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Flood Hazard Mapping and Flood Preparedness Literacy of the Elderly Population Residing in Bangkok, Thailand

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Abstract: This research aimed at assessing flood hazard areas and flood literacy of the elderly population in Bangkok, Thailand and analyzing their flood preparedness through SWOT analysis. Expert interviews and a community survey were conducted. Using the analytic hierarchy process (AHP) and GIS technique, the results indicated that land-use, drainage density, and annual maximum rainfall were the most heavily weighted factors in flood hazard mapping in Bangkok. About half (50.32%) of Bangkok's total area was defined as high flood hazard area. A total of 736 questionnaires were distributed in flood-prone areas and in the areas with the highest percentage of elderly population. The results of both SWOT and survey analysis found that many senior citizens have low digital and media literacy and limited experience in using information technology for flood preparedness. Lack of integration of disaster risk reduction and aging population policy, ineffective warning system, and lack of access to disaster preparedness training were the key barriers in reducing vulnerability to flood hazard. The survey revealed that the majority of elderly respondents (75%) have neither used online applications for their flood hazard management both before and during flood disaster nor shared/communicated information via online platforms. Some respondents (13%) used Facebook and Line applications to obtain information before a flood event. Very few of the elderly respondents (<2%) accessed the national/provincial web-based platform to find out flood-related information. Almost all respondents, especially who are living in high-risk flood zones, had never participated in the community training of flood preparedness and management. Therefore, effective strategies in enhancing social engagement of the elderly and their literacy skills in flood risk preparedness and management are urgently needed.

Keywords: Bangkok; elderly; hazard; flood; literacy; Thailand

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1. Introduction

Global climate change tends to intensify the water cycle, potentially leading to an increase in both severity and magnitude of extreme precipitation events and flood risk around the world. According to the sixth assessment of the Intergovernmental Panel on Climate Change report [1], even if the critical threshold of 1.5 °C global warming could be limited, there will be an increased chance of some extreme weather and climate events unprecedented in the observation record. As the most devasting natural disaster globally, flooding has a large variety of social consequences for both individuals and communities that span across space and time [2]. Although changes in climate are expected to have adverse effects on both ecosystems and the well-being of human communities, certain groups of people will likely face greater challenges than others. More specifically, the elderly population is the age group most vulnerable to climate change induced extreme weather events and flood risk due to their poor health and functional limitations (i.e., lower sensory ability and greater susceptibility to environmental stress), as well as the burden of their comorbidities [3].

Southeast Asia is considered one of the world's most vulnerable regions to climate change and one of the most flood-prone areas [4,5]. In Thailand, the World Bank [6] revealed that the unprecedented flood disaster in 2011 was the fifth most costly catastrophe worldwide between 1995 and 2011. The Global Climate Risk Index 2021 [7] reported that Thailand has been ranked ninth on a list of countries that were most affected by extreme weather events during the period 2000–2019. It is also important to highlight that Thailand has the third most rapidly aging population aged 60 years or older in the world [8], with 13.4 million or approximately 20% of the total population. The percentage share of the elderly in Thailand is projected to rise significantly from 20% in 2019 to 35.8% in 2050. Regarding the Sendai Framework for Disaster Risk Reduction (2015–2030), disaster risk management should be based on understanding disaster risks in all dimensions (i.e., hazard characteristic, exposure, and vulnerability of persons). Moreover, disaster risk reduction and prevention strategies should also be promoted to enhance the socio-economic, health, and cultural resilience of persons, communities, and countries. In building community resilience, it becomes apparent that the elderly population may be physically and emotionally less resilient in coping with the effects of extreme climate events and disasters than the rest of the population [9]. There are various techniques designed and applied to increase awareness of flood preparedness among the public. For instance, Arrighi et al. [10] performed an integrated analysis of risk of flooding, hydraulics, transport accessibility, and human safety to explore the implications of disaster emergency routes. Accessibility issues (i.e., risk to residents, impact to pedestrians and parked vehicles) and scenario-based analyses focusing on safety issues were modelled to assess urban resilience. Further, supporting the development of a shared understanding of flood hazards amongst local community stakeholders is considered one of the ultimate goals of flood resilience and risk reduction. A study by Costabile et al. [11] generated flood maps with the combination of 2D flood simulations and 3D visualization techniques as a new approach for flood risk communication and perceptions.

Despite its growing importance, there is a lack of updated information and mapping of flood hazards of the capital city of Thailand. There is also limited research on the elderly people's risk perception, risk communication, and preparedness for extreme climate and disaster events. Moreover, less is known about the influence of flood risk literacy on the elderly and their flood management decision making [12], especially in Thailand's context. Some studies have only focused on the health impact of climate and natural disasters in elderly adults [13–15]. A few studies have carried out research to understand how older adults can adapt to climatic change that might be affected by changes to family networks and migration [16]. To ensure social equality in flood resilience, the ultimate goal of this research is to expand the database to address the gap in understanding the potential challenges faced by the elderly in flood disasters, for both reducing their exposure and vulnerabilities and strengthening their capacity to deal with flood risk in their community. Therefore, the overall aim of this study was to define flood hazard areas and also assess the current situations of flood literacy of the elderly respondents who are living in flood hazard areas of Bangkok, Thailand. Specific objectives were designed to define flood hazards areas to analyze strengths, weaknesses, opportunities, and threats (SWOT) of flood perception and related preparedness actions of the elderly population in Bangkok, to explore their perceptions of flood hazards, and also to investigate types of sources of flood information. The following research questions were consequently addressed: (i) what is the distribution of flood hazards in Bangkok; (ii) what are the strengths, weaknesses, opportunities, threats, and related factors affecting flood literacy, perception, and preparedness actions of the elderly adults; (iii) how does the elderly perceive flood hazards in their community; (iv) what are the sources of online media and information on flood preparedness the elderly respondents are familiar with? Key practical issues in strengthening flood perception in the elderly and their coping abilities to flood events were also provided. Ultimately, the outcomes of this study can be used effectively in the event of an urban flood disaster by providing first-hand information on the degree of impact expected based on an updated

flood hazard map of Bangkok, Thailand. A greater understanding of the key drivers and barriers that affect flood risk perception and preparedness literacy can help local authorities and related stakeholders improve responsiveness, efficiency, and readiness to build an integrated and open access system for engagement in flood protective behaviors, especially among the aging population.

2. Materials and Methods

2.1. Research Case Study

As one of the fastest aging countries in the world, and the capital as the most populous city of Thailand, Bangkok was selected as the research case study. Bangkok is recognized as the economic center of Thailand, dominating the economic development of the country. Geographically, Bangkok is also located in the central region of Thailand (Figure 1) along the Chao Phraya River, leading to the risk of floods in the downstream river basin. In terms of flood hazard management, each local government of Bangkok and has its own direct responsibilities to cope with flood disaster.

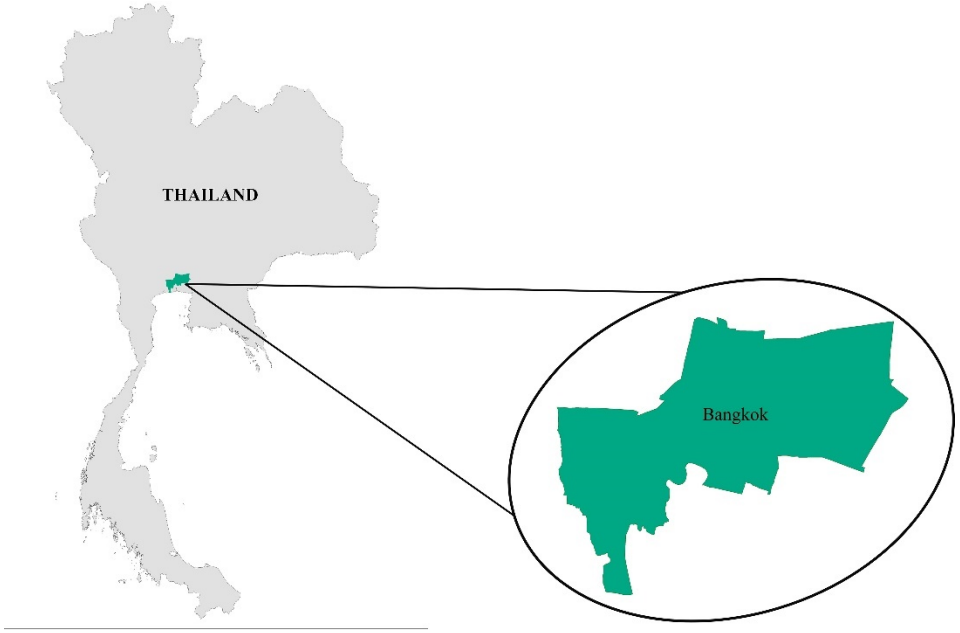

Figure 1. Research case study, Bangkok, Thailand.

2.2. Flood Hazard Assessment

Bangkok's flood hazard map was conducted by applying the combination of Analytic Hierarchy process and Geographic Information System (AHP-GIS). By using ArcGIS 9.3, the overlay operation was applied to combine the characteristics of the following eight climatic, geological, and hydrological factors into the flood hazard areas (Figure 2): annual maximum rainfall, past flood experiences, sea level rise, land subsidence, land-use types, drainage density, road density, and slope of the area. Each thematic layer was combined by the weighting approach, in which the weighted averages of continuous criteria are consequently standardized to a weighted average. By using Equation (1), the final flood hazard areas based on the overlay AHP-GIS technique were obtained from the sum of the rate multiplied by the weights of each factor related to flood hazard. Flood hazard level was classified as high, medium, and low. As noted, each district of Bangkok is managed by a district director and has its own direct responsibilities to cope with flood disaster.

$$H = \sum_{i=1}^{n} W_i \times X_i \quad (1)$$

where H is flood hazard area;

n is the number of the factors related to flood hazard;

W_i is the weight of each individual factor$_i$ related to flood hazard;

X_i is the rating of each individual factor$_i$ related to flood hazard.

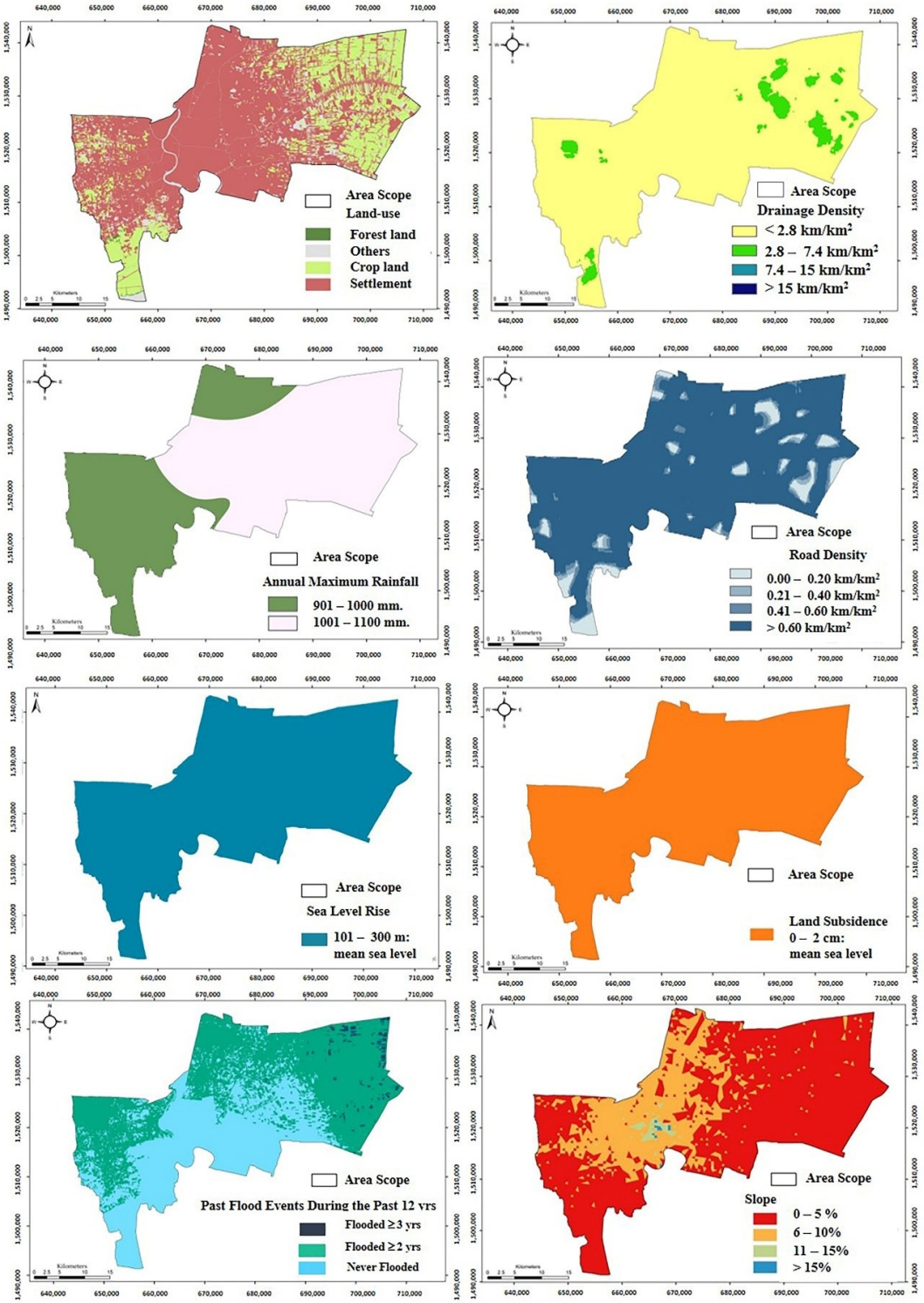

Figure 2. Eight thematic layer factors used for flood hazard analysis in Bangkok, Thailand.

In the AHP-GIS technique, the weights of each factor related to flood hazards in Bangkok were evaluated by the experts' judgment (n = 9), including those of representatives from the Bangkok Metropolitan Administration (BMA), Department of Disaster Prevention

and Mitigation, Department of Groundwater Resources, Water Resource Department, Land Development Department, Thai Meteorological Department, Hydrographic Department, Department of City Planning and Urban Development of BMA, and Office of Natural Resources and Environmental Policy and Planning. By the pairwise comparison method, all experts were asked to rate the alternative of each flood hazard factor between 1/9 to 9, ranging from less important to the most important variables. In the AHP technique, the weighting coefficients of each factor were consequently computed using the pairwise comparison matrix (Equation (2)). All numerical values of the experts' preferences in pairwise comparison were normalized and summed to 1. In the last step, the normalized values were then averaged across the rows of comparison matrix to provide the relative importance weight for each flood hazard factor [17].

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{ij} \cdots & a_{1n} \\ 1/a_{ij} & 1 & a_{2n} \\ 1/a_{1n} & 1/a_{2n} & 1 \end{bmatrix} \quad (2)$$

where $A = [aij]$ is a representation of the expert's preference for one flood hazard factor over another compared to alternative aij and all comparisons $i,j = 1, 2, \ldots, n$.

Further, the consistency ratio (CR) and the consistency index (CI) were computed (Equations (3) and (4)) to avoid any incidental judgment of the experts in the pairwise comparison matrix. The acceptable value of CR is equal to (or even less than) 10% (0.1).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

where λmax is the largest eigenvalue of the pairwise comparison matrix.

n is the number of flood hazard factors.

$$CR = \frac{CI}{RI} \quad (4)$$

where CI is the consistency index.

RI is a random consistency index. The RI of 1.41 was selected for the eight factors [17].

2.3. SWOT Analysis and Expert Interviews

In disaster risk and water management research, some scholars have applied a SWOT analysis for better understanding of flood disaster management plan strengths, weaknesses, opportunities, and threats [18]. For instance, a SWOT analysis was performed for flood management in the southeast of Iran [19] and urban water management in China [20]. Further, a study of Al-Hussain et al. [21] conducted a SWOT for vulnerability assessment of flood and drought in the river basin in Bangladesh. In this study, to better understand policies or management strategies which engage the older people in flood risk management, SWOT analysis was also conducted based on expert interviews (n = 9), including those of representatives from the Bangkok Metropolitan Administration (BMA), Department of Disaster Prevention and Mitigation, Department of Groundwater Resources, Water Resource Department, Land Development Department, Thai Meteorological Department, Hydrographic Department, Department of City Planning and Urban Development of BMA, and Office of Natural Resources and Environmental Policy and Planning. Strengths and weaknesses were internal factors of the people in the community [22] (i.e., elderly population in Bangkok), whereas opportunities and threats were considered as external factors that may adversely affect older adults' performance of flood literacy and related preparedness actions. The following are the key interview questions:

- What are strengths and weaknesses of flood disaster management (i.e., flood hazard perception and communication, flood awareness, flood literacy, knowledge about flood, and related preparedness actions, etc.) of older Thai respondents?

- How can the flood situation to the people in the community be communicated or shared?
- Who would be the key person in authorizing the actions when a flood comes?
- What are opportunities for enhancing flood hazard perception, flood literacy skills, and related flood preparedness actions (i.e., national and provincial development plans on climate change and related disaster management, etc.) among older Thai respondents?
- What are attitudes of flood perception and flood literacy of older Thai respondents and implications for their flood risk management and related actions?
- What are overall recommendations to strengthen flood literacy, perception, communication, and preparedness actions to respond to flood events among older Thai respondents?

2.4. Community Survey

Community survey was conducted in 2021 to address the current situations of how the elderly perceive and respond to flood hazards. The target group was the people aged 60 years and older who are residing in Bangkok (N = 1.02 million in 2018) [23]. The calculated sampling size should be greater than 399 at a confidence level of 95% [24].

By purposive random sampling, Samphanthawong and Chatuchak were selected as the districts with the highest elderly population of male and female elderly and female elderly, respectively. Further, simple random sampling was conducted for the selection of the elderly respondents who are living in the flood hazard areas that experience frequent floods (Figure 3).

Regarding to the definition of literacy, UNESCO's definition of literacy [25] is a means of identification, understanding, interpretation, creation, and communication in an increasingly digital, text-mediated (i.e., printed and written materials), information-rich and fast-changing world. In the context of disaster preparation, the application of information technology plays important roles in information sharing and dissemination. In this research, 'flood literacy' is defined as the ability of the elderly to use, access, communicate, or share all related flood information on online platforms (i.e., social media, internet, mobile technologies, etc.). All aspects of common interests of the elderly, flood training experiences, and their flood preparedness actions were included in the survey questions. The details of survey questionnaire are given in Table 1.

Table 1. Contents of survey questionnaire.

Contents of Survey Questionnaire	Factors
Demographic factors	• Gender • Education • Occupation • Income
Topics of interest	• Economic news • Social issues • Entertainment • Health related topics • Environmental news
Flood-related information	• Willingness to know about flood-related information • Digital technology in flood risk preparedness and management • Belief in flood information from internet source
Applying online applications for flood management/Sources of flood information	• Experiences with using online applications for flood preparedness • Line • Facebook • Twitter
Flood training experiences	• Participation in community flood training
Flood preparedness actions	• Flood management or related preparedness actions

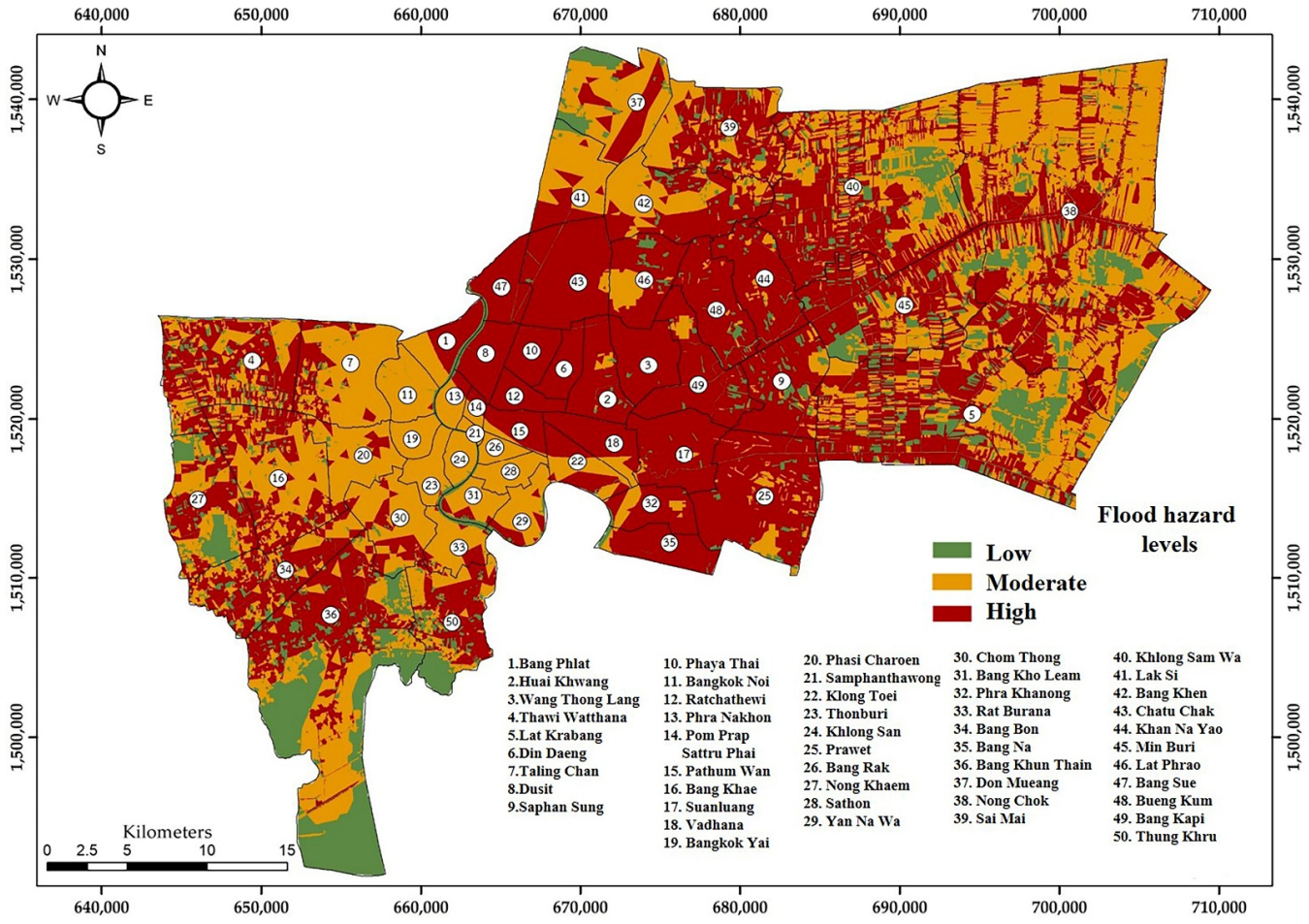

Figure 3. Bangkok's flood hazard map based on GIS-AHP Multicriteria Analysis.

3. Results and Discussion

3.1. GIS-Based Flood Hazard Mapping

As shown in Table 2, the results of the AHP pairwise comparison showed that land-use, drainage density, and annual maximum rainfall were the three most important factors that influence flood hazards in Bangkok. Road density and sea level rise were ranked fourth and fifth, respectively. The relative weights of land subsidence, past flood events, and slope of the city had the lowest scores in terms of contribution to flood hazards. A previous study on AHP-GIS flood hazard identification in another city of Thailand, namely Ayutthaya, by Kittipongvises et al. [26], found that runoff and road density were considered the most important contributors to flooding. It was observed that road density is closely linked to land-use and land cover with respect to both runoff and drainage in a floodplain [27]. In addition to this, a study of Hilly et al. [28] described a methodological framework for investigating cascading effects from flood events in the Sukhumvit area of Bangkok Thailand and found that the roads in this case study area are prone to flooding. Therefore, an uncertainty and sensitivity analysis of urban road density and flood disaster risk should be fully considered in further research. For this study, spatial data and weight evaluation of all factors influencing flood hazards in Bangkok are presented in Table 2. The weights of each factor were used to generate a flood risk map (CR = 0.098). As depicted in Figure 3, by employing the AHP-GIS overlay technique to define flood hazard areas in the Bangkok city, approximately 50.32% of Bangkok's total area, mainly situated in its central region, was determined to be at a high risk of flooding. Bangkok's hazard flood risk mapping demonstrated that high-risk areas were concentrated in economic centers, densely populated regions, and regions with non-agricultural economic activities, whereas about one-third (35.41%) and only 14.27% of the total area, mainly in the southwest of Bangkok,

were categorized as moderate and low flood risk areas, respectively. Regarding the number of the elderly residing in Bangkok, Samphanthawong and Chatuchak had the largest population of male and female elderly (29.4%) and female elderly residents (Figure 4), respectively. The results of this analysis are somehow consistent with the flood hazard map of Bangkok reported by the Geo-Informatics and Space Technology Development Agency of Thailand (GISDA). By considering historical flood events during the past 12 years, GISDA [29] demonstrated that the flood hazard was highest on the northern (i.e., Don Mueang, Lak Si, Sai Mai, Bang Khen, Chatuchak, etc.), northeastern (i.e., Nong Chok, Klong Sam Wa, etc.), and northwestern edges of the city (i.e., Thawi Watthana, Taling Chan, Bang Phlat, Nong Khaem, Bangkok Noi, Bangkok Yai, Phasi Charoen, etc.). However, in practice, the difference between methods of flood hazard analysis performed by a domestic authority (i.e., GIS single layer analysis and remote sensing techniques) and the methodology of this current study (AHP-GIS technique) should be taken into consideration in further research.

Table 2. Spatial data and weight evaluation of factors affecting the flood hazard areas in Bangkok, Thailand.

Factors	Rank	Weighting	Sub-Factor	Rating	Source of Data
Land-use	1	0.332	Settlement Crop Land Others Forest Land	8 6 4 2	Land-use data from Land Development Department
Drainage Density (km/km^2)	2	0.179	>15 7.5–15 2.8–7.4 <2.8	8 6 4 2	Land-use data, 2019 from Land Development Department
Annual Maximum Rainfall (mm/y)	3	0.17	>1100 1001–1100 901–1000 <900	8 6 4 2	Annual maximum daily rainfall during 2010–2019, Thai Meteorological Department
Road Density (km/km^2)	4	0.164	>0.6 0.41–0.60 0.21–0.40 0.00–0.20	8 6 4 2	Department of City Planning and Development, 2018
Sea Level Rise (m: mean sea level)	5	0.05	>500 301–500 101–300 0–100	8 6 4 2	Annual maximum daily sea level rise during 2010–2020, Hydrographic Department
Land Subsidence (cm: mean sea level)	6	0.047	≤ -2 −2–0 0–+2 $\geq +2$	8 6 4 2	Soil subsidence data, 2018, Department of Groundwater Resources
Past flood events during the past 12 years	7	0.038	Flooded $\geq$ 3 yrs Flooded $\geq$ 2 yrs Flooded in a year Never flooded	8 6 4 2	Previous floods in Bangkok during 2005–2017, Geo-Informatics and Space Technology Development Agency: GISTDA), TISTR (1999)
Slope (%)	8	0.019	0–5 6–10 11–15 >15	8 6 4 2	Land-use data, 2019 from Land Development Department

3.2. SWOT Analysis

Flood literacy and related actions to the response to flood risk of the elderly population were analyzed through SWOT analysis (Table 3). In terms of strengths, the results found that overall awareness to flood disaster risk of Thai residents was observed at a high level. This is possibly due to the flooding continues to affect wide areas of the country after heavy precipitation events. Bangkok, for instance, is located in the delta of the Chao Phraya River Basin and prone to flooding. Conversely, as the weaknesses of flood resilience, many older adults with limitations in physical function are living in old houses, possibly due to limited income, making the process of flood preparation and management even more difficult [30]. Most of them often have low digital and media literacy and limited experience in the use of information and communication technology for disaster risk reduction and flood risk management. Moreover, lack of knowledge about flood disaster

and training opportunities may limit the participation of older adults in risk reduction and emergency preparedness. The presence of a provincial development plan on climate change management, national policy responses to an aging society, and the developmental implications of digital platforms in Thailand are considered as the opportunities to enhance flood resilience. However, lack of research databases and disaster preparedness of the older adults, and also lack of access to flood management training sessions for the elderly in disaster risk reduction, are the key barriers in reducing flood vulnerability. More importantly, ineffective flood forecasting, warnings, and risk communication are considered as a major threat. To support this, a study by Kittipongvises and Mino [31] revealed that the majority of Thai respondents reflected that they did not receive any early warning during the 2011 Thailand floods. Over half of the respondents reported received a warning less than one hour before the flood arrived. Waiting until the flood disaster is fully established means that the risks of inaction are borne by vulnerable people themselves.

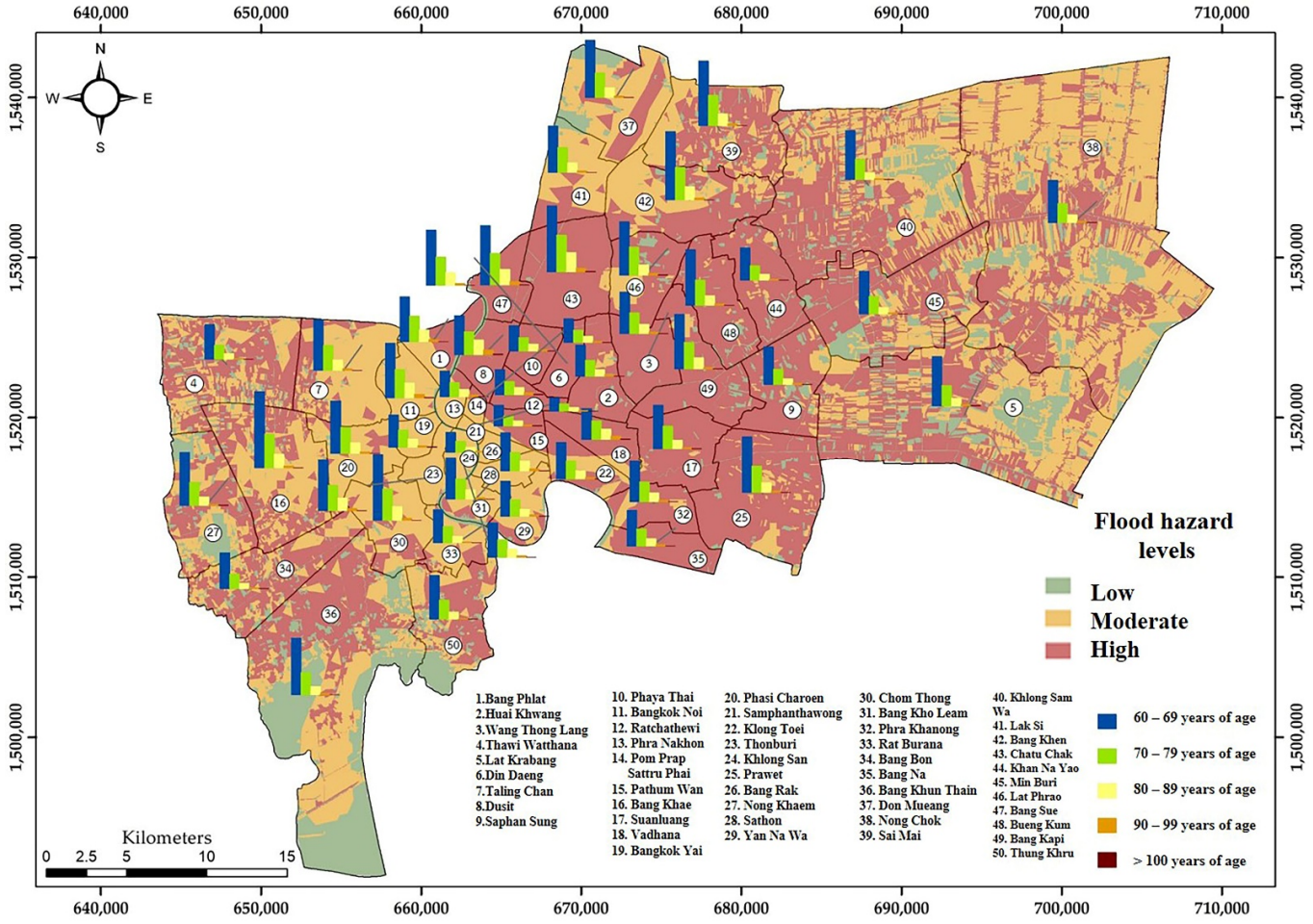

Figure 4. Number of the elderly residing in flood hazard areas of Bangkok, Thailand.

3.3. Questionnaire Results

3.3.1. Demographic Characteristics

Survey data were obtained from the elderly respondents (n = 736) who are residing in Samphanthawong, Chatuchak, Don Mueang, Thawi Watthana, Phasi Chareon, Wang Tonglang, and Bangkok Yai (14–15% of each district) of Bangkok, Thailand. Over half of respondents (59%) were female and aged 60 to 69 (48%). The majority of the elderly respondents completed primary (63%) and secondary school (20%). About half the respondents are retired from work (51%) and over 26% were unemployed. Percentage of the respondents who reported no income was 35%, while 39% received an income of below USD 300/month

approximately. Interestingly, most of the elderly respondents were interested in issues related to environmental problems (75%) and entertainment news (66%), whereas some respondents (36–38%) reported interest in economics and health-related topics.

Table 3. Strengths, weaknesses, opportunities, and threats analysis of flood literacy, perception, and related actions of the elderly population.

Strengths (S)	Weaknesses (W)
- Residents living in Bangkok (i.e., the elderly population) are commonly aware of flood-related risk in their communities. - Bangkok is the location of the senior citizens club. - The folk wisdom of the elderly people in Thailand.	- Bangkok is a natural floodplain which is situated downstream of the Chao Phraya River. - Aging society situation in Bangkok. - High unemployment rate and limited literacy in the elderly. - Older adults have difficulties in implementing information and communication technology for disaster risk reduction and flood risk management. - Housing conditions (i.e., old house) and the vulnerability of the elderly (i.e., physical function limitations). - Little knowledge of disaster risk reduction and flood risk management of the older adults. - Lack of access to training opportunities for the elderly population on flood preparedness, response, and management.
Opportunities (O)	**Threats (T)**
- Bangkok has its own provincial development plans for climate change and related disaster impact management (i.e., Bangkok Master Plan on Climate Change 2013–2023). - Thailand has a well-prepared national policy and related strategies on aging and also for long-term care systems for the older adults. - Collaboration between agencies and private organizations to support quality of life for elderly people. - Digital literacy promotion is one of missions of Digital Economy Promotion Agency of Thailand. A digital literacy platform for adults is also available. - Thailand Massive Open Online Course (Thai MOOC platform) is available to the public. - Several international organizations and NGOs are working in Bangkok.	- Intensity and frequency of floods in Bangkok has increased. - Lack of scientific evidence on older people and disaster preparedness and management in Thailand. - Lack of effective flood forecasting, warnings, and risk communication to the community. - Low multi-stakeholder engagement in disaster risk reduction and flood risk management. - Limited professional training on disaster risk reduction and flood risk management, especially for the older adults. - Lack of governmental support (i.e., - Adequate budgets and human resources) for building capacity of the elderly population to respond to flood risk. - Lack of effectiveness of flood emergency management systems. - Each district of Bangkok mainly focuses on providing a non-structural means of flood risk management (i.e., the canals, tunnels, pump stations and retention ponds of Bangkok's drainage system).

3.3.2. Flood Perception and Online Information Sources

The survey analysis demonstrated that almost half of the elderly respondents (49%) strongly agreed and agreed that they were willing to know about information about flooding (Figure 5a). Around 44% of the total respondents agreed that online digital technologies can be used to promote their flood preparedness and management (Figure 5b). Approximately 40% and 5% of the respondents agreed and strongly believed flood information from internet sources (Figure 5c). These results are in line with previous research conducted by Brockie and Miller [32], indicating that many older adults in Australia do not engage with the internet, Facebook, and Twitter, therefore will be unable to access to flood information from these communication channels [32]. In Thailand, Kittipongvises et al. [31] also indicated that most Thai respondents reported that they did receive information about flood-related risks and disaster preparedness from television (95%), newspaper (51%), the

internet (50%), and radio (23%). A study of Molla et al. [33] observed that television and internet were the most powerful tools for flood risk communication for the young Thai respondents, while the older respondents mainly relied on radio and pamphlets. More interestingly, the older respondents showed a higher level awareness and concern over flood risk mitigation than the younger respondents [33].

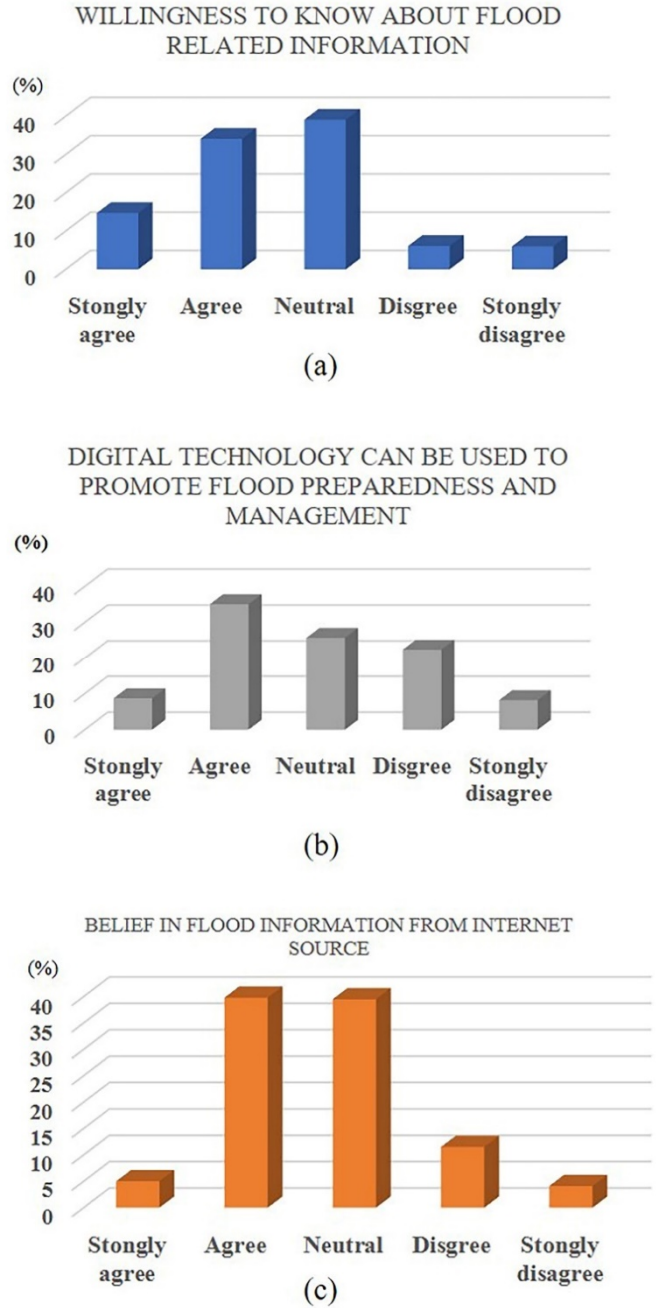

Figure 5. (**a**) Willingness to know about flood information of the elderly respondents, (**b**) their perception of digital technology influences flood preparedness, and (**c**) belief in flood-related information from internet sources (n = 736).

3.3.3. Using Web-Based (Online) Applications in Flood Management

As depicted in Figure 6a,b, nearly three quarters of the elderly respondents (75%) did not use online applications for their flood hazard management both before and during flood disasters. Most of them (75%) did not attempt to share and communicate flood-related information via online platforms. By asking the elderly respondents to identify the source

of information on flood response and monitoring via online and web-based applications, 13% of total respondents have had experience using Facebook and Line applications to obtain information before a flood event (Figure 6c). This was supported by a study of Vacek and Rybenská [34], showing that the difficulties experienced by the older adults in using information and communication technology are very common.

Interestingly, the results of this survey found that very few of the elderly respondents (<2%) have used a national web-based platform for finding flood information before a disaster (i.e., website of Department of Disaster Prevention and Mitigation, Bangkok Metropolitan Administration, GISDA, etc.). In this respect, a study by Kittipongvises and Mino [31] also reported low levels of satisfaction with flood risk communication and management by the local authorities of Thailand. During the event of a flood, this survey's results also found that Facebook and Line are two of the most popular web-based applications as tools to access flood-related information (Figure 6c,d). These findings were similar to a study conducted in Malaysia [35], which found that people used social media (i.e., Facebook) to obtain and share information in the occurrence of floods in their local community. Compared to similar study in Sri Lanka by Jayasekara [36], Facebook was the most popular social network both during disasters and in post-disaster phases. During disaster situations, the respondents used the Facebook application to share posts, share contact numbers of rescue teams, as well as request for help. In post-disaster situations, Facebook was used to request volunteer help, call for donations, and also provide feedback about disaster management in their local area.

3.3.4. Flood Training Experiences and Preparedness Actions

In terms of flood training (Figure 7a), almost all respondents (86%) had never participated in the community training of flood preparedness and management. Half of the respondents reported that they would take actions in response to a flood disaster (Figure 7b). The study is supported by Brockie and Miller [32], who revealed that past flood experiences, support from family (i.e., how their family members called to warn them about flood risk), and evacuation decision during flood disasters were the three drivers of flood preparedness of the older respondents in Queensland, Australia. During a flood, the older respondents were confronted with real situations of flood disaster response, such as whether to stay or evacuate. Support from emergency operation officials, family and neighborhood, their physical and emotional conditions, and flood experiences were the key factors affecting flood response of the older respondents in Australia. For instance, one of the female older respondents reflected that she did not find out about the location of the flood evacuation center and had no idea at all where to go during a flood disaster. In Hong Kong, a study conducted by Loke [37] revealed that only 22% of the total number of older respondents (n = 1137) were defined as being prepared for disasters. However, in case of an emergency, most of the respondents reported having an emergency survival kit (87%), knowing how to shut down the water, electrical power supply, and gas before evacuating (79%), and also knowing how to communicate and contact their family members (54%). In preparing for disasters, most of them (50–80%) kept a radio, a flashlight, candles and lighters, a mobile phone, and a first aid box at home.

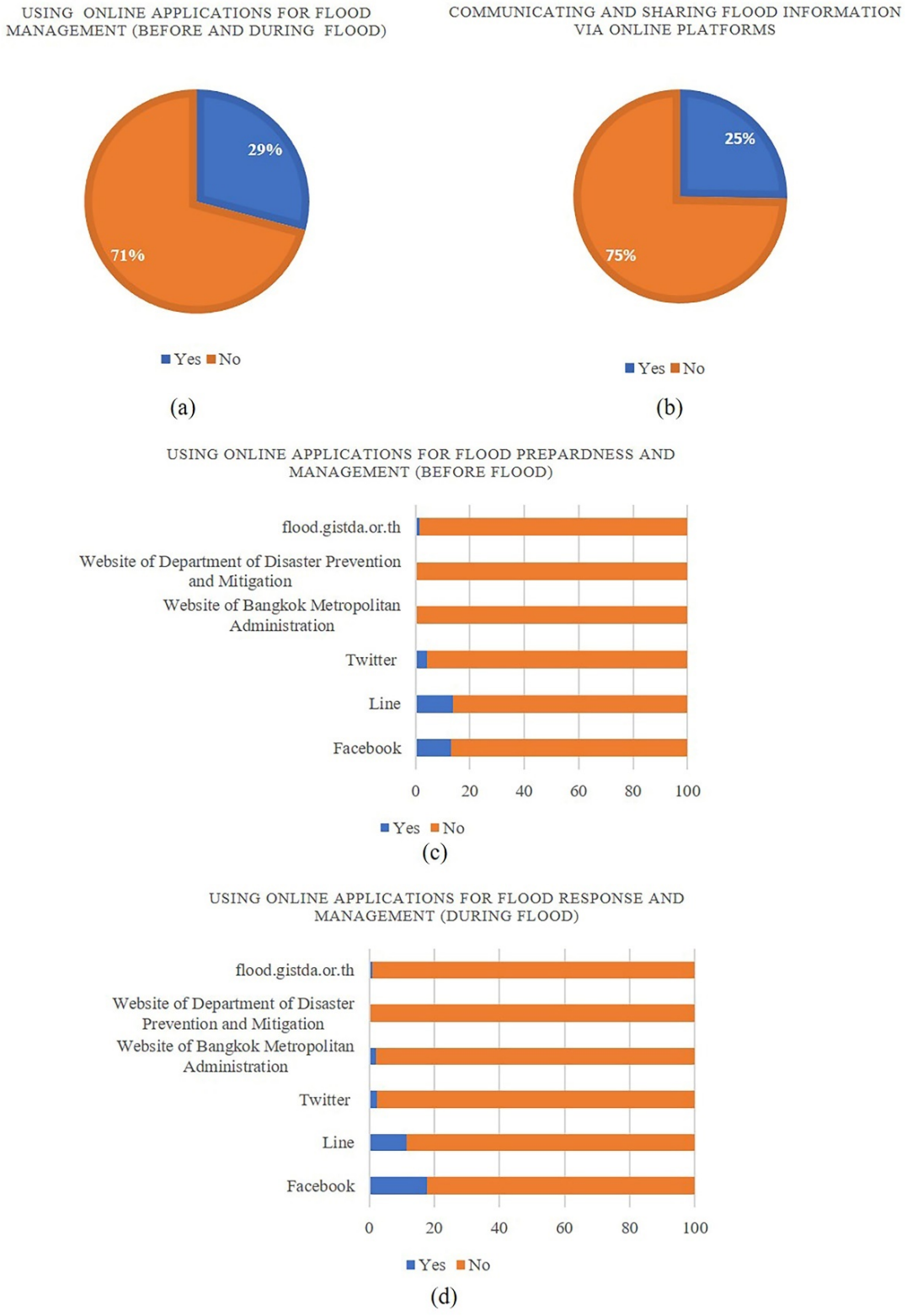

Figure 6. Experiences in using web-based applications in flood management both (**a**) before and (**b**) during flood disaster, and (**c**) lists of open-source web applications for flood preparedness (before flood) and (**d**) flood response and management (during flood) (n = 736).

Complexity of flood disaster, communication problems, and lack of training could possibly prevent local people from voluntarily engaging with flood risk management. A study on crisis management conducted by Rothkrantz and Fitrianie [38] highlighted that

many local residents underestimated the risk of flooding and speed of the raising flood water. They did nothing until it was too late. During a flood crisis, the management team should be contacted in time and be involved in flood communication via a social media platform. The local government should also reach the older adults through promotional talks and sharing disaster information to them in their own home [37]. More importantly, it must be recognized that disaster risk communication to vulnerable older adult populations has often been ineffective because of barriers associated with their literacy and age-related hearing loss and vision impairment [39]. Matching readability and usability materials and media in disasters more closely to the literacy levels of elderly users, and empowering them through participatory design processes, are significantly useful to improving the complexity of disaster preparedness communication for these populations [40]. Further, local authorities and related stakeholders (i.e., the Bangkok Metropolitan Administration (BMA), Department of Disaster Prevention and Mitigation) should examine flood-related deaths based on analysis of indoor fatalities and assess the circumstances and surrounding environment that led to indoor flood fatalities, especially among elderly people and persons with disabilities [41].

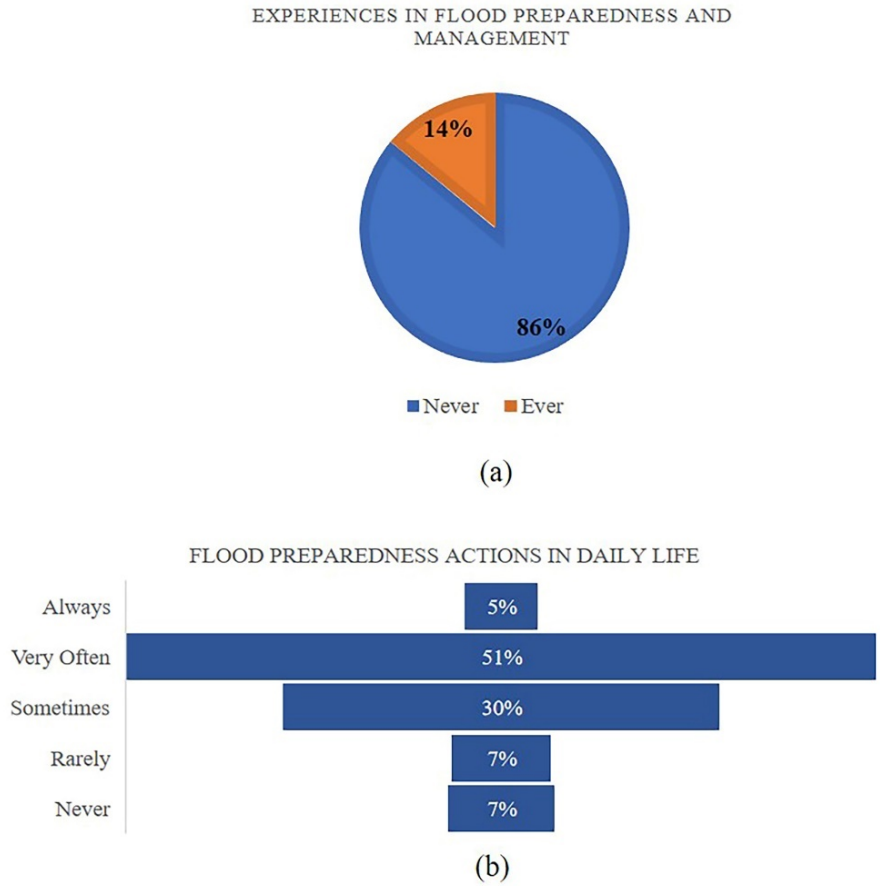

Figure 7. (**a**) Flood training experiences and (**b**) preparedness actions in their daily life (n = 736).

3.3.5. Experiences in Flood Training and Using Online Applications for Flood Hazard Management in Each District

As the district with the highest elderly population, more than 80% of the elderly respondents living in Samphanthawong have used online applications for finding flood-related information, whereas 54–92% of the respondents who are residing in other districts reported that they never used web-based applications (i.e., Facebook and Line) for their information regarding floods both before and during a flood event (Figure 8a,b). In addition, nearly all respondents (86–88%) living in the vulnerable areas, namely Samphanthawong

and Chatuchak (the district with the highest female elderly), had never attended the training of flood preparedness, response, and management in their local community (Figure 8c)

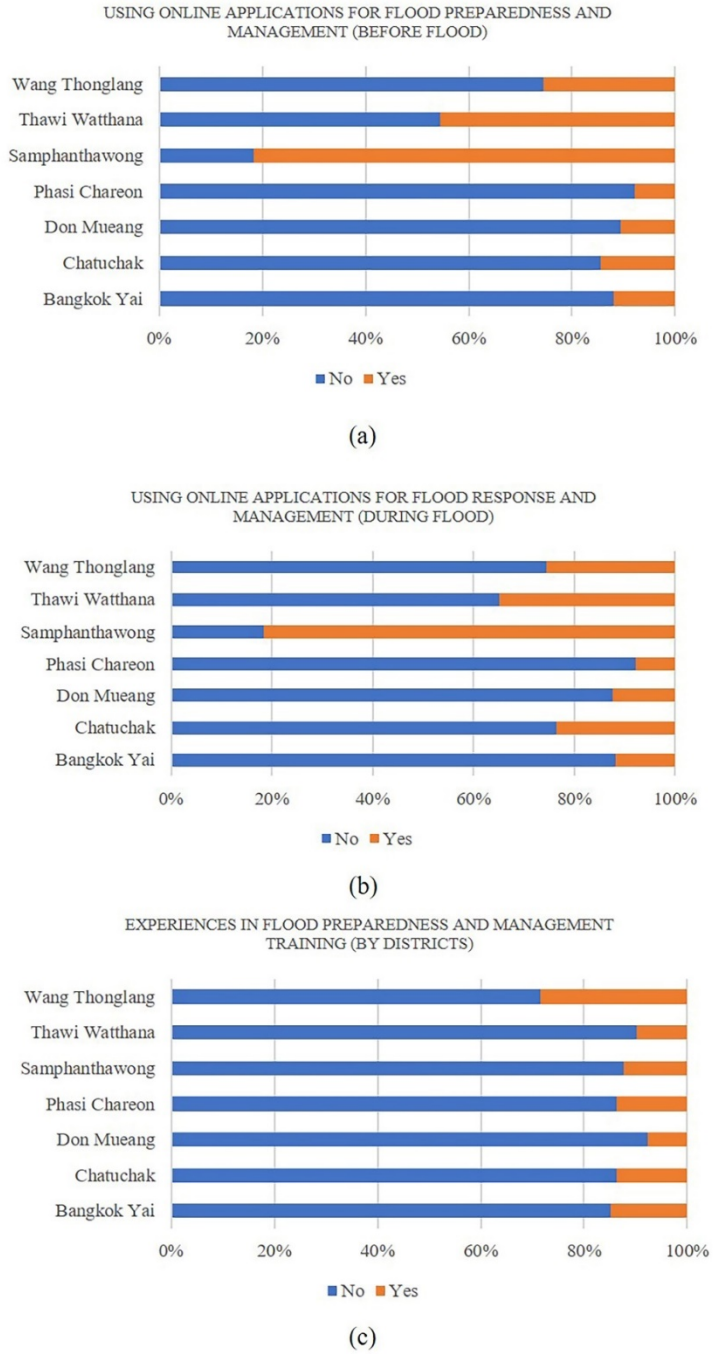

Figure 8. Experiences in using web-based applications in flood management both (**a**) before and (**b**) during flood disaster, and (**c**) flood training experiences (by districts) (n = 736).

Overall, the following recommendations were provided to promote flood literacy of the elderly population and strengthen their preparedness capacity to deal with climate-related flood risks:

Integrating elderly empowerment into climate change and disaster-related policies: National governments should support the development of provincial climate change master plans that incorporate the empowerment of the elderly in both disaster risk reduction (i.e., flood and extreme climate events) and community resilience. Importantly, risk man-

agement and flood literacy (i.e., digital and media literacy) should be an integral part of both an immediate emergency flood response and long-term development program.

Arranging a community flood training program and engaging the elderly in disaster preparedness and resilience activities: Local government organizations should coordinate with the relevant stakeholders to organize training activities to disseminate knowledge on flood disaster and their response and preparedness to the elderly population. Information on the frequency or intensity of flooding and property protection should be provided before a flood happens, whereas more information on food and water supply and health-related problems should be given promptly during a flood event [33]. To engage the elderly in awareness-raising of a flood risk, the elderly who have direct flood experience should share their lessons with those who have not [31]. The senior citizens club may be potentially useful in terms of increasing awareness of vulnerability to flood hazards among the elderly.

Promoting flood literacy in older adults by using information and communication technology: Social media is an important strategy to enhance information sharing and collaboration on flood risk reduction and management. Both tacit and explicit knowledge about a flood hazard is an important component in flood risk perception of the elderly. With the use of information and communication technology, knowledge can be acquired through discussion and chatting online [42]. A study of Hashim et al. [35] observed that high levels of tacit knowledge of the respondents would distort the information sharing task during a disaster. The ease of use in information and communication technology is important to promote flood disaster perception, preparedness, and active response among the elderly respondents. Further research is needed to investigate how the technology-task fit theory (i.e., technology characteristics and task characteristics) affects the use of technology by the elderly to deal with flood risk.

Enhancing the role of community-based flood information centers: An effective flood risk communication and disaster management plan with strong information network and effective flood forecasting and warning is urgently needed to improve flood resilience in Bangkok. Updated flood maps, media alerts, and flood risk assessment checklists are essential to communicating flood hazards to those at high risk. A study conducted by Costabile et al. [11] observed that flood hazard maps are an effective means to increase public awareness regarding flood impacts, to increase transparency in local authorities' actions for coping with flood risks, and also to impart on citizens the importance of preparedness.

Flooding MOOC applications for risk perception and management: The result of the SWOT analysis showed that the Thai MOOC Platform is now available to the public to promote the understanding of the complexity of a flood disaster. Alternatively, an MOOC on the flooding should be developed as a training software tool for the elderly to cope with floods in effective and efficient way. A study of Rothkrantz [43] revealed that an MOOC platform could create the feeling of presence and improve the levels of engagement in the flooding disaster. The option of special training events, serious gaming [44] during a flood crisis simulation, and digital learning should be also more promoted and provided to the elderly as tools for flood preparedness education.

Building local knowledge of flood disaster management based on the citizen science approach: The role of senior citizens and their contributions to flood risk management should be more recognized. A study by Assumpção et al. [45] highlighted that the role of citizen contributions is to provide information for not only monitoring and generating flood risk maps but also for flood risk modeling and forecasting. Commonly, there are several types of flood-related information (i.e., flood extent, water level, flood velocity, and land cover and topography) that can be directly observed and gathered by citizens. For instance, in terms of flood monitoring, the citizens provided flood-related data by reading water level gauges and sending the information by text message [46], through applications/websites [47], and through social media (i.e., YouTube, Twitter, Facebook) [48,49]. Further, in Queensland, Australia, the citizens sent geographic information such as photographs and videos through social networking services (i.e., Twitter, Facebook and e-mail) for generating their flood risk map [50].

4. Conclusions

Elderly people are the most vulnerable to natural disasters (e.g., floods). To boost flood resilience, literacy is considered one of the most important skills, as a person can use, access, communicate, and share flood information on online platforms. Based on expert interviews and SWOT analysis, the following are the key results of this research. Many older people in Bangkok, Thailand face many difficulties in using information and communication technology for disaster risk reduction and flood risk management. Lack of effective policy integration for the aging population and disaster preparedness, limited community flood warning systems and training sessions on disaster management, as well as low literacy skills of the elderly population were the key barriers to enhancing community flood resilience. The results of the community survey (n = 736) highlighted the importance and limitations of the use of information and communication technology for flood risk reduction and preparedness among the elderly respondents (i.e., those who are living in the high-risk areas). Thus, exploring the possibility to engage the elderly and promote their flood literacy skills (both media and digital), and also improving the role of online platforms (i.e., Facebook, Line, Twitter, national web-based platform, and other social applications, etc.), are vital to build up flood resilience and to minimize communities' vulnerability to flooding.

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