Adaptation of Buildings in Urban Flood Plains in Malang, East Java of Indonesia

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Abstract

The area of flood plain is susceptible to disaster, however, most inhabitants have still held out in their environment as settlements at the flood plains in Embong Brantas, Malang. In anticipating the threat of any disaster, the inhabitants have adapted to the physical condition of the buildings where they live.

Objectives of the research were to analyze the physical adaptation of buildings to disasters and to analyze factors that affect it. Method of the research was the qualitative method, which so-called Method of Successive Interval (MSI).

Result of the research showed that both adaptation and recovery of the physical buildings from disasters are hierarchal changing the floor materials; building the floodwall; changing wall materials; elevating the building floor; developing storied buildings. Factors that affect adaptation and recovery of the physical buildings in urban flood plains are (1) income; (2) experience in disasters; (3) education; and (4) zone.

1. Introduction

Flood hits areas along the river banks, lowlands, downstream areas, and others that having bad drainage system [1]. Such flood may be caused by extreme natural phenomena and human activities [3]. Along with the rapid growth of population as well as less-planned urban development, both geographically and demographically, the threat and flood risk have been increasing. The impact of urbanization has also contributed to the change of hydrologic characters in urban areas [4]. Consequently, river waters in urban areas easily overflow and flood the areas around them. The overflowed waters have quickly turned into flood. The impact of physical damage of the buildings (architecture of the buildings, structures, and utilities) and non physical damages [5]. Therefore, further review is required concerning with physical adaptation of buildings at the flood plains and mitigation to reduce the flood risks [2].

Geomorphologic land (topography, soil, and geology), climate or higher rainfall, as well as human activities highly influence the occurrence of the Critical River Course Zone [3]. The increasing numbers of critical River Course Zone in Indonesia have affected number of flooded areas. Settlements along the flood plain of Brantas River are frequently and periodically hit by flood as commonly occur in the areas of Kidul Dalem District, Klojen Subdistrict of Malang. Based on the history of flood in Embong Brantas village, a flash flood hit this village in 1963 and the flood had submerged most of the settlements. Small-to-large scale flood has periodically hit once that ranges from 10 (ten) to 20 (twenty) years. By reason of history, routines of natural events, land slope, density of populations and buildings, Embong Brantas settlements is chosen as focus of the research.

Based on the Government Regulation Number 37 of 2012 about River Course Zone Management, parameter for characteristics of the River Course Zone could be from spatial and non spatial elements that include biophysical, social, economical, and cultural components including disasters. However, the disastrous elements in the River Course Zone management are important aspects, which include controlling the flood, both structurally and non-structurally. One of non-structural management of the River Course Zone is applying flood proofing of buildings in that area. Such effort does not prevent the flood, but reduce the impact of disaster during the flood, which includes:

a. *Elevation, raising a building* so that flood waters will go under it;

b. *Relocation* , moving a building *to high ground, above flood level;*
c. *floodwalls* , building a wall to keep flood water from reaching a building;
d. *dry floodproofing,* making the walls of the building and the openings watertight;
e. *Wet floodproofing*, altering a building to minimize damage when flood waters enter.

Effort to control flood is intended to reduce the attack of flood waters, dragged along by flows, erosion caused by backup of waters, landslide around/below the foundation, hit/eroded by crash of heavy objects that are dragged along by the river flow [7].

Laws Number 1 of 2011 about Housings and Settlement Areas that "the potential location that may create danger" such as the River Border Zone, railways borders, under the bridge, Extra High Tension Wind Pipe Zone, susceptible areas to disaster, and specific areas such as military zone. In particular, Article 140 states that everyone is forbidden to build housing, and/or settlement in any area that is potential to danger. Settlements should not locate on susceptible areas. In particular, article 141 states that such prohibition for officers to issue any permit to build houses, housings, and/or settlements that not conform to function and space utilization at the susceptible zone. Restoring house must be done by everyone (article 92, verse 1), however, restoration for public utilities and infrastructures in the settlement environment must be done by the government (article 92, verse 2). Therefore, house restoration at the susceptible area may be done by each family as long as it does not endanger any objects and or man.

In Theory of Ekistics [8], settlement is so-called as "human settlement" in relation to aspects of man, society, nature, network, and shell. Man means the subject who should meet the biological needs, spaces, fresh air, thermal comfort, and etc. Moreover, fulfillment of the emotional needs include feel of secure and safe from any threat of disaster, relation with others, and beauty. Furthermore, *Doxiadis* described society as public, which is viewed from demographic aspect that includes composition and density of the population. Within the society, there are social stratification, cultural pattern, economic growth or income, education levels, health, and other aspects that relate to the prevailing law in that society. Adaptation taken by society who lives by the flood plains relates to "human security", which means adaptation of "container" and "content" to create a sense of security in that settlement. If the settlements have not fulfilled the criteria as required for the survival, the settlements transformation will be done continuously.

Adaptation to disasters is an effort of adjustment to threat of disasters. This adaptation belongs to eight-stage of Maslow's model, in which the subject (doer) is categorized into quantity unit in the society. It ranges from the smallest unit in family/individual level, environment, to area or municipality. Such categorization can be simply divided as follow [9]: a) area in municipality level; b) area in environment level; b) area in family level.

In the scope of family, it can be applied in the settlement by paying more attention on security and safety from any disaster. However, the disaster is caused by nature, climate, and social, as well as social culture. This process is considered as reciprocal relationship among nature, human, and environment in order to achieve an equilibrium, safety and security in living in that settlement [9].

More studies about housings and settlement architecture have been conducted. But, few research concerning with adaptation of buildings in the flood plains have been conducted. While the adaptation has become significant, along with the frequency of disasters that hit settlements in urban and rural areas. Based on general theory by Maslow, transformation and adaptation of settlements may due to deficiency needs, which include fulfilling the needs of security and safety [24]. Besides that, adaptation of buildings is also due to adaptation to local climate, such as design of buildings for areas that having tropical climate as in Indonesia.

In order to study adaptation of buildings to threat of flood in an area, it will examine the source of running off water, its run-off, so that the susceptible zone can be identified [10]. In European countries, the susceptible zoning and the risk management have been determined [11]. Results of the research would determine the adaptation forms of buildings, land uses, public service, and source of running off water as well as standard of the sewage networks [12].

Product of the susceptible zone map is important to inform about susceptibility and the risk of disaster in specific area to the public. Such threatening map shows area in 3 (three) levels that ranges from low, medium, and high. Each level is evaluated for kinds of flood, water height, water flows velocity, possibility of water flows, and etc. [13]. Then, implementation of the risk management does not only focus on physical parameter and technology, but also social, economic, and political parameters. Besides nature, other factor that affects the occurrence of disaster is the economic activity in a region and etc. [14].

At last, adaptive and continuous settlements in the food plains are the susceptible settlements that manage risks by reducing threat, establishing more resistant economic and social resilience to disasters [15]. The discourse of risk reduction and disaster management has close relationship with the quantity of threat and susceptibility of the society in a disastrous location. Susceptibility is a condition and process resulted by physical, social, economic, and environmental aspects, in which those aspects affect the resilience of society to the danger impact [16].

MATERIALS AND METHODS

Based on the previous research, the selected locations are settlements at the Flood Plains, Embong Brantas in Kidul Dalem District, Klojen Subdistrict, Malang by rasionalization as follow:

a. Location of the research is one of food plain settlement that susceptible to flood, the location is on the land slope of > 40 %, near the main city;

b. Location of the research is one of food plain settlement, which has existed since the Dutch Colonialism era and has long stories in its development. Information about the age of the old settlement is derived from several key persons who born and live in that area up to the present time;

c. Location of the research is one of food plain settlement that has the densest buildings (95-106 houses/Ha) and the densest population (379 peoples/Ha).

Research in the field was conducted through direct observation, structured interview via questionnaires, and documentation. Research on physical adaptation involves 70 samples of household in RW 05 and RW 06 as presented in **Figure 1**.
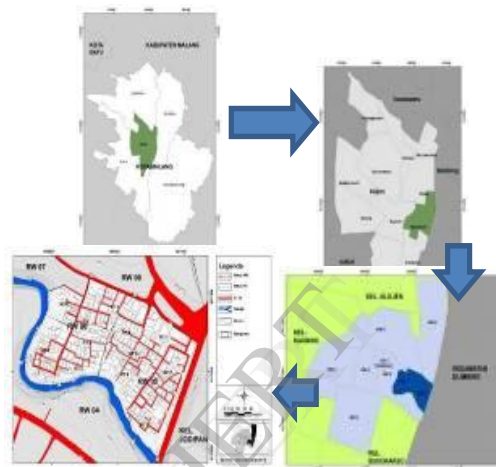

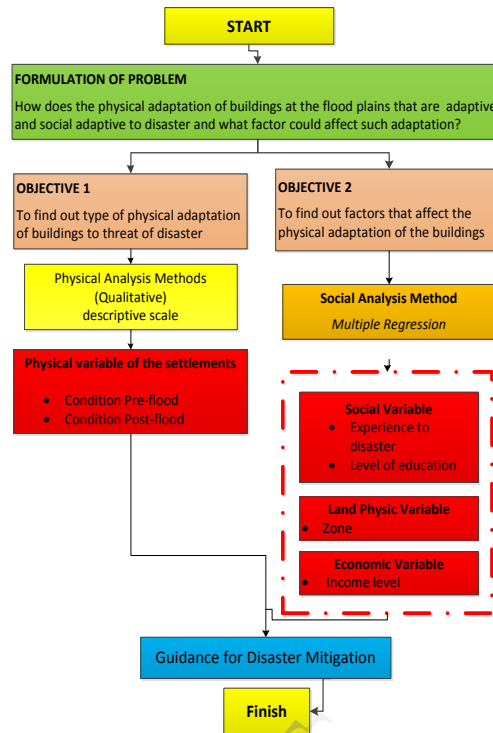**Figure 1.** Location of the Research

Figure 2. Methodology of the Research

Method in collecting data and analyzing physical adaptation of buildings was done purposively through interview. The field reconstruction was conducted to find out the adaptation process pre-and-post-disaster. Then categorization and assessment were conducted using 1-5 scoring category on quality of physical adaptation of buildings toward the flood.

Method in collecting data and quantitative analysis are applied to study factors that affect quality of physical adaptation of the buildings using multiple regression analysis. This research assessed the effect of some factors (zone, level of education, level of income, and experiences of the respondents concerning with flood) on quality of physical adaptation of the settlements. Variable of the settlement location on certain zone represents the physical aspect. Level of education and experience variables toward flood are chosen to represent the social aspect, while level of income represents the economic aspect. Those three variables are independent variables, which will be assessed their effects on dependent variables, the quality of physical adaptation of buildings toward threat of flood. This dependent variable is a physical adaptation that has been applied by the respondents on their houses. Method in collecting data to study factors that affect the social adaptation is similar to method applied in physical adaptation. Variables used in social adaptation are level of education, level of income, and experience on disasters.

Multiple regression analysis is an approach used to define the mathematic relationship between output/dependent (y) variable and one or some input/independent (x) variables. A regression model is used to predict the output (y) value based on specific input (x) value [19].

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots b_nX_n + e$$

3. RESULTS AND DISCUSSION

3.1 ADAPTATION OF BUILDINGS AT THE SUSCEPTIBLE FLOOD PLAINS

The physical adaptation of buildings at the flood plains was done in stages. It is starting from the lowest level and simple stage to the greater one that is considered costly. It is done to provide continuous security and balance (equilibrium) [9]. The smallest adaptation in settlement scope is applied to provide security and safety to the family from

disaster. Based on result of observation in the field, the physical adaptation of buildings at settlements in the flood plains has transformed, pre-flood and post-flood. The physical adaptation is divided into 5 categories as presented in **Figure 4**.

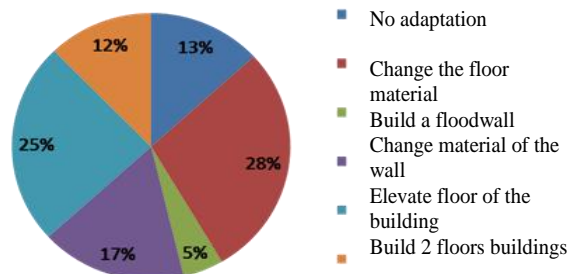**Physical Adaptation that can be Done**

Figure 4. Diagram of Physical Adaptation Type

The physical adaptation of buildings to flood is started by changing the floor materials, building floodwalls, changing wall materials, elevating the floor into 2 floors settlement.

Transformasion on this physical building is only to reduce the attack of river waters and erosion by backup of water. Therefore, most of the inhabitants have strengthened and elevated the foundation to reduce the flood and landslide [7]. Land slope on the flood plains > 40 % is highly susceptible to landslide.

So, physical adaptation of buildings at the flood plains is started from overcoming any damage on the base of buildings (foundation, floor), damage on wall (change the material) and at the top part of the building (build 2 floors building) to save the property.

In order to answer the second problem, which study aspects that affect quality of the physical adaptation of the buildings, results of the finding in the field are categorized into some categories. The results found five categories of adaptation quality, which are assessed within 1-5 scores. Score 0 refers to sample that not take any adaptive effort. The given score is assumed and assessed, based on quantity of efforts that have been done to achieve the adaptive effort. Categories for quality of adaptation are hierarchal presented in **Table 1.**

Table 1. Categories, Type and Percentage of Adaptation Efforts on Buildings

Category	Type of Adaptation	Percentage
0	No adaptation	13
1	Change the floor material	28
2	Build a floodwall	5
3	Change the wall material	17
4	Elevate floor of the building	25
5	Build 2 floors buildings	12

Table 1 presents the hierarchy of adaptation. Category 0 refers to sample, which does not make any physical adaptation at all. However, this category is highly affected by ability of the respondent. Some samples have made more than 1 physical adaptation, so that these physical adaptations will be added and values of the categories will be distributed evenly.

In the next discussion, these assessed categories are so-called quality of physical adaptation. Such physical adaptations of building are changing the floor material, wall material, building floodwall, raising the floor of buildings, and building room on the second floor. Out of total 70 samples, 106 physical adaptation efforts in which some of the samples have done more than 1 adaptive effort. However, 13 % of the samples have done no adaptation due to inadequate ability of the respondent.

a. Change floor material of the buildings

The lowest category goes to category 1, 28 %, which refers to the adaptive effort by changing the floor material in order to assume that the effort requires the least effort, material, and cost. **Figure 5** describes that changing the floor material is started from the earth floor into plastered floor, and from plastered into ceramic/tile floor. The inhabitants describe that the effort was done due to the settlement uses earth floor and they have in difficulty to clean it up, particulary post-flood. After changing the floor material into plastered floor, it is easier to be cleaned up. Some samples

have changed the material again into tile/ceramic floor, as the materials are more easily to be cleaned up post-submerged with flood. Out of total 70 samples, these efforts are found in 30 samples.
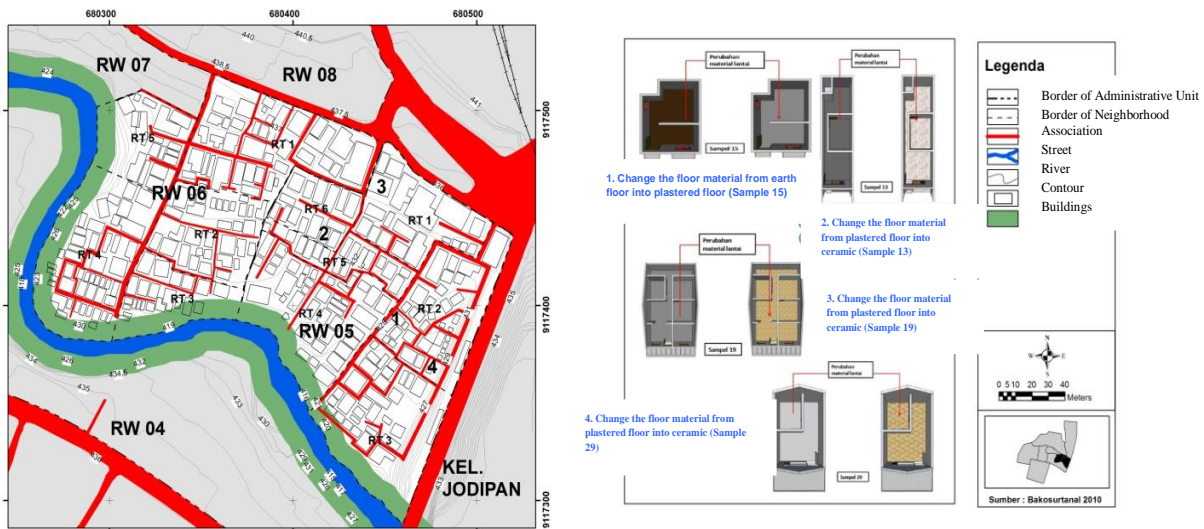

Figure 5. Examples of Adaptation on Floor Material Change of the Buildings

b.   Build floodwall of the buildings

Category 2, 5 %, refers to adaptation effort by building the floodwall. Number of this category is the least, particularly for buildings that are adjacent to the river. So, this floodwall functions as space divider between settlement and nature, as well as a kind of mitigation of overflowed water. Such floodwall is generally built by settlements, which are the most adjacent to the river (**Figure 6**). This adaptation effort highly depends on distance of the buildings and the river as found in 5 samples.
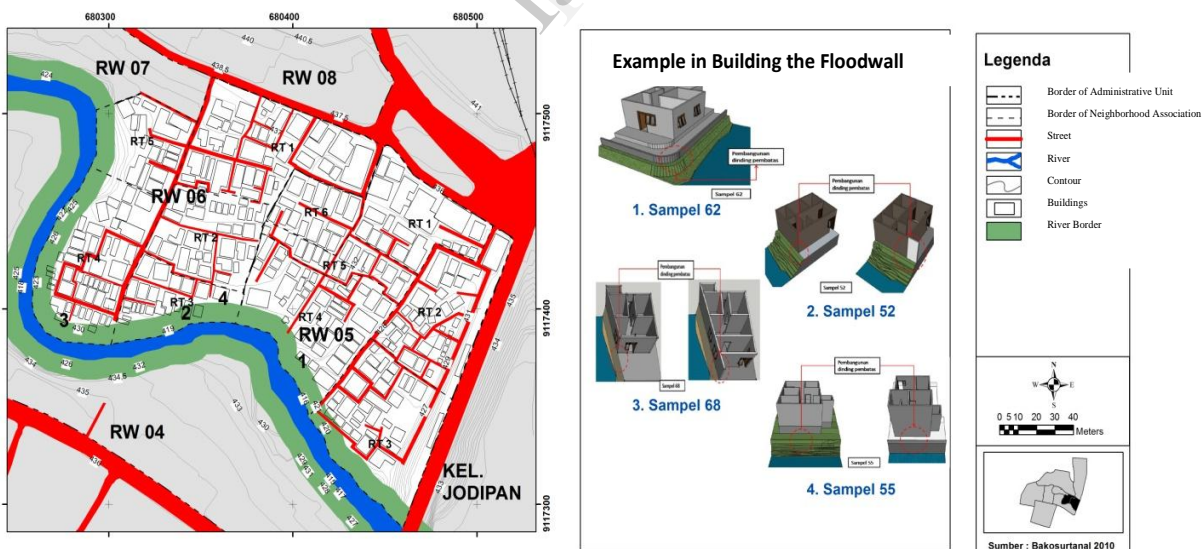

Figure 6. Examples of Adaptation on Floodwall of the Buildings

c. Change wall material of the buildings

Category 3, 17 %, refers to adaptation effort by changing the wall material. Number of this category is adequate in order to make the wall of the settlement to be more resistant to water seepage. This effort is divided into 2, by changing the wall material as a whole and changing a part of the wall material. A part of the efforts are applied on specific parts of the wall, outer wall, as well as the part that the closest to the flood source **(Figure 7)**. This effort is found in 18 samples.
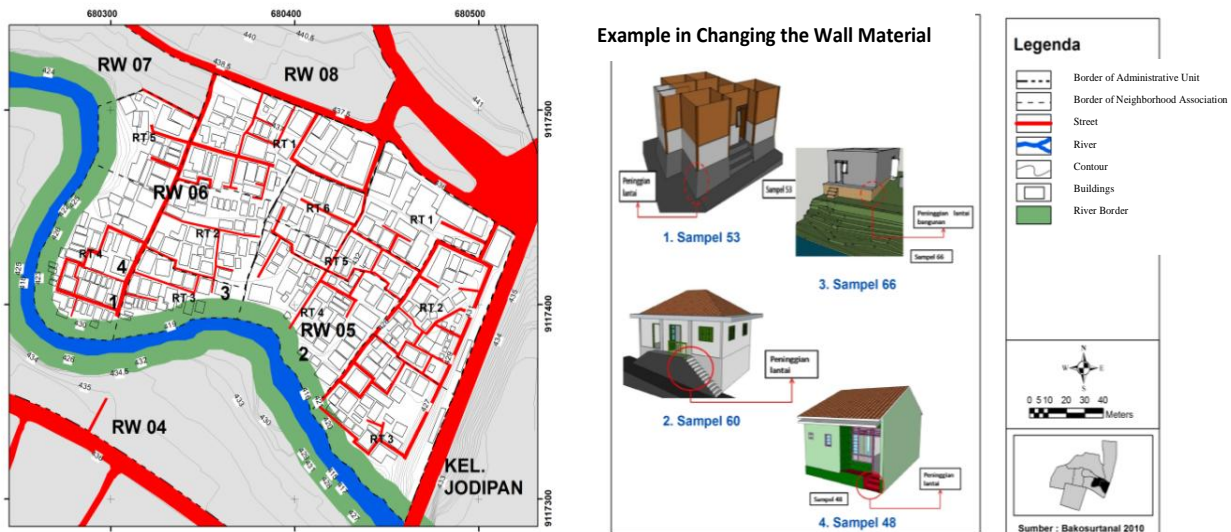
d. Elevate/raise the floor of the buildings

Category 4, 25 %, refers to adaptation by raising the floor of the buildings. This category has greater numbers, particularly for settlements on the upper zone. Most of the inhabitants say that such elevating the buildings is intended to avoid the overflowed water of the river or heavy rainfalls due to bad drainage. Elevating/raising the floor of the buildings comprises of 2 cases. First, such elevating was done since the beginning when the buildings was built, and the other one is when the buildings were renovated in order to avoid the threat of flood. However, raising/elevating the floor of the buildings during the renovation is generally done simultaneously with changing the floor material and not. Elevation of the building floor should be different and varying **(Figure 8)**. It depends on position of the settlements on the related zone. Such elevation effort is applied in 26 samples.
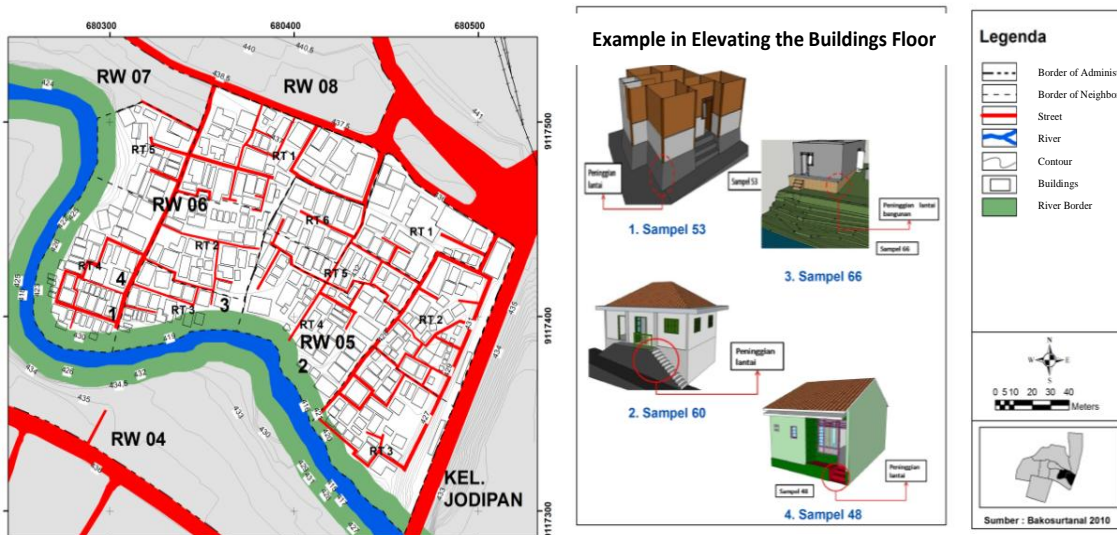

Figure 8. Examples of Adaptation on elevating/raising floor of the buildings

e. Build 2 floors buildings

The highest category, category 5, 12 %, refers to adaptation by building room on the second floor. This category is assumed to require more efforts, materials, and costly. The building of room on the second floor is functioned as room expansion to keep valuable properties and it is considered as the safest place during the flood. A few inhabitants state that the highest zone is chosen as the safest place to monitor the overflowed water. Based on experiences that the inhabitants have, they prefer staying in their houses to move out while keeping their properties, as found in 13 samples.
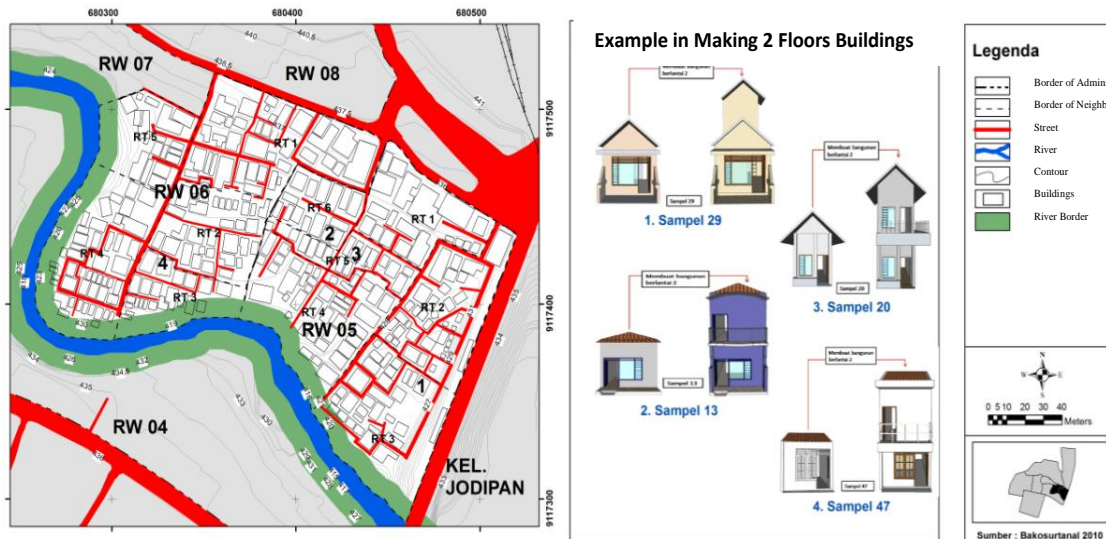

Figure 9. Examples of Adaptation on Building 2 Floors Buildings

Among 5 (five) types of physical adaptation quality on buildings toward the flood threat at the flood plains, they can be categorized as recovery effort on buildings post-disaster. The recovery is divided into 4, such as :
- Recovery of the building architecture (changing the floor and wall materials of the buildings);
- Recovery of the building construction (elevating/raising the building floor);
- Recovery of the building security (building floodwall to avoid the overflowed water);
- Recovery of the building safety (building 2 floors buildings);

Such physical recovery of the buildings toward flood, a part of it has conformed to Urban Flood Risk Management World Meteorological Organization. But, flood adaptation in the area of the research is highly affected by character of the flood plain locality, the physical variable of the land [16], such as :
- The closer the distance of the buildings to the disaster source (the overflowed water), the greater possibility and the threat (architectural and building damages) therefore, it requires relocation, dry floodproofing, as well as wet floodproofing;

Recovery on the physical buildings from disaster can be done by reconstructing the building security, which is affected by the zone, such as :
- The closes the buildings zone to the threat source (bad drainage) and the possibility, the recovery effort could be done by building the floodwall. Floodwalls are highly significant to be brought into reality in order to avoid any runoff water entering the buildings.

While the recovery toward threat to the family safety by building 2 floors buildings is usually done in a given zone and the subject (the doer) who possibly has adequate and greater ability.

Therefore, regulations and guidance of the space-use management are required in accordance with social and technical requirements, including socialization of the building permit.

So, these 5 (five) recovery of buildings from disaster in areas of the research are responses to disasters. Such response could be a mitigation effort toward flood in the family scope for protection, security, safety, and continuation purposes [24].

Meanwhile, adaptation and recovery in the settlement environment scope has been done by society in RW 05 and RW 06, in which they work together in building a dike at the edge of river in order to prevent from erosion because of river water. Then, preparation, protection, and normalization of water would be done by local government in order to control water flows and height of water level. So, in order to make the adaptation effort on settlements at the flood plains would be run continuously, it must be done in stages from family, society, and government of municipality levels.

3.2 ASPECTS THAT AFFECT QUALITY OF THE PHYSICAL ADAPTATION

In order to study and analyze aspects that affect quality of the physical adaptation of the buildings, therefore, variables that affect on physical adaptation of the buildings must be found out. They include physical, social, and cultural variables. Then, an analysis has been done in 2 (two) steps, transforming ordinal data into interval data by regression analysis.

The education level of the inhabitants in area of the research shows 32% graduated from Senior High School, 30% graduated from Junior High School, 26% graduated from Elementary School, 6% ungraduated from Elementary School, and the rests got diploma and bachelor degrees. The income level of the respondents are 44% for Rp 500,000-1,000,000 monthly, 26% earns Rp 1,000,000-2,000,000 monthly, 26% earns less than Rp 500,000 monthly, and the rests earn more than Rp 2,000,000 monthly.

Result of the findings that relates to flood experience variable shows 46% respondents experienced flood, but the water did not enter into their houses, 24% admitted that they have not experienced flood, 20% of them have experienced flood, which submerged and destroyed parts of their houses.

The linear regression model of this research can be seen in table of Coefficients in column Unstandardized Coefficients (B). The regression model is given below.

$$Y = 0,732 + 0,765X_1 - 0,149X_2 - 0,102X_3 + 0,566X_4$$

In which :
Y   = quality of adaptation
X_1 = level of income
X_2 = level of education
X_3 = zone
X_4 = experience toward disaster

Based on the regression model, an estimation can be made as follow :

- The higher (1 percent) the level of income, quality of the physical adaptation would be greater for about 0.765.
- The higher (1 percent) the level of education, quality of the physical adaptation will be reduced for about 0,149.
- The higher (1 percent) the zone change or the settlements are getting closer to the river, quality of the physical adaptation will be reduced for about 0,102.
- The higher (1 percent) the level of experience in disaster, quality of the physical adaptation would be greater for about 0,566.

Based on the description above, the observed variables can be put in order to determine which is the most influential variable so that which variable that has less influence toward quality in adaptation can be found out as well.

a. Level of Income

The most influential variable is income. Based on the regression model, it can be said that addition 1 percent of income would increase quality of adaptation for about 0,765. Of course, it can be understood that quality of adaptation, which is applied by individual, highly depends on his/her daily or monthly income. The higher income, the better quality of the adaptation is

b. Experience in Disaster

The second variable, which is the most influential toward quality of adaptation, is experience of the society toward the disaster. It can be seen from the coefficient value for the experience effect of the society toward the disaster for about 0,566. More frequent the disasters hit the people, it will increase quality of adaptation or reconstruction to the settlement

c. Level of Education

The third variable, which affects the adaptation quality of the society, is level of education. It has negative influence for about -0,149. Actually, level of education has influence or relationship toward level of income. The higher levels of education, the higher income will the individual have. Then, such level of income will affect quality of adaptation. Result of the regression has proven that level of income is more influential than level of education due to level of education has indirect influence on quality of adaptation. It presumes that level of education affects the level of income and then, affects the quality of adaptation.

Example of the relationship between education aspect and negative quality of adaptation

d. Zone

The last level for variable, which affects quality of adaptation, is zone by coefficient of -0,102. The closer the settlements to the river, the quality of adaptation would be lower. It is surprisingly, why the zone has negative influence on quality of adaptation. In general, perhaps it assumes that the closer the settlements to the river, quality of adaptation should be higher. But, it is contrary to the expectation. It may relate to income aspect. Maybe, the closer the settlement to the river, the inhabitants tend to have low income. In fact, it can be said that zone is not so influential to quality of adaptation in comparison with level of income and experience in disaster. For instance, settlement of an inhabitant is frequently got damage due to it lies by the river, but his/her income is not enough to make an adaptation or reconstruct his/her settlement. As a result, quality of the house reconstruction is still lower due to limited income. Example for relationship between this aspect and the positive quality of adaptation is presented below

Result of the research shows no negative relationship between the zone and quality of adaptation.

Even though education and zone tends to have negative relationship with the physical adaptation, it means that higher education does not automatically make the individual builds more adaptive settlement toward flood and also, the zone that is closer to the river does not always make the settlement to be more adaptive to flood.

Therefore, publication and informational dissemination must be done that relating to the danger zone of flood in urban area. This map information becomes more important because it is expected that the related agencies, which correlate to the flood management, could take an action and make a policy as soon as possible.

By taking an example of document that related to flood management in Germany [23], the susceptible area mapping has become one of important elements of the whole flood management efforts, including guidance and steps taken to construct and develop the product of susceptible area mapping. Product of such mapping will provide obvious description about prospect and intensity of flood at the specific and susceptible zone. This prospect can be classified into high, medium, low, and the lowest level. Meanwhile, the product of map for the susceptible zone division shows more specific area, based on category of the flood danger. Such category is based on two elements of the flood danger, prospect and intensity of the flood. Therefore, the local government should conduct a mitigation and preparation of disaster in urban area by :

- Socialization to the society about mitigation, preparation, response, and recovery when the flood occurred (the prospect and intensity);
- Socialization to the society about the shape and function of the building reconstruction that must be applied by the society;
- Socialization to the society about material of building capacity improvement in context of increasing income and education of the society, particularly the women to play actively in managing and sorting the trash in their own household environments.

Model for relationship of adaptation, disaster mitigation in the Settlements at the Urban Flood Plains and factors that affect them is presented in Figure 10.
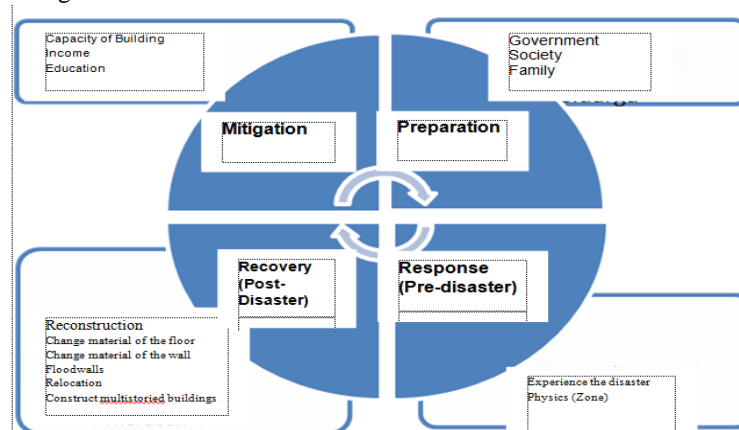

Figure 10. Model of the Adaptation Cycle – Mitigation of Disaster in Settlements at the Urban Flood Plains

Adaptation and recovery of buildings at the susceptible flood plains could be structural (technical mitigation) and non-structural (social, economic, and cultural mitigation). Guidance of mitigation is important and should be applied in order to conform to the zone and locality characters. This preparation can be started from technical, simple and less costly efforts to costly technical efforts.

CONCLUSION

Adaptation and recovery of the settlements at the flood plains pre-and-post-disaster are required to reduce the disaster risk. Risks for settlements, which lie at the flood plains, are flood or overflowed water from the river. Therefore, process of adaptation and mitigation from the buildings scope to settlements and urban area.

All processes of adaptation and recovery can be done for settlement mitigation in order to :

- Create security of the buildings;
- Create social environment safety;;

The most influential factors on quality of adaptation and recovery of the physical buildings post-flood are (1) level of income; (2) experience in disaster; (3) level of education; and (4) zone.

Based on result of the research about adaptation of buildings in the settlements at the susceptible flood plains, it shows that the income aspect is the most important aspect, which determines quality of adaptation and recovery of the buildings. Therefore, improving socio-economic aspects of the society should be concerned and handled by the government in mitigation at the flood plains. The income aspect plays the most important role in adaptation of disaster. The increasing income will motivate the society to move on to the safer place. So that it requires an economic empowerment effort, in which it is expected that the society would be able to leave the flood plains, as well as an effort of technical approach on buildings.

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