Scenarios and Impacts of Future Floods on Low Income Housing in Chiang Mai, Thailand

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Abstract
This study aimed to estimate the risk of low-income people whose suffer livelihood problems and housing damage due to present and future flooding, which will be affected by climate change. Data about problems in livelihood and housing damage affected by various flooding characteristics of households were collected in three low-income settlements in Chiang Mai which experience different flood types: flash floods, drainage floods and river floods. The data about livelihood problems and housing damage was developed using mathematical models by using ordinal logistic regression methodology. The five variables included house style, flood depth, duration, flow velocity, and frequency. These variables were used in the models which estimated housing damage and living problems probability during the floods. Then the future flood scenarios of the household were put into the models. It was found that living problems and housing damage were different among the households even though they were in the same community. This difference was due to the variations in housing style and the flood characteristics of each household. These models could be used to estimate future living problems and housing damage of other low-income settlements. The results could be analyzed and used to design low-income housing that is more resilient to flooding.

Keywords: Damage, Flood, Flooding impact, Low income housing, Scenario.

Introduction

Chiang Mai is an economic region and development center in northern Thailand. It is highly developed and possesses high tourism rates, a strong economy, rapid growth, and investment potential. At present, Chiang Mai's economy is ranked second in Thailand after Bangkok (Thai Chamber of Commerce, 2015). This city's growth has led to a rise in migration of people from surrounding areas to find jobs, which results in increasing numbers and expansion of existing low-income settlements around the city (Thawinpipatkul, 2005). There is interdependence between low-income settlements and cities. The cities promise more jobs and diverse income opportunities, and the low-income settlements are important to the urban economy, especially by providing unskilled labor in various industries (Katz, Kling, & Liebman, 2001; Edelman & Mitra, 2006). The Community Organization Development Institute's survey reveals that there are 132 slums with 25,459 households in Chiang Mai, which ranked third behind Bangkok and Nakhon Ratchasima. This number is predicted to increase in the future (Community Organizations Development Institute, 2011).

In normal situations, low-income people face many intractable housing problems such as overcrowding, poor housing, lack of land tenure, poor infrastructure and public utilities, and flooding due to the vulnerable location (Bagheri, 2012). It can be seen from 10 years ago that Chiang Mai sustained four extreme floods (Department of Disaster Prevention and Mitigation, 2013) that led to housing damage, living problems, and homelessness in various areas especially in low-income settlements (Bourque, Siegel, Kano, & Wood, 2006; Huchzermeyer, 2011). Therefore, they are predicted be prone to more frequent and severe flooding due to climate change impacts in the future (IPCC, 2013). This is consistent with studies of the projected future climate changes in Thailand (Shinawanno, 2010), which found that average annual rainfall is expected to increase in all regions. At the end of the century, it could rise by about 15-25% in terms of distribution areas and rainfall volume during the monsoon season. This means that there is an increased risk of flash floods, which can result in other flood disasters (Djalante & Thomalla, 2012).

This research aimed to predict the risks regarding low-income people's lives, damage to their property, and loss of habitat affected by future climate change in flooding scenarios. These risks were predicted under the terms of existing context and physical location. The results of the research can be used as a basis for preparation of measures to improve the low-income settlements and housing to foster resistance and resilience against future floods. Furthermore, this study's results can be used as basis data for low-income housing policy formulation. In addition, the models can be applied to estimate similar issues for other low-income settlements in the other areas.

Materials and Methods

Three low-income settlements i.e. Bansanku (21households), Samugkeepattana (64 households) and Kampangam (61 households) were selected for this study as shown in Figure 1. These communities have existed for over 10 years and have more than 20 households in each settlement. They are also located in different flood prone areas that have different flood characteristics, i.e. flash flood, drainage flood and river flood. Household geographic information, drainage, and housing style were collected by using a survey, and the data was put into a geographic information system (GIS).

Interviews and observations were included to collect flood information (flood frequency, duration of flood, flood depth and flood flow velocity) and flood impacts (livelihood problem and housing damage) from 2001 to 2015.

Figure 1 Location of the three low-income settlements

The housing damage and livelihood problem models were developed using ordinal logistic regression methodology, which is an extension of the general linear model to ordinal categorical data. Ordinal logistic regression was used to predict the ordinal dependent variable (housing damage) given one or more independent variables (flood characteristics and housing style). In addition, it enabled the researchers to determine which of all the independent variables had statistically significantly affected housing damage and livelihood problems (Pistrika & Jonkman, 2010; Wind, Nierop, Blois, & Kok, 1999). Therefore, these models were used to calculate the probability of housing damage and livelihood problems due to future flood characteristics.

Future flooding scenarios of the three low income settlements were created by using data from future climate projections for Thailand, which were based on dynamic downscaling of global climate change scenarios generated by the ECHAM4 GCM: A2 scenario (Shinawanno, 2010). It was the wettest scenario of all existing research in which the increase in the amount of rainfall and the results were close to the actual amount of rainfall in the study area. A grid area measuring 25x25 km covering the three areas of study (upper Ping River) was chosen, and the rainfall data from two periods 1980-2009 and 2020-2049 was used to calculate percentage change in various return periods of 2, 5, 10, and 25 years. The researchers predicted occurring rainfall in the future as shown in Table 1.

Table 1 One day duration probable maximum rainfall over the areas

Return Periods	ECHAM4 GCM: A2 scenario			Monitoring Stations in the Areas			
	1980-2009 (mm.)	2020-2049 (mm.)	Percentage Change	Samukeepattana and Kampangam		Bansanku	
				1980-2009 (mm.)	2020-2049 (mm.)	1980-2009 (mm.)	2020-2049 (mm.)
2-yrs	52	63	0.21	75.6	90.72	81.8	98.16
5-yrs	89	120	0.34	99.7	134.595	108.2	146.07
10-yrs	133	193	0.45	115.6	167.62	125.6	182.12
25-yrs	228	365	0.6	135.7	217.12	147.6	236.16

Future flooding characteristics in the areas were projected by using the synthetic unit hydrograph of Snyder (equation 1-3) and runoff coefficient (equation 4) of the Yom River in Phrae station (Y.20) that covered the study areas (Royal Irrigation Department, 2014). Runoff volumes (m3/sec) from 1 mm rainfall of each low-income settlement could be seen.

$$t_p = 0.75\, C_t\, (L * L_c)^{0.3} \quad (1)$$
$$q_p = 0.275\, C_p * A / t_p \quad (2)$$
$$t_r = t_p / 5.5 \quad (3)$$
$$CO(\%) = 3.4343 + 0.2343 * RF_{max} \quad (4)$$

where, L is length of the main channel from the outlet to the watershed divide in kilometer.

L_c is length of the main channel from the outlet to the center of gravity of the basin in kilometer.

A is drainage area in square kilometer.

t_p is the time-to-peak discharge in hour

C_p is storage coefficient from 0.56 to 0.69, using 0.60 for this study since they are the slope blends with the general plain.

C_t is coefficient for representation differences in types and locations of streams, generally ranging from 1.8 to 2.2, using 1.8 for this study since they were small areas.

q_p is unit-hydrograph peak discharge in cubic meter per second.

t_r is the time of recession in hour, which is triangular unit hydrograph.

RF is the greatest 1 day rainfall amount in millimeter.

The runoff volumes were calculated as the amount of water expected to flood in the areas according to drainage box culverts related to each low-income settlement location. Their cross-section and drainage capability (m^3/s) reduced to about 60%, which is closest to reality , were determined under the study assumptions, which were based on existing geography and public policy . The runoffs did not include the outside runoff and rainfall, which probably affected the study areas. The results showed the flood depth (meters) and flood duration (hours) to be used as variables to put into the models. By using this data, the probability of housing damage and livelihood problems at future flood characteristics of each household were calculated.

Results

1. Housing styles and geography

The three low-income settlements are located in different geographic areas. Bansanku is located 300.90 meters above the mean sea level (MSL) in a basin-like depression. Samunkeepattana is located in a drainage canal around 307.75 meters above MSL, but it is about 0.75 meters lower than the road and surrounding areas. Kumpangam is located along the Mae Kha canal with an average height of 304.47 meters above MSL. The area in each low-income settlement is at different heights; the contours are shown in Figure 2(A-C) with the dark color representing low-lying areas and the light color representing elevated areas.

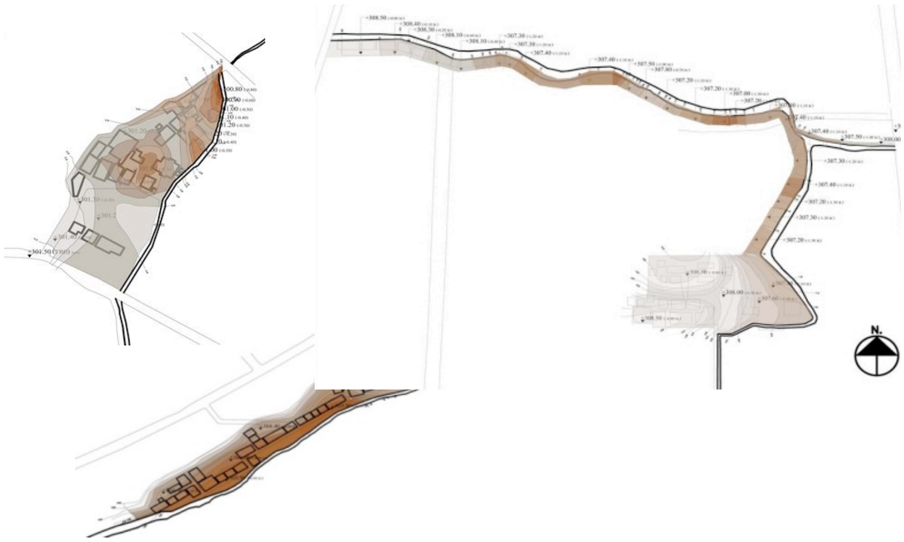


Figure 2 Geography and contour of the 3 low income settlements

(A) Bansanku's geography and contour

(B) Samunkeepattana's geography and contour

(C) Kampangam's geography and contour

The housing styles in the three slums were divided into eight styles (A-H) by house structure, construction materials, and number of floors. Styles A (1 floor), D (1 floor with high space under the house) and G (2 floors) are permanent houses, which refers to a house with strong structure, floors and walls built by reinforced concrete or wood in perfect condition and roofed by double corrugated roofing tiles or galvanized iron sheets as shown in Figure 3(A). Styles B (1 floor), E (1 floor with high space under the house) and H (2 floors) are semi-permanent houses, with structures and floors built from reinforced concrete or wood, walls made from light-weight material such as galvanized iron sheet and plywood, and roofed by double corrugated roofing tiles or galvanized iron sheets as shown in Figure 3(B). A small number of blocks and wood may be used. Styles C (1 floor) and F (1 floor with high space under the house) are non-permanent houses, which refers to a house with a wooden structure, floors and walls made by various materials such as galvanized iron sheets, wood, bamboo sheets or others, and roofed by double corrugated roofing tiles, galvanized iron sheets or other material as shown in Figure 3(C).

(A) (B) (C)

Figure 3 Examples of housing styles
(A) Permanent housing style
(B) Semi-permanent housing style
(C) Non-permanent housing style

From the survey, it was found that Bansanku and Kampangam had various housing styles in terms of functional area, structure and construction materials. Thirty percent of all houses in the two slums were in A style, followed by G and H styles. In Samunkeepattana, most of them were in E style, followed by A and D styles. D and F styles could not be found in Bansanku and D style could not be found in Kampangam as shown in Figure 4.

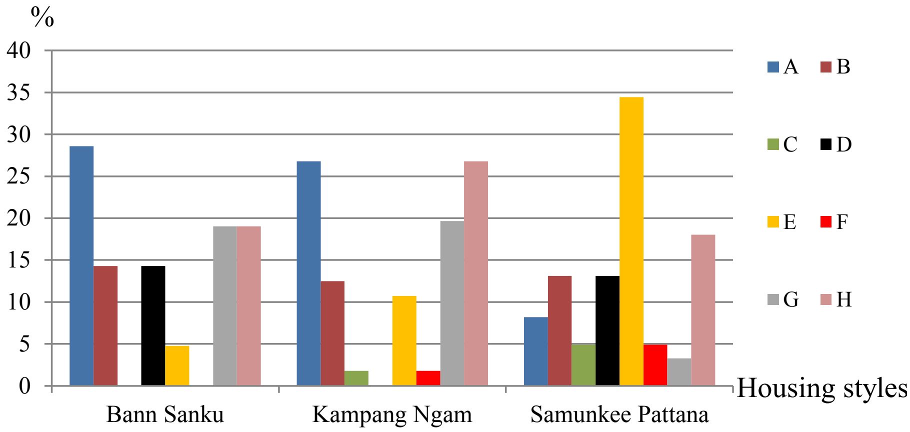


Figure 4 Housing styles in the three low-income settlements

2. Past and future scenarios of flood characteristics

The three communities have different flood characteristics such as flood frequency, duration of flood, flood depth, and flood flow velocity. It was found that Samunkeepattana experienced flash floods, which have high flood level, high flow velocity (>3 m/s), and frequent flooding (>15 time/yr) but short duration (<1 day). It was different from Bansanku, which experienced drainage floods—high flood level (0.7-1.1 m) but low flow velocity (slow-rising flood) and long duration (2-10 days). Kampangam sustained river floods from the Maekha canal; these floods have low flood level (0.5 m), middle flow velocity, frequent flooding and about 2 days flooding (as shown in Table 2). The future scenarios in return periods of 2, 5, 10, 25 years in term of flood duration and flood depth showed that the 2-year return period flood characteristics were not different from the actual floods in each community. If the return periods were 5, 10, 25 years, the flood would still have the same characteristics but with more extreme floods. For velocity flow and flood frequency, the data were taken from the actual information of each community.

Table 2 Past and future scenarios of flood characteristics of three low-income settlements

Community	Year	Flood Depth at Benmark (m)	Flood Duration (days)	Flow Velocity (m/s)	Flood Frequency (number/yr)
Bansanku	Regular flood	0.4	5	1.2	3
	2001	1.4	10	1.2	4
	2006	0.7	10	>1.2-1.5	3
	2011	0.9	6	>1.2-1.5	2
	2-yr return period	0.55	7	>1.2-1.5	4
	5-yr return period	1.24	7	>1.2-1.5	4
	10-yr return period	1.94	7	>1.2-1.5	4
	25-yr return period	3.26	10	>1.2-1.5	4
Kampangam	Regular flood	0.3	3	1.6	5
	2006	0.55	3	>1.6-2.0	4
	2011	0.7	4	1.6	4
	2-yr return period	0.67	2	>1.6-2.0	5
	5-yr return period	0.83	2	>1.6-2.0	5
	10-yr return period	1.11	4	>1.6-2.0	5
	25-yr return period	1.87	3	>1.6-2.0	5
Samunkeep.	Regular flood	0.5	3	3.4	15
	2001	0.65	1	>3.4	10
	2007	1.15	1.5	>3.4	15
	2011	0.7	1	3.4	15
	2-yr return period	0.58	2	>3.4	15
	5-yr return period	0.86	2	>3.4	15
	10-yr return period	2.39	2	>3.4	15
	25-yr return period	6.12	3	>3.4	15

3. Three low-income settlements' risk of flooding

The risks of 146 households from the floods were different depending on housing style and housing location, which is related to flood characteristics in 2001-2015. Therefore, some households were affected and some households were not affected by the floods at the same time. The housing damage was categorized into four levels (0-3) as shown in Table 3. The housing which did not sustain any serious damage (only becoming dirty) was considered at the 0-level. The 1-level damage was architectural damage which involved building materials or architectural components such as moldy doors, windows and walls. The 2-level damage involved structural damage such as columns and beams and could be recovered or repaired. If the houses were destroyed by the floods, it would be considered 3-level damage.

Table 3 Case processing summary of housing damage and living problem

		N	Marginal Percentage
Housing damage level	0	376	72.3%
	1	86	16.5%
	2	43	8.3%
	3	15	2.9%
Living problem level	0	242	46.5%
	1	215	41.3%
	2	63	12.1%
Flow	1	84	16.2%
	2	192	36.9%
	3	244	46.9%
TYPE	A	133	25.6%
	B	72	13.8%
	C	35	6.7%
	D	20	3.8%
	E	69	13.3%
	F	15	2.9%
	G	80	15.4%
	H	96	18.5%
Valid		520	100.0%
Missing		0	
Total		520	

The data in Table 4 shows that flood duration was not significantly related to housing damage. However, this study still used flood duration as a variable in the equation since the literature review found that long flood duration would increase housing damage level . The models fitting information were shown that satisfied as the chi-square test value was 230.076, the degree of freedom equals 12, which had a significant level higher than 0.01, or 99% of the models (Table 5). They were appropriate to be used to predict damage to housing in the future.

Table 4 Housing damage parameter estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Damage = .00]	2.726	.548	24.727	1	.000	1.652	3.801
	[Damage = 1.00]	4.344	.583	55.582	1	.000	3.202	5.486
	[Damage = 2.00]	6.088	.641	90.135	1	.000	4.831	7.344
Location	Dept	3.048	.333	83.846	1	.000	2.396	3.700
	Duration	0.029	.116	1.227	1	.268	-.099	.357
	Fequency	0.058	.112	5.275	1	.022	-.477	-.038
	[Flow=1.00]	0.211	.843	.063	1	.802	-1.863	1.441
	[Flow=2.00]	0.853	.486	3.082	1	.079	-.099	1.806

	[Flow=3.00]	0[a]	.	.	0	.	.	.
	[TYPE=1]	-0.041	.344	.014	1	.906	-.715	.634
	[TYPE=2]	-0.030	.374	.006	1	.936	-.762	.702
	[TYPE=3]	1.809	.549	1.230	1	.267	-.467	1.684
	[TYPE=4]	-0.750	.658	.823	1	.364	-1.886	.693
	[TYPE=5]	-0.302	.406	.554	1	.457	-1.097	.493
	[TYPE=6]	1.425	.616	6.955	1	.008	.417	2.832
	[TYPE=7]	-0.060	.406	3.412	1	.065	-1.545	.046
	[TYPE=8]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Table 5 Model fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	792.779			
Final	562.703	230.076	12	.000

Link function: Logit.

For example, the equations predicted that style A at level 1 flow velocity would probably cause damage levels 0, 1, 2 and 3, as in equations (5)-(8). In the case that style A encountered a different type of flood characteristics, the equations could be used to calculate the probability of housing damage by substituting the variables (X_{1-3}) into them. For other housing styles (B-H), equations could be established as detailed in Table 4. There were 32 equations for predicting housing damage probability.

$$PD_0T_A = 1/(1+EXP(-(2.726-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211)) \quad (5)$$

$$PD_1T_A = 1/(1+EXP(-(4.344-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211))-P_0T_A \quad (6)$$

$$PD_2T_A = 1/(1+EXP(-(6.088-3.048X_1-0.029X_2-0.058X_3-(-0.041)-(0.211))-P_0T_A-P_1T_A \quad (7)$$

$$PD_3T_A = 1- P_0T_A - P_1TA - P_2T_A \quad (8)$$

where, PD_0T_A is the probability of 0 level damage to style A

PD_1T_A is the probability of 1 level damage to style A

PD_2T_A is the probability of 2 level damage to style A

PD_3T_A is the probability of 3 level damage to style A

X_1 is flood depth (meters)

X_2 is duration (days)

X_3 is frequency (number/year)

The data in Table 6 shows that the flood frequency, flow and type of housing was related to living problem levels. The flood duration was only slightly related to them but this study still used it as a variable in the equation since the literature review found that long flood duration also affected to the living during the flood . The living problem model fitting information was shown that satisfied as the chi-square test value was 396.608, the degree of freedom equals (1)-(2), which had a significant level higher than 0.01, or 99% of the models (Table 7), so they were appropriate to predict living problems in the future.

Table 6 Living problem parameter estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Living Problem = 0]	1.137	.430	6.984	1	.008	.294	1.981
	[Living Problem = 1]	5.033	.525	91.951	1	.000	4.004	6.062
Location	Depth	3.226	.325	98.538	1	.000	2.589	3.863
	Duration	.032	.082	.156	1	.693	-.128	.192
	Frequency	-.411	.078	27.583	1	.000	-.565	-.258
	[TYPE = 1]	1.552	.328	22.409	1	.000	.909	2.195
	[TYPE = 2]	1.850	.375	24.360	1	.000	1.115	2.584
	[TYPE = 3]	3.996	.560	50.909	1	.000	2.898	5.094
	[TYPE = 4]	-1.875	.687	7.438	1	.006	-3.222	-.527
	[TYPE = 5]	-.433	.408	1.124	1	.289	-1.233	.367
	[TYPE = 6]	.845	.680	1.542	1	.214	-.489	2.178
	[TYPE = 7]	-.122	.376	.106	1	.744	-.859	.614
	[TYPE = 8]	0^a	.	.	0	.	.	.
	[Flow = 1]	.637	.549	1.347	1	.246	-.439	1.714
	[Flow = 2]	.669	.367	3.320	1	.068	-.051	1.388
	[Flow= 3]	0^a	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Table 7 Model fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	933.960			
Final	537.353	396.608	12	.000

Link function: Logit.

The equations from the data in Table 6 could predict the future living problems probability of each housing style (A-H) at level 0, which would allow the owners to live in their houses during the flood, and at level 1, at which they would experience one or more problems such as toilet problems, cooking problems or utility problems. The level 2 was the most extreme living problems. The owners could not live in their houses during the floods. The equations predicted living problem levels 0-2 of housing style A as shown as equations (9)-(11). In the case that style A encountered different types of flood characteristics, the equations could be used to calculate the probability of living problems by substituting the variables (X_{1-3}) into them. For other housing styles (B-H), equations could be established as detailed in Table 6. There were 24 total equations for predicting future living problems probability.

$$PL_0T_A = 1/(1+EXP(-(1.137-3.226X_1-0.032X_2-(-0.411X_3)-1.552-0.637)) \quad (9)$$

$$PL_1T_A = 1/(1+EXP(-(5.033-3.226X_1-0.032X_2-(-0.411X_3)-1.552-0.637))-P_0T_A \quad (10)$$

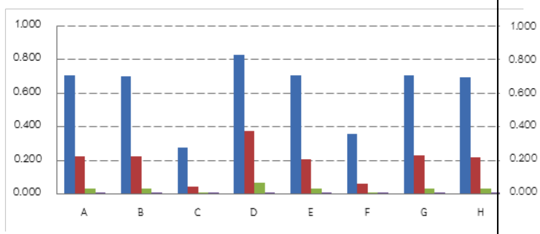
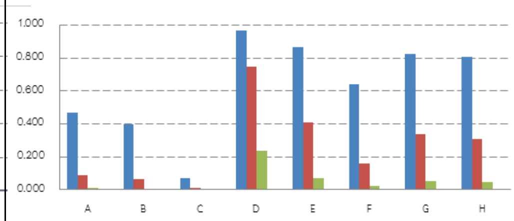
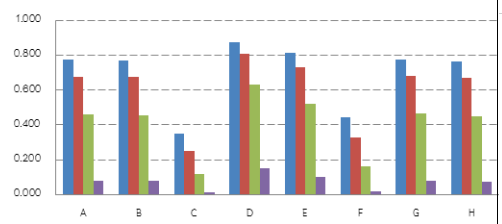
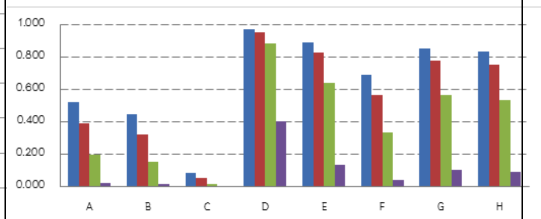
$$PL_2T_A = 1-P_0T_A - P_1T_A \quad (11)$$

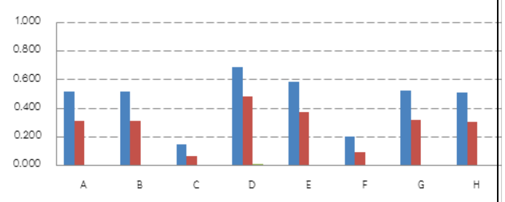
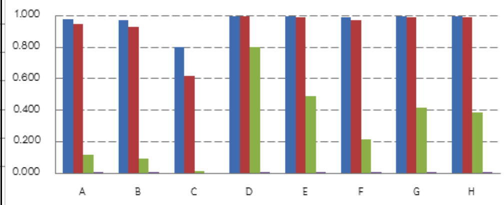
where, PL_0T_A is the probability of 0 level living problem to style A
PL_1T_A is the probability of 1 level living problem to style A
PL_2T_A is the probability of 2 level living problem to style A

The future risk of the household (probability of housing damage and living problem) of the three low-income settlements were predicted by housing style and future flood characteristics at return periods of 2, 5, 10 and 25 years. It was found that probability of non-problem in living (level 0) and non- damage of housing (level 0) would decrease parallel to the number of return period years. Kampangam had the least future risk of probability of both housing damage and living problems when compared to the others. Samukeepatana had more risk of living problems than housing damage and high probability to non-damage of housing in 2- and 5-year return periods. Bansanku had the highest risk during the 5-year return period.

In addition, it was found that C style was not suitable for the future flooding in these areas and the D, E, G and H styles should be chosen for every community. It is seen that high flood levels but short durations (<1 day) would affect living problems more than high flood levels and long durations. The number of floors of the housing was more important for living during the floods than structural and architectural parts, but all components of housing style were related to housing damage level.

Table 8 Future risk of the household of 3 low income settlements

Low Income Settlement	Probability of 0-Level in Living Problem	Probability of 0-Level in Housing Damage
Bansanku		
Kampangam		

Samunk.		

2 year return periods 5 year return periods 10 year return periods 25 year return periods

Discussion and Conclusion

The locations and existing geography of the low-income settlements affected the flooding and flood characteristics which are flood prone areas (Jabeen, Allen, & Johnson, 2010). The projected future flood scenarios of the study areas showed that all communities would experience high flood levels, and the 2- and 5-year return periods of flooding were likely the previous highest level but the 10- and 25-year return periods were very high. This flood changing affected the risk of housing damage and living problems. For example, the people in Bansanku did not suffered from previous floods, but in the future, the risk of flood damage will increase in parallel with the years of return periods. These results could be used for preparing future low-income housing in terms of the number of floors, structure and materials. Communities in the city with flash floods, similar to Samukeepattana’s flood, should be concerned only about living problems since it was for a short duration although the people suffered the greatest impact from frequent, high-level, heavy flooding. The structural part of their houses was affected, so the house structures must be strong. Communities with drainage floods, similar Bansanku’s flood, should be concerned about both living problems and housing damage. Bansanku frequently encountered high-level floods for a long duration, so the owners should prepare the housing with a high space underneath and permanent construction materials to ensure flood resiliency for about 15 days and at an average of more than 2 meters from the ground. In communities with river floods, similar to Kanpangam’s flood, which was slightly damaged and sustained living problem by floods, all housing styles (A-H styles) could be built and only prepared for easy cleaning.

This research determined several limitations. The runoff was only from rainfall in the area—not accumulated water from other areas. In addition, existing geography and other conditions were determined, and the future policy related to drainage management was not included. Therefore, if the existing conditions were changed, the flood characteristics of the three communities would be changed and the risk would be changed, too (DTI, 2004; Land Development Department, 2014). In addition, it could be seen that the future flood scenarios and risk estimations were important before housing design. Some design issues were unnecessary for some communities, but they might be essential for others (Jabeen, Allen, & Johnson, Built-In Resilience: Learning from Grassroots Coping Strategies to Climate Variability, 2010). In addition, the flood details such as flood depth and duration were related to site selection, building structure, material selection, number of floors, building height, and building system. This resulted in cost savings and optimized architectural design for flood resilience in various areas.

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References

Bagheri, M. (2012). The Challenge of Slums: Socio-Economic Disparities. International Journal of Social Science and Humanity, (5) 410-414.

Bourque, L., Siegel, J., Kano, M., & Wood, M. (2006). Handbook of Disaster Research. New York: Springer.

Chatterton, J., Viviattene, C., & Morris, J. (2010). The Costs of the Summer 2007 Floods in England. Bristol: Environment Agency.

Community Organizations Development Institute. (2011). Slums Report: Slums in Northern Areas. Chiang Mai: CODI Northern of Thailand.

Construction Research Division Research. (2011). Housing Standards and the Environment. Bangkok: National Housing Authority of Thailand.

Department of Disaster Prevention and Mitigation. (2013). Floods. Retrieved December 19, 2013, from http://61.19.54.141/yla/Acobat/flood.pdf

Djalante, R., & Thomalla, F. (2012). Disaster risk reduction and climate change adaptation in Indonesia: Institutional challenges and opportunities for integration. International Journal of Disaster Resilience in the Built Environment, (3) 166–80.

Douben, K. (2006). Irrigation and Drainage. Retrieved July 2014, 15, from Characteristics of River Floods and Flooding: A Global Overview: http://dx.doi.org/10.1002/ird.239

DTI. (2004). Foresight Future Flooding. London: Department of Trade and Industry.

Edelman, B., & Mitra, A. (2006). Slum dwellers' access to basic amenities: The role of political contact, its determinants and adverse effects. Review of Urban and Regional Studies, (18) 25-40.

Government Housing Bank: Academic section. (2013). Housing Market and Mortgage in 2012 and Trends in 2013. Retrieved December 8, 2014, from Government Housing Bank: http://www.ghbhomecenter.com/.../download.php?

Huchzermeyer, M. (. (2011). Cities with Slums: From Informal Settlement Eradication to A Right to the City in Africa. Cape Town: University of Cape Town Press.

IPCC. (2013). Fifth Assessment Report: Climate Change 2013: Synthesis Report. Retrieved March 6, 2017, from https://www.ipcc.ch/report/ar5/wg1/

Jabeen, H., Allen, A., & Johnson, C. (2010). Built-in resilience: learning from grassroots coping strategies to climate variability. Environ. Urban., (22) 415–431.

Jabeen, H., Allen, A., & Johnson, C. (2010). Built-In Resilience: Learning from Grassroots Coping Strategies to Climate Variability. Journal of Environment and Urbanization , 415-431.

Jonkman, S., Maaskant, B., Boyd, E., & Levitan, M. (2009). Loss of Life Caused by the Flooding of New Orleans After Hurricane Katrina: Analysis of the Relationship Between Flood Characteristics and Mortality. Risk Analysis, 676-698.

Katz, L., Kling, J., & Liebman, J. (2001). Moving to opportunity in Boston: Early results. Quarterly Journal of Economics, (116) 607-654.

Kreibich, H. (2009). Is Flow Velocity A Significant Parameter in Flood Damage Modelling? International Journal of Natural Hazards and Earth System Sciences, 1679-1692.

Land Development Department. (2014). Knowledge of Soil. Retrieved January 20, 2014, from http://oss101.ldd.go.th

Pardue, J., Moe, W., McInnis, D., Thibodeaux, L., & Valsaraj, K. (2005). Chemical and Microbiological Parameters in New Orleans floodwater Following Hurricane Katrina. Environ. Sci. Technol., 8591-8599.

Patanung, A. (2008). Impact of Flooding. Retrieved July 15, 2014, from https://www.gotoknow.org/posts/215379

Pecharanon, S. (2014). Urban Economics. Bangkok: Kasetsart University Press.

Pistrika, A., & Jonkman, S. (2010). Damage to Residential Buildings Due to Flooding of New Orleans After Hurricane Katrina. International Journal of Natural Hazards and Earth System Sciences, (54) 413–434.

Pistrika, A., & S.N., J. (2009). Damage to residential buildings due to flooding of New Orleans after hurricane Katrina. Natural Hazards, (54) 413-434.

Pornchokchai, S. (2014). The Wrong Development of Slums. Retrieved Jully 13, 2014, from http://www.skyscrapercity.com

Royal Irrigation Department. (2014). Information Systems for Monitoring and Surveillance for Flood Warning. Retrieved January 14, 2014, from http://imine.biz/imine_mixkey/index.php

Shinawanno, S. (2010). Projection of Future Climate Change, the Effects of Regional Climate Models –PRECIS. Bangkok: Center of Excellence for Climate Change Knowledge Management: CCKM.

Slomp, R., Kolen, B., Westera, H., Verweij, J., & Riedstra, D. (2016). Interpreting the impact of flood forecasts by combining policy analysis studies and flood defence. 3rd European Conference on Flood Risk Management. Lyon, France.

Sullivent, E., West, C., Noe, R., Thomas, K., Wallace, L., & Leeb, R. (2006). Nonfatal Injuries Following Hurricane Katrina—New Orleans, Louisiana, 2005. J Safety Res, 213–217.

Thai Chamber of Commerce. (2015). Potentiality and Economy of Chiang Mai. Retrieved January 13, 2015, from http://www.thaichamber.org

Thawinpipatkul, D. (2005). The Process of Urbanization and Social Change in Developing Countries. Bangkok: Chulalongkorn University Press.

United Nations Habitat. (2003). The Challenge of Slums: Global Report on Human Settlements. United Nations Human Settlements Programme. London: Earthscan Publications.

United Nations Habitat. (2009). Planning Sustainable Cities: Global Report on Human Settlements. United Nations Human Settlements Programme. London: Earthscan Publications.

Wind, H., Nierop, T., Blois, C., & Kok, J. (1999). Analysis of flood damages from the 1993 and 1995. Water Resources Research, (35) 3459-3466.

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