The Use of Spatial Data to Analyze Flood Hazard Areas and Senior Households at the Community Level

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Abstract

Thailand is vulnerable to natural water related disasters, accounting for 25 percent of total deaths among persons aged 60 years old or older. The lack of disaster preparation has further caused unexpected impacts. This study focused on Salaya Sub-district, which is the most vulnerable, and accounted for 60 per cent of all households in Phutthamonthon District. The study is aimed at evaluating flood hazard areas based on the density of senior households in Phutthamonthon District, Nakhon Pathom Province. The use of Geographic Information System with Potential Surface Analysis and overlay techniques for prioritizing the areas based on potential impact and number of senior households in the hazard-prone areas. The results show that most senior households fell into "moderate" flood zones accounting for 47 percent of the total households followed by "high" zones with 27 households (31percent) approximately.

Keywords: Flood Hazard Assessment, Senior Household

Introduction

The world is facing climate change and will witness natural disasters resulting from it every year such as floods, storms, earthquakes, volcanic eruptions and landslides. Asia is one of the regions whose population has been affected hardest by natural disasters (86.3 percent of the population affected by disasters worldwide) (Centre for Research on the Epidemiology of Disasters, 2011). In 2010, an estimated 524 million people—8 percent of the world's population—would be 65 years or older. By 2050, this number is expected to nearly triple to about 1.5 billion, representing 16 percent of the world's population. Between 2010 and 2050, the number of older people in less developed countries is projected to increase more than 250 percent, compared with a 71 percent increase in developed countries (World Health Organization, 2011). By then, there will be more older people than children - a turning point in human history. As a result, the elderly will be increasingly in need of a range of demand for health care and social services which are presently limited or poorly funded, particularly in crises situations.

Thailand, located in the Southeastern region of Asia, can be divided into 25 river basins. Its average annual rainfall is about 1,700 mm (Office of the National Water Resources Committee, 2000). Thailand faces several natural disasters each year in the form of floods, drought and landslide (Department of Disaster Prevention and Mitigation, Ministry of Interior, 2007). Based on geographical characteristics, there are different disaster impacts in each province. For example, the Central Plain is a low-basin area where flooding normally occurs when the water level exceeds the river's holding capacity. The flooding may last a week or more, or even months. The North and Northeast has high mountains, valleys, and plateaus where flash floods can take place under several conditions. In the South, there are coastal areas where floods are common (Office of the National Water Resources Committee, 2000).

The response of the Thai Government to natural disasters in the past was based on a reactive approach, especially in dealing with rescue operations and rehabilitation. Several of agencies involves in water resources development, but there are not sufficiently clear guidelines. Despite this, the related database has been unsystematic and outdated, while the laws and regulations related to water resources management are obsolete. Furthermore, the country has not produced any master plan in water resources management in river basins (Tingsanchali, 2005).

In 2011, Thailand was hit by severe floods. The World Bank estimated that this particular disaster ranked as the world's fourth costliest disaster. The others were the 2011 earthquake and tsunami in Japan, 1995 Kobe earthquake and Hurricane Katrina in 2005 (Centre for Research on the Epidemiology of Disasters, 2011). The lack of knowledge and perception about flood risks and its prevention may have contributed to this carnage.

After 2011, the Thai government began to pay more attention to water resources management. The government focused on the principles of proactive disaster management (Proactive Approach) and set up a strategic committee to draft the long- and short-term flood prevention plans. In addition, a flood mitigation fund was set up by the government to upgrade its water infrastructure including a flood management system and a reconstructed sophisticated institution, which acts as a single command unit under the Prime Minister's Office based on the concept of Community-Based Disaster Risk Reduction Approach. This approach aims to enhance the capacity of local people and the government by strengthening capacity and motivation among people at the community level through participatory methods (United Nations Centre for Regional Development (UNCRD), 2004).

Although the government and non-government agencies had invested a lot of resources in disaster preparedness for risk reduction, there have not been major flood disasters since 2011 to test whether this approach really works. There is a perception that when manmade preventable disasters such as riverbank levees, dams are built, disaster is completely preventable. In addition, most people believe that if a major flood disaster strike very hard, no major flood disaster will occur for a long time after that. These are perceptions and myths that people tend to have toward disaster preparedness actions (Motoyoshi, 2006).

Besides, as there is an increasing number of nuclear families, a decline in conventional communities, and a trend for elderly people to live alone, local communities are not prepared for disasters. An increase in number of buildings due to population growth and development, may also contribute to the severity of flood-related disasters (Middelmann, 2002). Therefore, it is important to be aware of flood risks and understand how the residential areas may be affected. It is also important to develop a disaster preparedness plan to manage the aftermath of a disaster as Thailand has become an aging society.

During a crisis, the elderly is among the most vulnerable groups as they face physical difficulties, namely to move quickly to safer areas. The particular important groups are the elderly who live alone, those in households with only elderly member, the lower-income elderly and the elderly without close relatives or a social network to help them. The difficulty is compounded if the person has a chronic condition. Many elderly also suffer from fragile emotional health and seek comfort in familiar locations and it is hard for them to adapt readily to new surroundings. In 2004, a freak Tsunami devastated parts of coastal Sumatra and Thailand's Andaman sea coast. Among the Thai casualties, nearly one in 10 were elderly (Issarapakdee, 2006). In the 2011 mega-floods, there were elderly casualties in every region of the country. A survey found that 61 percent of the elderly in Ayuthaya Province said they never considered evacuating and preferred to stay at home in time of floods (Poromyen, 2012).

The Thai government chose to address the overall problem by centralizing flood monitoring and allocating additional flood-relief financial support to the affected provinces (World Bank, 2012). However, there was no specific response, especially for households with older people with limited mobility, chronic illness and stress. Thus, the senior citizens are particularly vulnerable to harm in the event of disaster. Thus, all the relevant agencies should have adequate data which can contribute to disaster response plans, including specific sections and guidelines on how to assist the elderly.

The selected area for this study is Salaya Sub-district in Phutthamonthon District of Nakhon Pathom Province. It is located in the Central River Basin which is slightly above sea level, meaning that the slope of river basin from the west to the east and the area's height of Nakhon Pathom do not exceed 10 meters. Such a geographical feature -slightly higher than the sea level - means that settlers in this area have experienced flooding over many generations. In 2011, Salaya was hit the most by flooding in Nakhon Pathom Province with different degrees of impact faced by the local residents. Phutthamonthon District is one of the seven districts in Nakhon Pathom Province which was directly affected by floods. The affected areas include 18 villages in three sub-districts: Salaya, Mahasawat, and Klong Yong. When taking the number of households affected by the flood into account, Salaya was mostly affected as its households accounted for 60 percent of all households in Phutthamonthon District (Department of Disaster Prevention and Mitigation, Ministry of Interior, 2011). Almost half of the elderly faced crisis at the average level of flood -1.5-2.0 meters -and the average period of flooding was 45 to 60 days. It was reported in the past, the elderly did not want to abandon their homes, even temporarily (Chuanwan et al., 2014)

The Civil Registration data for Salaya of Phuttamonthon District as at end March 2009 showed a total population of 11,813, including 5,165 males and 6,548 females, living in 4,072 households. About 8.4% of Salaya Sub-district's population is considered elderly has (aged 65 years or older). Two-third (68.0 percent) of the elderly in Salaya lived with a child, 5.2 percent lived with a grandchild, 14.4 percent lived with another elderly person(s), 8.2 percent lived alone while 4.1 percent lived with other relatives. Nearly all (96.9 percent) had lived in the home community for five years or more and had never considered moving elsewhere (Siwilai, 2011).

This study is aimed at analyzing flood hazard areas and senior households in Phutthamonthon District, Nakhon Pathom Province. Geographic Information System (GIS) is applied with Potential Surface Analysis (PSA) techniques, the data from the survey of the Management and Preparation for Disaster of Vulnerable People Project funded by the Thailand Foundation Fund were overlaid on flood hazard areas for assessing the number of at-risk senior households based on hazards areas.

The results provide an understanding of the level of hazard, and this information could the relevant authorities to come up with appropriate plan and assistance including health services as well as economic and social support. It can also help local admirations to conduct both short and long term interventions options and formulate appropriate approaches or policies to reduce the risk from future flooding in the community. Additionally, these findings of this study may also help improve the efficiency of risk management, especially in the preparation process.

Methods and Materials

In Thailand, Geographic Information System (GIS) is used in conjunction with the Potential Surface Analysis (PSA) and Overlay techniques to assess areas that are at risk of disaster as well as develop maps that indicate the level of severity and risk of potential damages and effects on the population. This may enhance efficacy in correct, suitable, and efficient preparedness for disasters (Chumriang, 2008; Chatputi and Intarat, 2012). Potential Surface Analysis (PSA) is a technique for assessing the potential areas for development of each activity systematically by easily identifying potential areas for activities. It also shows hypothetical results and purposes. The PSA helps in identifying suitable locations for activities. Weighting scores are given to each factor according to its level of importance, and values were given based on its capacity to serve the goals of the tasks (Pattanakiat, 2002). The calculation formula is as follows:

$(S) = (R_1 \text{ x } W_1) + (R_2 \text{ x } W_2) + \ldots + (Rn \text{ x} Wn)$

When: S = Suitability;

R = Value of each overlapping factors

W = Weighting score of each factor used in the average

N = Number of factors used in the analysis

This study analyzed flood-hazard areas by using GIS and PSA, and delineated the senior households based on hazard areas by using data from the survey of the Management and Preparation for Disaster of Vulnerable People Project funded by the Thailand Foundation Fund. It used quantitative research to collect data among people aged 60 years and above in Phutthamonthon District, Nakhon Pathom Province. Data from the survey was linked with spatial data utilizing Global Positioning System (GPS) technology in order to develop preparation plans for the study area and household there to cope with potential disasters.

To analyze flood-hazard areas, according to Dhanarun and Amonsanguansin (2010), the main process of PSA is as follows.

1) Selection determinants factor of flooding

Nine factors contribute to floods hazard in Thailand: rainfall, slope, altitude from sea level, water density, water obstruction, watershed area size, land cover use, soil drainage capacity, and flood history (Office of Natural Resources and Environmental Policy and Planning, 1998). To determine the relevant factors of flooding, each factor was given a score by panel of specialists from government agencies. The selection for determining factors is as important step. The selected factor in this study are based on specialists. The six specialists from the Central Region Irrigation Hydrology Center, the Department of Public Works and Town and Country Planning (DPT), the Thai Meteorological Department (TMD), the Department of Disaster Prevention and Mitigation (DDPM), the Office of Natural Resources and Environmental Policy and Planning (ONEP), and Salaya Municipality Office were determinants the factor of flooding. Three factors —rainfall, watershed area size and slope—were excluded for the reason that the size of study area is small and, thus, does not affect the formation of water masses in the area. Hence, the quantity of the rainfall does not directly affect flooding in this area. Similarly, given that it is a plain area, the size of sub-watersheds as well as slope do not have much impact on flooding. Altitude from sea level is then taken into consideration.

2) Spatial data preparation

In the analysis, all data selected have to be standardized and stored in Geographic Information System requirement and the same mapping scale. The spatial data sources are the secondary data from government and non-government organizations. The province boundaries were taken from the Department of Provincial Administration (DOPA). The watershed boundary and watersheds with density were provided by the Office of Natural Resources and Environmental Policy and Planning (ONEP). The soil and land use covering type data obtained from Land Development Department (LDD). The transportation layers were provided by the Department of Highways (DOH). The flood history were obtained from spatial information of flooding provided by the Geo-Informatics and Space Technology Development Agency (GISTDA).

3) Weighting and rating factors of flood causes

A weighting score was given to each factor. The more important the factor was, the higher the weighting score. Weighting scores were all above 0 (zero).

The rankings, in terms of the level of importance of factors, were rated concerning the severity of each factor that causes flooding, and ranges from one to four. The rank is defined as follows: rank 1 is assigned the value of the factor has the least relevant factors of flooding, rank 2 and rank 3 is assigned the value of the factor has more relevant factors of flooding, and rank 4 is assigned to the value of the factor has the most relevant factors of flooding.

The selected factors were processed by Geographic Information System software. The rating score of the severity and the potentiality of factors is the determination of the level of relevance of elements or rank of the main factors by considering the correlation ratio in percentage. The value of factors that are not correlated or do not have potentiality is 0 (zero). The value starts from the lowest at 1 and increases to the highest at 100 for factors that are most correlated. Rating values were identified by experts from relevant organizations. In this study, the weighting and rating scores from six experts were assigned to each factor.

Data Manipulation is calculated process by the potential equation. The equation below generates the scores after data analysis and rating:

$$S = (R_1W_1) + (R_2W_2) + (R_3W_3) + (R_4W_4) + (R_5W_5) + (R_6W_6)$$

When: S = Total score of flood factor

R_1 = Rating score of flood history

W_1 = Weighting score of flood history

R_2 = Rating score of water density

W_2 = Weighting score of water density

R_3 = Rating score of obstruction

W_3 = Weighting score of obstruction

R_4 = Rating score of sea level

W_4 = Weighting score of sea level

R_5 = Rating score of soil drainage capacity

W_5 = Weighting score of soil drainage capacity

R_6 = Rating score of land cover use

W_6 = Weighting score of land cover use

To identify the proper level of flood factor, the total score of flooding factor (S value) was distributed into the proper level of the area. Standard deviation was used to define the range. The total score was classified into four ranks of risks: very low, low, moderate and high.

4) Data Visualization on map

The results of analysis were visualized on a representative map scale of 1:50,000. The area with highest risk is displayed in red, the ones with moderate, low and lowest risk are in orange, light green and dark green respectively.

Results

With approaching of Potential Surface Analysis method, the rankings are evaluated by six factors, including the flood history, water density, water obstruction, altitude from sea level, soil drainage type and land cover use. The result are shown in Table 1 below:

Table 1 Selected six factors with weighting scores and rating scores

Factors	Weighting Score	Factor Condition	Rating Score
Flood History	6	Flooded ≥ 3 years ago	4
		Flooded ≥ 2 years ago	4
		Flood History	3
		Never Flooded	2

Table 1 (Cont.)

Factors	Weighting Score	Factor Condition	Rating Score
Watershed Density	5	0.1 – 0.35 km. / km^2	2
		0.36 – 0.70 km. / km^2	2
		0.71 – 1.00 km. / km^2	2
		> 1.00 km. / km^2	3
Water Obstruction	4	> 0.60 km. / km^2	3
		0.41 – 0.60 km. / km^2	2
		0.21 – 0.40 km. / km^2	2
		0.00 – 0.20 km. / km^2	2
Sea Level	3	< 2.75 m.	4
		2.75 – 7.25 m.	3
		> 7.25 m.	2
Soil Drainage Type	2	Draining very Low	4
		Draining Low	3
		Draining Moderate	2
		Draining High	2
Land Cover Use	1	Rice Fields	4
		Farm Plants	2
		Perennials, Fruit Trees	2

The scores from the potential equation (S) were analyzed by Geographic Information System software. The use of Geographic Information System application is the process of overlaying of the data according to the criteria were applied to determine as specified in the objectives of study. The calculated scores are classified into four ranks of flood-hazard area by using the analysis of standard deviation. The red color indicates the high index of flood-hazard area, the orange represents moderate hazard area, green represents low hazard area and the dark green represents very low hazard area. The results of the flood hazard area and the percentages of classes, in relation to study area, are shown in Table 2 and Figure 1.

Table 2 Flood-hazard level by area and proportion at the study area

Level	Area (Rai)	Percent (%)
Very Low	862.5	5.5
Low	2,675	17.0
Moderate	6,531.25	41.6
High	5,612.5	35.9
Total	**15,681.25**	**100.0**

From the Table 2, the result of analysis are presented that the very-low flood-hazard area covers 862.5 Rai or 5.5 percent of total area. The low flood-hazard area covers 2 ,675 Rai or 17 percent, the moderate are mostly flood-hazard area, and the other of 5,612.5 Rai or 35.9 percent are the high flood-hazard area. To assess the number of at-risk senior households based on criteria, data from the Survey of Management and Preparation for Disaster of Vulnerable People in 2012 were overlain on flood-hazard levels. The results indicate that approximately half of senior households fall into "moderate" flood hazard zones for 47 percent of the total households followed by "high" zones with 27 households (31 percent) approximately, whereas 19 senior households (22 percent) are located in "low" zones. There are no senior households that fall into "very low" zones, as shown in Table 3. The results from the analysis are shown in Figures 1 and Table 2.

Table 3 The number of senior households by hazard level and proportion

Hazard Level	Number	Percent (%)
Very Low	0	0
Low	19	22
Moderate	40	47
High	27	31
Total	**86**	**100**

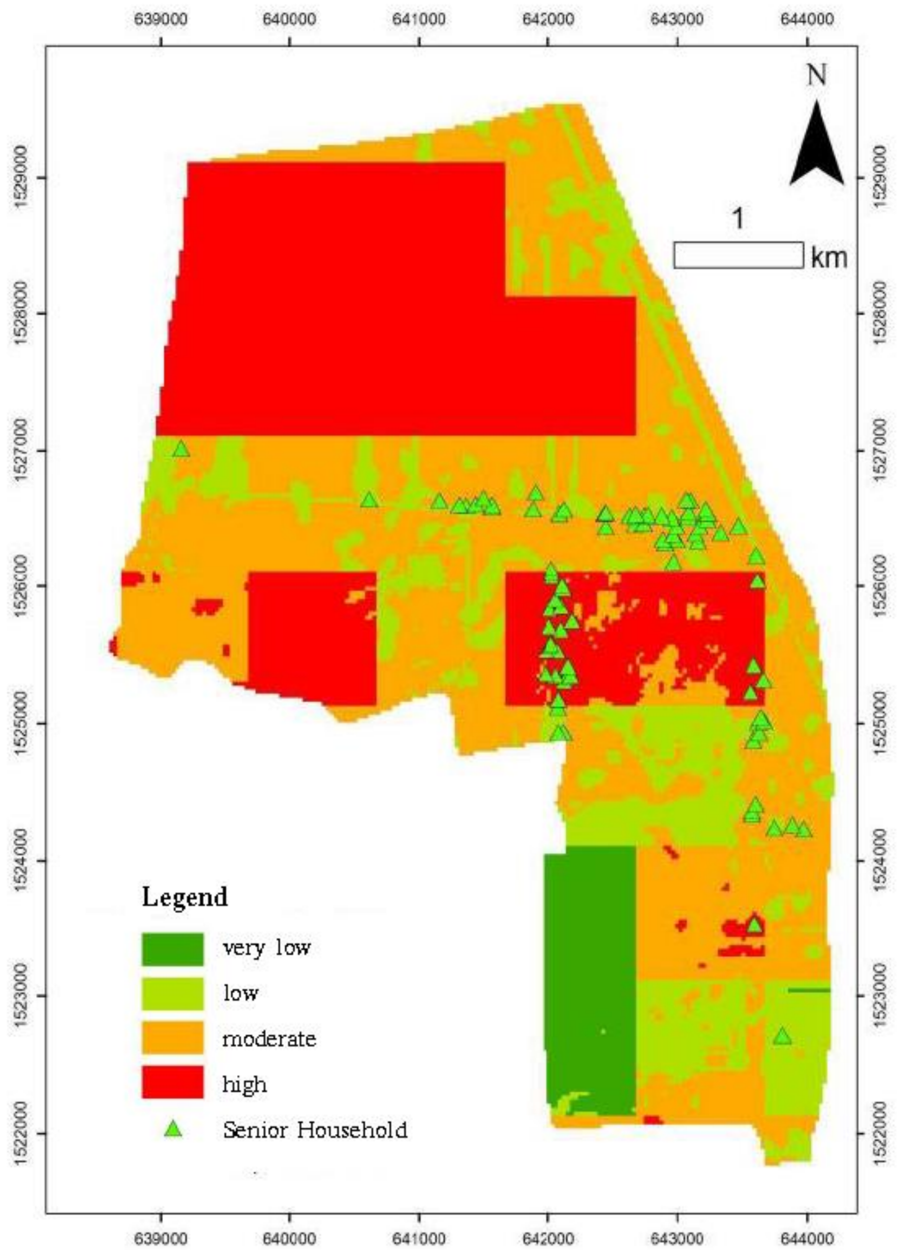

Figure 1 Flood-hazard map with senior household density on a scale of 1:50,000

Conclusions and Suggestions

This study is presented the results evidence of the application of the mixed Geographic Information System and Potential Surface Analysis techniques to achieve specific research objectives. It is concluded that the high flood-hazard area covers 5,612.5 Rai or 35.9 percent and 6,531.25 Rai or 41.6 percent for moderate, the very-low flood-hazard area covers approximately 862.5 Rai or 5.5 percent and the low flood-hazard area covers 2,675 Rai or 17 percent. The methodology considers to assess the number of senior households with defined zones of flood hazard areas, data from the Survey of Management and Preparation for Disaster of Vulnerable People in 2012 were overlaid on flood-hazard levels. The results indicate that around half of senior households—40 households or 47 percent- are located in "moderate" flood hazard zones. The "high" flood hazard zones contain 27 households (31 percent), whereas 19 senior households (22 percent) are located in "low" zones. There are no senior households living in the "very low" zones.

The results show the overall flood hazards areas. The findings can be used to prioritize the area based on potential impact and number of senior households in the hazard-prone areas which must be taken into consideration by decision makers to avoid settlement in flood prone areas. In addition, delineating the senior households provide a map which indicates community needs at different levels of disaster response. The decision makers can use this map as a planning tool during emergency when there is an urgent demand for flood mitigation efforts in the area. For example, the data could be used to target 'hot spots' that require assistance or the elderly who are at risk, as well as to identify where impact-reduction strategies should be implemented.

In this study, the results are based on Geographic Information System and Potential Surface Analysis techniques by determining the suitable areas by the parameters associated with the physical criteria and the rating values utilizing specialist-identified Spatial Multi-Criteria Decision-Making Analysis. The rating values illustrate the potential level of the area which is at risk of flooding. Using Geographic Information System to overlay data and Potential Surface Analysis allows accuracy in identifying geographic coordinates and rating value calculation. It is also quicker, more convenient, and more cost-effective for the planning of future activities compared with field visits and surveying which require more time and a larger budget allocation.

However, the use of geographic information in this area has several limitations. The geographic information gathered from each organization has different scaling. Data had to be converted to the same scaling before the analysis. Criteria for rating values and the weighting scores of each factor taken into consideration is not fixed, but depending on the purpose of the analysis and the analysts themselves. The analysts must be unbiased as well as open to discussion with experts in geography, environment, and city planning which are related to each factor to help identify the rating values and weighting scores. Given the restriction on time, the rating values and weighting scores were then co-identified by a group of experts. In addition, this study only focused on the physical factors, and not economic, social, and other aspects that are important to the area development as well. Regardless, social and economic factors as well as policy plans related to the studied area appear to be too complex to be converted into geographical information. They are also too complicated to be analyzed by rating values and weighting scores. Another limitation in this study is the application of the results to the field survey to monitor the benefit from land use. In the future, when the geographical information technology is more developed and more convenient to use, further studies could be done by applying this technology to the policy-based information which may be converted to spatial data.

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