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The Analysis of Community Resilience and Fire Risk Management: a Case Study of Chiang Mai

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Abstract

The bustling Northern Thai city of Chiang Mai has a number of mixed-use areas, which are spaces of interaction of community and shopping areas, which are known as "Kad" or "Markets". These areas have high densities of commercial and residential activity. These busy and crowded market areas and the communities that have developed in and around them may feature the critical factors that make them "Fire Risk Areas". Therefore, in this study, the researcher studied the variables and physical relationships that led to some of the Chiang Mai market areas becoming fire risk areas, and then performed risk prioritization in the same areas to determine risk classes as key data for managing the areas. The market areas were examined for 7 factors: age of the area, population density, commercial land use, residential land use, type of building material, road networks, and fire station location. A Geographic Information System (GIS) was applied in the study for processing and analysis by determining the weight of each factor and the data type score of the factor. Based on the factor analysis, market areas were classified into 5 classes of fire risk: very high, high, moderate, low, and very low. The results can be used in systematic and logical planning and incident management. Analysis based on the key variables that could cause community fire risks within a radius of 400 meters around the markets revealed that there were 8 areas that met fire risk criteria. Of the 8 markets analyzed, 3 areas, namely communities surrounding Chiang Mai Gate Market, Ming Muang Market, and San Pa Koi Market were at high fire risk, 3 areas, namely communities surrounding Kom Market, Chang Puak Gate Market, and Warorot Market were at medium fire risk, and 2 areas, namely communities surrounding Siriwattana Market and Ton Payom Market were at low fire risk. The classification of fire risks can facilitate risk prioritization and thus lead to better ways of handling serious and less serious risks. Our research can help communities to analyze which areas are at serious risk and need prompt action. Furthermore, the research can be used to plan for risk management in the next phase of development.

Keywords: *Fire risk; Risk management; Surrounding the market; Community Resilience*

1. Introduction

Chiang Mai, one of the provinces in the upper northern part of Thailand, has a history of more than 727 years (built in 1839 B.E.). The city is a vital cultural heritage site of the country, and has a history of the past civilization with values in arts, nature, landscapes, urbanization, architecture, culture, beliefs, and Lanna traditions, along with other key components. It is also the center of economy, trade, education, medical care, transportation, and tourism destination in the North. Thus, the city structure of Chiang Mai portrays the uniqueness caused by the assortment of small neighborhoods, and each often possesses diverse history, culture, political dynamics, and urban development (Daungthima, & Tansukanun, 2018). The city's economic district is one of the reflections of Chiang Mai's development to become a major commercial and tourism center of the country along with a systematic connection according to the concept of Garden City (Simonds, 1994), leading to a spatial relationship between the community and the shopping area, called "Kad" or "market". Its mixed-use resulted in high density in the city's heart, community, and economic areas. The market is a crucial part of life that reflects the combined economic, social, and physical conditions. Momentous connections were formed through human activities (Francis, 1989). This illustrates the way of life of the Lanna people in the north as a source of fascinating civilization and uniqueness, and a connection

in communication and interaction among people in the community as scholars (Fisher, 1985 & Natsupa, 2014) stated that markets and communities are related. A community is influential in creating a sense of belonging for the development of neighborhoods and urban areas as a whole, including physical areas, common ties, and social interactions of members living together in each community (Knox, & Pinch, 2000). Activities that occur in and around the market create a lively environment.

Currently, Chiang Mai has become an economically significant city with an international standard (Chiang Mai Municipality, 2014). Consequently, the neighborhoods have shifted in terms of residential styles, environment, culture in the city, and lifestyles. The distributions of community areas and fresh markets from the past to the present were parallel. For the area with many communities, there will be many markets as a node rather than communities that are horizontally spread out. The fresh market not only plays a role as a source of raw materials which are important to urban life, but it is also an area where urban people in the surrounding communities meet and strengthen relationships while shopping. The nodes of those areas may create opportunities for "Fire Risk Areas", fire problems or threats caused by a fire that can occur at any time, causing loss of life and property. Most fires occur in residential and densely populated communities or crowded areas. Therefore, community areas and markets are important factors that cause fire risk areas due to crowded conditions, population density, and area density. It was also found that streets and alleys in the community were small and twisted. If there is a fire, it will inevitably cause a charge and is difficult to control. A fire risk planning to determine fire risk areas is therefore vital for area management (Vinnem, 2010).

The study aimed to study the variables and physical relationships that cause fire risk areas in communities surrounding the market in Chiang Mai to analyze risk prioritization in the area and determine the classes of risk for the analysis of community resilience and fire risk management. (Nuthammachot, & Stratoulias, 2021) systematically and rationally (Figure 1).

Figure 1 Research Conceptual Framework

2. Objective

The purpose of this research is to investigate the variables and physical relationships that contribute to the designation of certain areas surrounding the Chiang Mai market as high-risk zones for fires. Subsequently, the researcher will undertake a risk prioritization analysis within these areas to ascertain distinct risk classes. The obtained data will serve as crucial information for effective area management and the development of targeted strategies to mitigate fire risks and fire risk management systematically and rationally.

3. Materials and Methods

Sites description

The research area in Chiang Mai covers an area of approximately 40.216 square kilometers, including 14 subdistricts (Figure 2), and 15 markets scattered in the area, including Chiang Mai Gate Market, Nong Hoi

Market, Ming Muang Market, Ton Lam Yai Market, Warorot Market (Kad Luang), Kom Market, Chang Puak Gate Market, Muang Samut Market, Muang Mai Market, Boriboon Food Market, Siriwattana Market, Thong Kham Market, Ton Payom Market, Thip Net Market, and San Pa Koi Market (Figure 3).

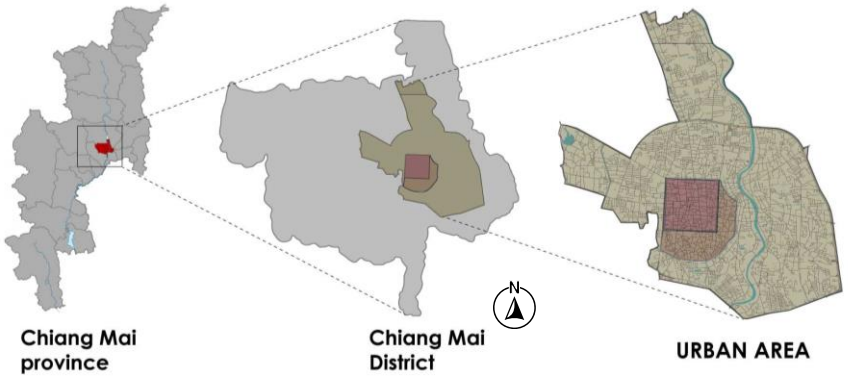

Figure 2 Area Scope of the Study

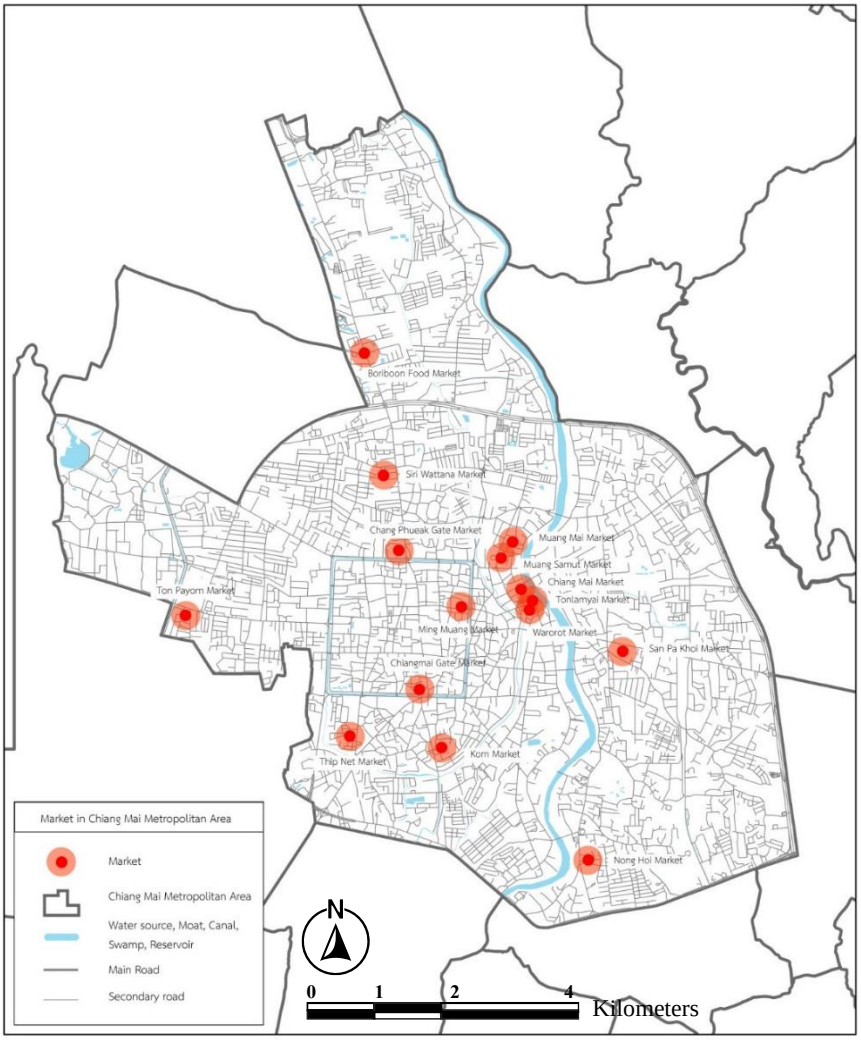

Figure 3 Community Locations Surrounding the Market (Scope of Research)

This research area included a target population in Chiang Mai municipality. The community areas surrounding the market in a radius of 400 meters included 8 areas, namely the communities surrounding Chiang Mai Gate Market, Ming Muang Market, Kom Market, Chang Puak Gate Market, Warorot Market, Siriwattana Market, Ton Payom Market, and San Pa Koi Market (Figure 4). based on the concept of Garden City. Those areas tended to be the city's economic areas, and consisted of 3 zones of urban areas:

1) ZONE A refers to an area with historical significance in Chiang Mai, a historic old town, or an area within the canal square along the boundary of the original city wall. The area contains ancient sites, architecture, fine arts, and temples. Generally, land use consists of residential areas, namely single-family houses, commercial buildings, and commercial hotels, with height limitations in business districts, government places, and religious places. Community areas in ZONE A included Chiang Mai Gate Market and Ming Muang Market.

2) ZONE B refers to the old outer city as the essential economic area of Chiang Mai since the past. The area is between the canal in the old city area and the outer old town area. Generally, land use is a combination of very dense residential areas, including commercial buildings, hotels, department stores, business districts, and educational institutions. Studied markets included Chang Puak Gate Market and Kom Market, as well as the largest traditional market, Warorot Market, which has been the center of Chiang Mai's commercial area for a long time (since 1965 - present).

3) ZONE C refers to a traditional commercial community ranging from the old outer city up to the boundary of Chiang Mai municipality. Generally, land use is similar to ZONE B but has a lower density of land use. Moreover, there are government organizations and warehouses. Studied markets included Siriwattana Market (Thanin Market), Ton Payom Market, and San Pa Koi Market. Therefore, ZONE C is another influential economic area due to its source of products and distribution centers to various parts of Chiang Mai and nearby cities.

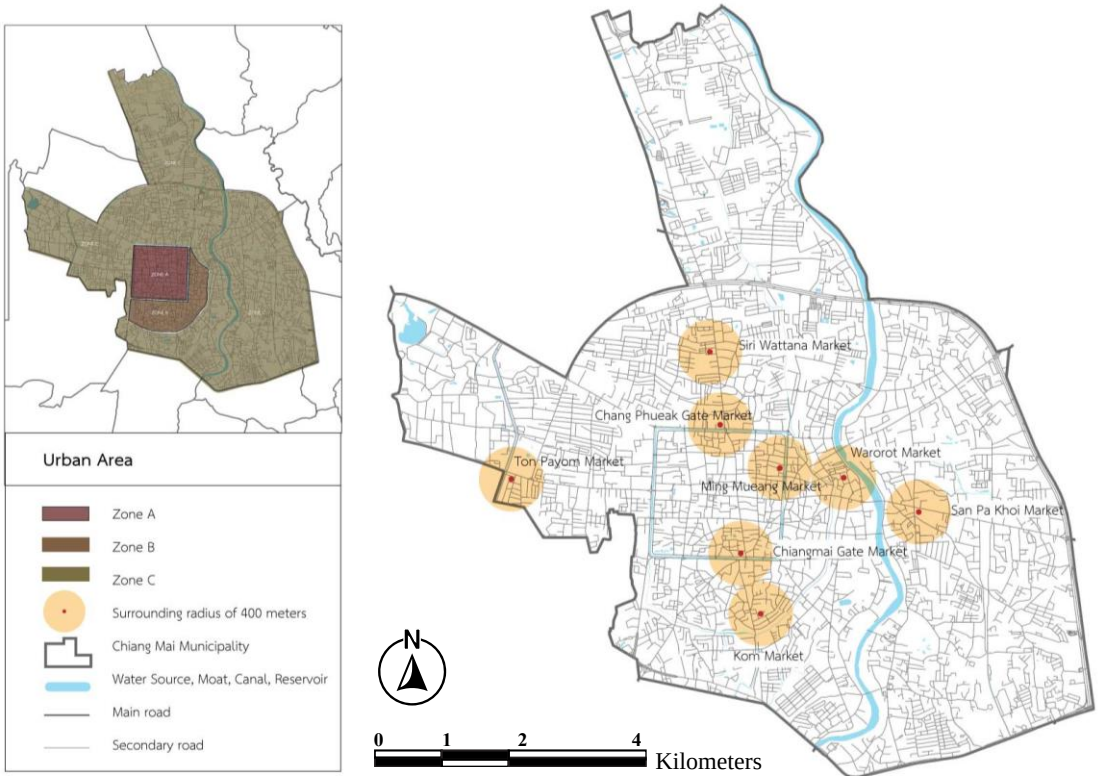

Figure 4 Target Population in Chiang Mai Municipality

Data collection

Data collection was performed by visiting the study areas to examine the physical, social, and environmental aspects of the areas. It included areas under the Chiang Mai municipality, community areas surrounding the market, and the surrounding context. Physical data was analyzed by Geographic Information System (GIS) through the Arc GIS program for spatial analysis. Then, the data obtained from the survey was analyzed in terms of the cause and risk of fire in the areas for the importance of each factor by creating a database and weighting to classify risk factors criteria into different categories in the most probabilistic way. The physical areas of the 7 factors were examined, namely the age of the area, population density, commercial land use, residential land use, type of building material, road network, and fire station location (Table 1).

Table 1 Impact Weighting of Risk Assessment Areas

Criteria/Factor	Class	Rank	Weight	Risk Classes
The Age of the Area	> 60	4	0.15	Very high
	59 - 40	3		high
	39 - 20	2		Moderate
	< 20	1		Low
Population Density	> 4500	4	0.20	Very high
	3500 - 4500	3		high
	2500 - 3500	2		Moderate
	< 2500	1		Low
Commercial Land Use	> 30%	4	0.15	Very high
	30 - 20	3		high
	20 - 10	2		Moderate
	< 10%	1		Low
Residential Land Use	> 80%	4	0.12	Very high
	80 - 70	3		high
	70 - 60	2		Moderate
	< 60%	1		Low
Type of Building Material	> 30%	4	0.09	Very high
	30 - 20	3		high
	20 - 10	2		Moderate
	< 10%	1		Low
Road	> 6 meters	1	0.10	Low
	6 – 5 meters	2		Moderate
	5 – 4 meters	3		high
	< 4 meters	4		Very high
Fire Station	> 1.2 kilometers	4	0.19	Very high
	1.2 – 0.8 kilometers	3		high
	0.8 – 0.5 kilometers	2		Moderate
	< 0.5 kilometers	1		Low

Risk assessment criteria for scoring employed the results to prioritize the risks for damage and impact assessment in the areas by categorizing fire risk areas. Data analysis was performed based on the determination of fire risk areas by applying the GIS to study related factors influencing fire incidents in the city to determine the relationship between physical factors and community areas surrounding the market, leading to the determination of fire risk factors and fire risk factor prioritization through arithmetic mean and standard deviation with the following details:

Data input in the Geographic Information System (GIS) must be spatial data in each layer. The Arc GIS program in the analysis determined the fire risk factors. The two types of processing and analysis included the weighting of each factor and the data type score of the factor. Subsequently, Factors related to fire incidents in the area in the geographic information system were performed by weighting based on the

importance of the factors in this study. The weights were set from 1 to 5. 1 is the minor importance and relation to a fire incident, while 5 is the most important and related to a fire incident.

All obtained scores were grouped into a chance of a fire risk explained by the mean of the score and then the distribution of the standard deviation data in each risk class, which is divided into 5 risk classes, including very-high, high, moderate, low, and very low. After the analysis was performed, data were presented in a chart to summarize and assess fire risk areas.

4. Literature Review

Fire risk areas can cause damage based on the context, region, topography, and the possibility of different natural disasters.

According to UNISDR (2009), fire risk assessment is a way to determine the severity and probability of negative impacts by analyzing the risks that may occur and vulnerabilities in the study area with potential harm to people, property, services, livelihoods, and the environment.

Vulnerability

Blaikie, Cannon, Davis, & Wisner. (2004) defined vulnerability as caused by factors affecting the life and property of people and those in the risk areas from both natural and social disasters with different impacts. The factors that cause vulnerable areas are measured by impacts from social status, career, race, gender, health condition, age, and social network of an individual and groups.

Hewitt (1997) described the risk area as effortlessly intimidated by various threats caused by population density, residential density, building structure, social activities, or harmful activities with an area limitation that cannot be avoided from disasters and low safety from incidents that cannot be mitigated for a safety state.

Bureau of Disaster Prevention Measures (2008) stated that vulnerable areas are related to the urban structures: community type, age, town planning, population density in community areas, traffic system, utility system, and building structure.

Risk Assessment

Risk assessment processes require numerous and various data sets, including both quantitative and qualitative forms, mostly involved with secondary sources, such as reports on data statistics, publications, and documents from reliable agencies, such as local government agencies and international agencies involved in fire incidents. Besides, the data on the location of various risk elements were not complete, thus leading to limitations in converting available data into a format suitable for use by the Geographic Information System (GIS) used in risk assessment and displayed in the form of a map. The location of the incidents should be recorded as well as the nature, the severity of the damage, and basic information about the damage. The severity of the incidents should be recorded at the scene as well. If these databases can be completely developed with the correct format, they will be very useful in disaster risk assessment with more accurate and comprehensive in the future.

Moreover, personnel in government agencies should be encouraged in terms of knowledge and understanding of risk assessment as at least a coordinator risk assessment along with an adequate understanding of quality control, guidelines for application, outcomes of risk assessment, and risk communication information for planning and developing the province to be safe from disasters. Since the risk assessment is related to the use of Geographic Information System (GIS) in terms of the risk assessment and the presentation of risk information, the development of personnel in the field of Geographic Information System within government agencies should be prioritized as well.

Qualitative Risk Analysis

Qualitative risk analysis explains the risks of the use of risk metrics to estimate the possibility of a threat and its impact. The example of the risk metric table (Table 2). reveals the risk classes according to the risk score as a result of a multiplied between the possibility of disaster and the level of impact. Numbers in the table indicate the risk classes. High numbers indicate a high-risk class. These risk values are useful in showing trends or comparing risk classes (such as the lowest to the highest). Therefore, the classification of

the fire risk areas was divided into 5 classes as follows: very high (more than 15) with possible severe impact managed by immediate actions, high (10-12) with preparation soon, moderate (7-9) with not very severe impact with a moderate consequence without urgent action or action at all depending on the existing resources, low (4-6) with mild level and little impact mostly acceptable by specifying the population that may be affected, and very low (1-3) without any special actions and with management by people in the area.

Table 2 Evaluation and Risk Prioritization

Evaluation and Risk Prioritization					
Risk Classes	Very High	High	Moderate	Low	Lowest
	Above 15 scores	10-12 scores	7-9 scores	4-6 scores	Below 3 scores
Importance	Immediate actions and emergency actions for very highly important areas	Immediate actions with fastest implementation for highly important areas	Moderate importance with fast actions	Low importance with planning and management within the areas	Acceptable risk without possibly needed actions and with management within the areas

Source: Adapted from ADPC,2011

Risk Estimation

In the final phase, it was a compilation of the results that can be analyzed above as a result of the risk of disaster. A simple method may be used by substituting the probability totaling 5 levels, namely Very High (5) High (4) Moderate (3) Low (2) Very Low (1) and the level of severity of the impact, totaling 5 levels, namely Very High (5) High (4) Moderate (3) Low (2) Very Low (1) Then, they were compared to the risk of disaster shown in Table 3.

Table 3 Example of Risk Estimation

Fire Probability	**Level of Severity**				
	Very Low (1)	**Low (2)**	**Moderate (3)**	**High (4)**	**Very High (5)**
Very High (5)	5	10	15	20	25
High (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Low (2)	2	4	6	8	10
Very Low (1)	1	2	3	4	5

Source: Adapted from Vinnem, (2010)

Accordingly, the outcomes of the risk assessment are very useful and can be used as a guideline for fire risk reduction as well as application in planning the development of risk areas. The key components in integrating disaster risk reduction into development included risk identification, risk analysis, and risk estimation, leading to risk management to reduce the risk (as shown in Figure 5). The risk assessment is used to analyze the likelihood of being affected by fire, determine appropriate measures to manage and reduce risks, and implement measures into the process related to development planning and implementing development activities at all levels. To reduce fire risks, knowledge, the importance of risk assessment, and the application of the outcomes of risk assessment should be promoted. This includes the production of personnel or hiring experts with abilities in various fields related to risk assessment to expand cooperation between government agencies to cooperation between the public and private sectors. Providing information to the public about the process and the outcomes of risk assessment assists people in the area to gain a better understanding of the risk and situation to create participation of stakeholders in planning for emergency response, early warning, danger preparation and confrontation, prevention and mitigation, rehabilitation and rebuilding together in a systematic manner.

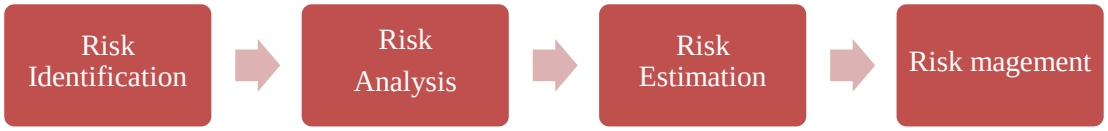

Figure 5 Risk Management Process Source: Adapted from ADPC,2011

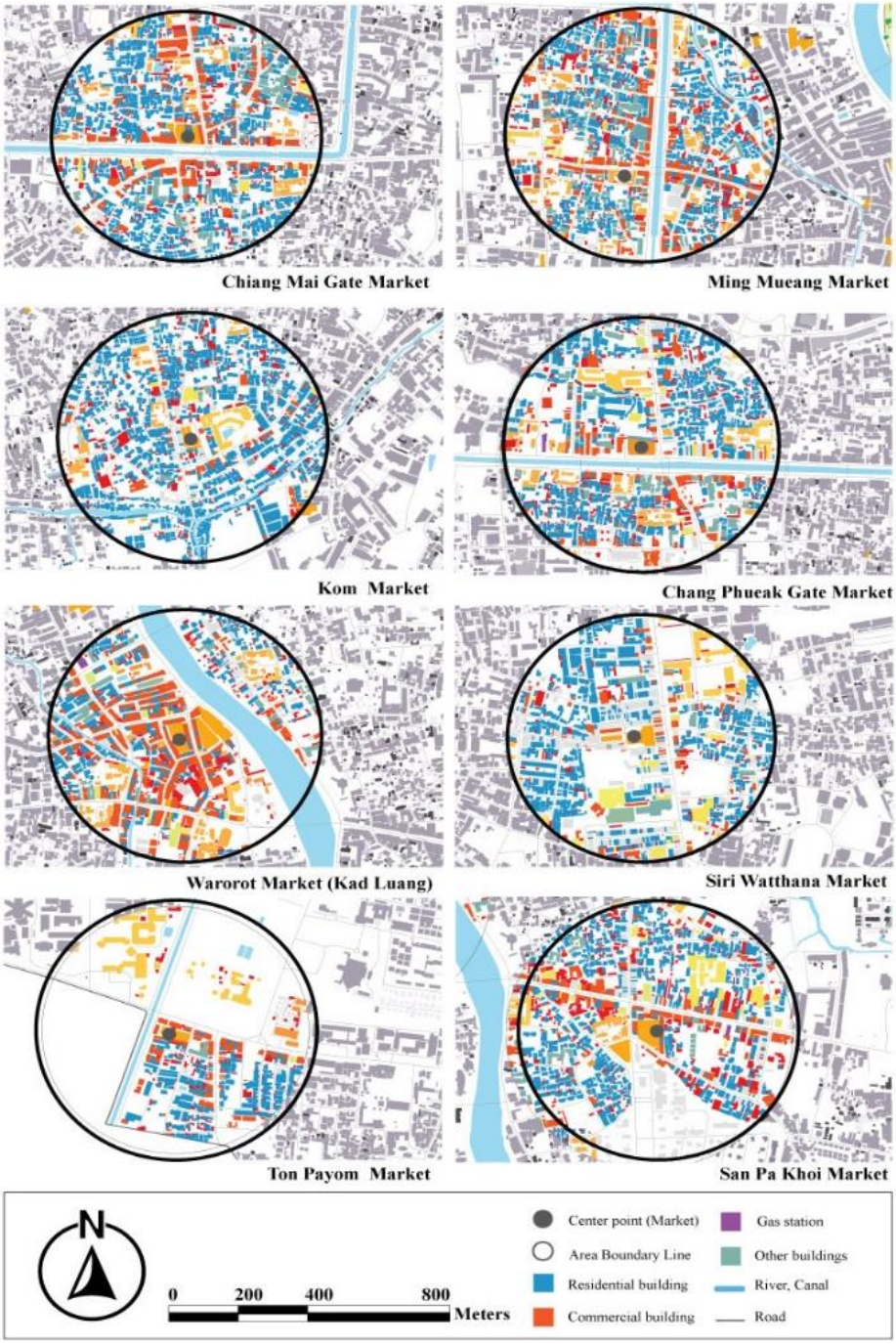

Figure 6 Analysis of Community Fire Risk Areas around the Market in Chiang Mai in a Radio of 400 meters

5. Results and Discussion

Regarding analysis results of essential factors for the proposal for the management of areas that cause risks, vulnerability, and potential, based on physical surveys with the application of geographic information system to estimate the damage level, loss, or the impact of the situation, it can be concluded that 3 areas around the market in Chiang Mai (Figure 6) met the high-class risk criteria, namely the communities around Chiang Mai Gate Market, Ming Muang Market, and San Pa Koi Marke with high importance and urgent actions. 3 areas met moderate-class risk criteria, including the communities around Kom Market, Chang Puak Gate Market, and Warorot Market, with normal actions. 2 areas met the low-class risk criteria, namely the communities around Siriwatthana Market and Ton Phayom Market Which without any actions or with management within the area (Figure 7). All of this was a quantitative risk. There may be different details in each area. The factors that result in differences in each area include the effect size on the people in the area, property damage, loss of life, and the estimation of the probability of damage or loss that will occur. The impact may be on the money, asset, property, social operations, or people. The risk analysis was an essential continuous step since it provides crucial data for risk estimation and decisions for overall risk management.

If figures are inserted into the main text, type figure captions below the figure. In addition, submit each figure individually as a separate file. Figures should be provided in a file format and resolution suitable for reproduction, e.g., EPS, JPEG or TIFF formats, without retouching. Photographs, charts and diagrams should be referred to as "Figure(s)" and should be numbered consecutively in the order to which they are referred

6. Recommendations in Research

The Risk prioritization can be used to identify the risk that needs special attention through the application of a geographic information system and the process of risk score criteria to analyze the importance of fire risks to consider influential risk factors in managing fire risk areas. Therefore, the researcher proposed the guidelines for prevention and mitigation management plan accurately and suitably for the context of the surrounding community areas as follows:

1. Fire protection should be enhanced by focusing on prevention to reduce opportunities and severity by raising awareness for community leaders and people of the problems and safety of the community at all times.

2. Public relations campaigns and activities should be held to stimulate community leaders, people, and public and private sectors to focus on the distribution of knowledge in prevention and mitigation in each area for the understanding of the danger of fire and knowledge and understanding of disaster prevention and mitigation in their areas and the surrounding areas.

3. Laws related to fire protection management should be integrated through clear classification of the issues, including the design, construction, and activities for the public and private sectors to understand the purpose of the law; the law to inspect the building should be enforced seriously through indicators to monitor and evaluate the performance.

4. Training should be provided to enhance knowledge on fire prevention and suppression for promoting public participation and various sectors to be aware of self-defense and understanding of fire, especially the dangers that may occur to young children and the elderly in the residential areas.

5. Community leaders, volunteers, or people in the area should practice using tools for effective prevention.

6. Tools should be sufficient for fire protection in the community.

7. The level of loss from fire risk should be maintained at the same level or not exceed the standard, or it should be reduced every year.

8. An emergency plan should be prepared to develop annual fire management drills along with training on situation assessment for community leaders, volunteers, or people in the area to recognize and understand the situation to reduce fire extinguishing time and losses in all parts.

9. The collaboration between the public and private sectors and the general public should be enhanced through cooperation networks with agencies to achieve maximum efficiency in the area, such as improving the transportation routes' efficiency.

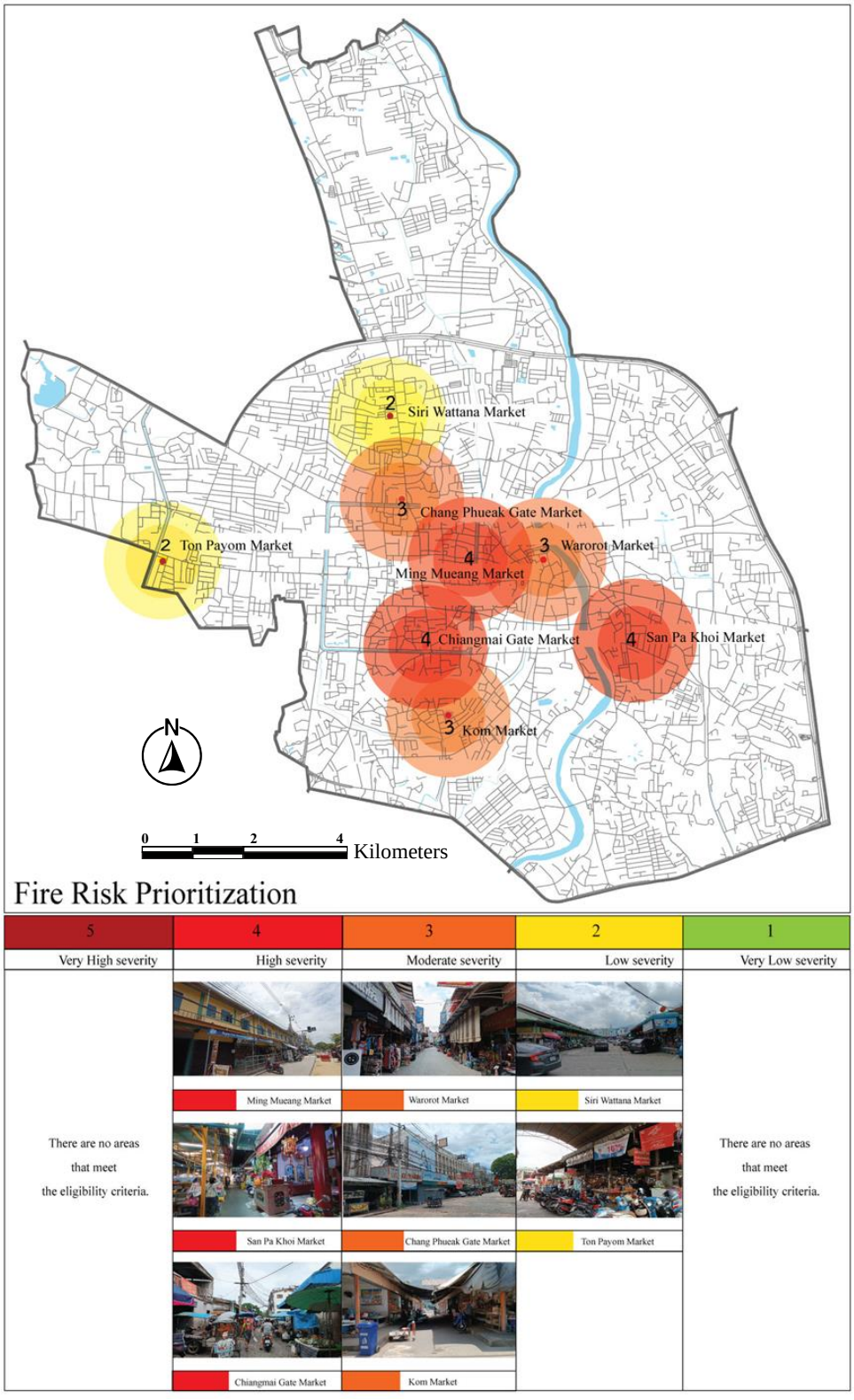

Figure 7 Analysis of Fire Risk Prioritization around the Market

7. Acknowledgements

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