0.30, 0.23, and 0.71.

4.5. Runoff discharge and inundation depth

To accommodate the uncertainty of rainfall, two types of runoff discharge approaches were used as the basis for determining the inundation depth in the study area, namely runoff discharge with a return period of 2 years (Q_2) and five years (Q_5). The calculation of the hydrological analysis uses a series of daily rainfall data for ten years, and the duration of heavy rain is about 30-60 minutes, and the following results are obtained:

1. Q_2 = 10.24 m^3/s, Q_5 = 12.73 m^3/s, and a drainage channel capacity = 7,00 m^3/s,
2. uncontrolled discharge for a return period of 2 years = 3.24 m3/sec, causing inundation of 0.95 ha, inundation depth of 20–50 cm, and shrinkage due to flooding consisting of the age of the building and interior, motorcycles, electrical equipment, furniture, livestock, and vegetable gardens, with a total loss of around IDR 94 million.
3. Uncontrolled discharge five year return period = 5.73 m^3/s, causing inundation of 1.42 ha, inundation depth of 50–100 cm, and flood losses consisting of damage to roads, buildings, and interiors, vehicles (cars and bicycles) motorcycles), electrical equipment, furniture, cattle pens, and vegetable gardens, with a total loss of around IDR 125 million.
4. The depth of inundation that often occurs in the study area ranges from 50–100 cm.

4.6. Existing flood resilience system

Based on the local wisdom value of cooperation, communities build their flood resilience system that combines structural and non-structural measures. Structural components consist of drainage channels, water level indicators, sluice gates for controlling water level, and pumping stations to raise water to the nearest receiving water body, as shown in Figure 3. Non-structural measures consist of natural flood early warning that uses the sound of lightning as a sign of impending heavy rain, evacuation routes to safe areas, helping neighbors' houses that are not flooded for shelter and helping each other clean up the effects of flooding. This system can reduce flood damage and losses by up to 30%. Flood damage can be minimized if the urban system has implemented some protective measures. The community in it can self-regulate so that no greater damage occurs [19].

Figure 3. The existing flood resilience system consists of water level indicators at subsurface sewer (a), sluice gates for controlling water level (b), and pumping stations to raise water to the nearest receiving water body (c)

4.7. Cost-effectiveness analysis

Cost-effectiveness analysis begins with identifying all costs and benefits of flood control projects in the study area. The implementation of flood resilience and risk management systems was then taken into account to reduce flood loss, considering monetary and non-monetary values. Additional project benefits were derived from modifying drainage channels for fish farming and canals, as described above. The harvested fish were sold in fresh fish and processed products in meatballs, snacks, menu packages of fresh vegetables, and spicy coconut milkfish. The average monthly sales of fish and its processed products are approximately IDR 7.5 million. While the average sales of vegetables and processed vegetables include juice, ice cream with pumpkin, and mustard greens ingredients, amounting to IDR 3 million per month. The amount of income in a month from fish and vegetable cultivation is IDR 10.5 million. Operational costs, including the purchase of fish and vegetable seeds, labor, additional materials, and food processing costs, are approximately IDR 6.5 million per month. Net income from fish and vegetable cultivation is IDR 4 million per month or 48 million per year.

Figure 4. Results of fish and vegetable cultivation.

Calculation of cost-effectiveness based on 2-year return period is divided into three categories, as follows:
1. Category 1: Condition without drainage channel improvement and concerted community effort.
2. Category 2: Condition after drainage channel improvement and was used for fish and vegetable cultivation.
3. Category 3: Condition of Category 2 plus the implementation of flood resilience systems.

The calculation result is shown in Table 6 below.

Table 6. Cost-effectiveness calculation, project implementation 2018-2019, in IDR million

No.	Components	Category 1	Category 2	Category 3
1	Flood losses	94.07	75.25	41.39
2	Investment cost of the drainage channel	0	178.54	178.54
3	Operation and maintenance	0	26.55	26.55
4	Revenue from fish and vegetable farming	0	48.00	48.00
5	Benefit	0	43.31	77.18
6	Cost-effectiveness (%)	0	32.50	49.20

Table 6 shows that Category 3 has the highest cost-effectiveness. Utilization of drainage channels for fish and vegetable cultivation and optimizing the existing flood resilience systems positively impact and add value to project investment.

5. Discussions

The results of the reliability, validity, correlation, and determination tests are as described in Table 2, Table 3, Table 4, and Table 5. The results show that community concerted effort to overcome flood problems that develop naturally in the community is strongly influenced by the level of knowledge of flood risk and local community involvement. Meanwhile, government programs do not have a significant influence on the emergence of community efforts. This research result has also disagreed with the research resulted by Šakić Trogrlić et al. [20]. He stated that the lack of financial resources causes the community to become dependent on the Government or other parties, a barrier to the program's fruitfulness. The fact is that the community flood resilience system in the study area was already established before the Government applied for the flood control program in the study area. Financial limitation encourages the community to generate creative and innovative actions such as using drainage channels for fish and vegetable cultivation. The community's sense of belonging makes efforts continue to grow; the financial benefits increase so that the program could keep continuing. Community involvements are also manifested as a rapid response to the dangers of flooding, where people who are not affected work together to help the affected community. Some communities, especially leaders and focal persons, proactively manage flood risk while increasing community food security. These results support the research of Tingsanchali [10], which stated that effort should be aimed at preventive measures so that the risk of flooding can be minimized. In this study, an example of this action is the availability of a flood warning system with simple technology already functioning well. Tables 3 and 5 also show that people do not need to understand the causes of flooding because they already know they live in flood-prone areas.

The results of the efficiency test and the deviation of the design parameter equation model using RMSE, MAE, and NSE as mentioned above, show that the model has a good efficiency in estimating the potential for concerted community effort based on the level of knowledge of flood risk and the level of local community involvement. The higher the level of knowledge of flood risk and the level of involvement of the local community to jointly overcome problems that occur in the community, not only the problem of flooding, the higher community concerted effort.

Table 6 shows the calculation of the cost-effectiveness of the three categories. In Category 2, investment costs for constructing drainage channels of almost IDR 180 million can provide benefits, namely reducing flood losses and obtaining income from fish and vegetable cultivation, which reaches around USD 650 per month. So there is the cost-effectiveness of about thirty percent in a year. While in Category 3, the reduction in flood depth is greater by considering the benefits of implementing the existing flood resistance system. It resulted in an increase in cost-effectiveness of 49.2% in a year. Therefore, the next government investment in flood control projects in this study area will serve benefits and added value about fifty percent of the project value. It shows that risk-sharing collaboration between governments at all levels and all sectors, as well as all stakeholders, is a key component to developing risk-based policies and actions so that effective flood risk management can be realized [6], [22]. Therefore, future government investment in flood control programs will provide social and economic benefits.

6. Conclusion

This paper tries to develop an understanding that a community in a flood-prone area can reduce flooding and even improve well-being through self-effort. The community's concerted effort has succeeded in changing the slum environment into a clean and healthy environment. The higher the local community involvement and knowledge of flood risk, the higher the strength of the collective action. The community also has local cultural values , namely cooperation and living in harmony, strongly implanted as cultural heritage and parental education. The flood resilience system and flood risk management that have developed naturally in the community for the past few years are based on these values. The high creativity and productivity of the community, supported by strong leadership, encourages the community to innovate in modifying drainage channels to develop fisheries and urban farming. Therefore, the flood control project invested in the study area provides a flood reduction benefit of up to one-third of the initial flood depth and provides a financial benefit of IDR 48 million in a year. The understanding that the community can deal with floods and manage the program's sustainability independently can be used to plan future flood control programs by involving the community as the main actor.

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