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A Spatiotemporal Analysis of Fire Incidents in Pampanga Province of Philippines: Inputs for Fire Prevention Programs

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Abstract

The use of spatiotemporal analysis in big data sets reveals the underpinning theories to understand the environmental phenomena, given the space and time, that later can be used in decision making. This study examined the fire-related incident data obtained from 2013 up to 2020 from the Bureau of Fire Protection in the province of Pampanga. The examination of fire-related data identified the top causes of fire in the province. The researchers obtained fire-related data from 2013-2020 from the Fire bureau for mapping and examining of correlation between space and time. Data cleaning was conducted to fix incomplete or duplicating data within a dataset. The processed data are interpreted through charts and were utilized to examine and correlate collected processed data. Key issues explain that fire incidents are likely to happen mostly on Sundays and Mondays in highly-urbanized cities (Angeles, Mabalacat, and the City of San Fernando) in March and December, mostly occurring in the afternoon between 2:00-3:00 PM. Furthermore, spatiotemporal process reveals specific barangays geographically-located in flood-prone areas are likely to experience fire cases. The application of spatiotemporal method is likewise recommended to strategically identify and empowers the programs to be developed in fire bureau strategic planning.

Discipline: Spatial Analysis, Data Science (Data Mapping and Analysis), Fire Management & Prevention.

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1 Introduction

Fire has been a global contributing factor that takes away life and non-life properties and affects the economic growth of the community. The implementation of the Philippines' Bureau of Fire Protection (BFP) mandates and functions enforces the prevention and extinction of any damaging fires, including those that occur in buildings, houses, and other structures, forests, automobiles and machines and equipment, and petroleum industry installations, among others (Bureau of Fire of Protection, n.d.). In addition to this, the said bureau is mandated and has the capacity to examine all causes of fires and participates in judicial processes should there be legal obstructions in the said fire incidence. This is bound by the enforcement of the Fire Code of the Philippines and other related directives. Fire has been recognized globally as a perennial tragedy where most of the time victims were left homeless and nothing was spared. Fire incidents impact people's lives, property and the environment.

The bureau designs and implements a strategic plan in preventing fire in the community. As part of fire prevention, a variety of fire prevention programs are created in an attempt to instill consciousness among the community about the sources of fire. In this paper, the researchers process fire data from the year 2013-2020 in the province of Pampanga. Data analytics will be employed to uncover significant information that will be used as input in designing fire prevention programs. It is necessary to view fire incidents in totality. The cause of the fire, its location, affected lives and properties, its cost and damages, the time it happened, as well as fire services such as response time are essential key data that may later draw fire patterns. Data analytics deals with processes, tools and strategies for analysis and management, as well as data collection, organization, and storage. The basic objective of data analytics is to use statistical analysis and technology on data to discover trends and solve problems (Olavsrud, 2021). As a tool for analyzing and influencing business processes, as well as improving decision-making and business outcomes, data analytics is becoming increasingly important. Thus, spatiotemporal analysis was used to examine the data from the BFP in the province of Pampanga to provide input to its fire prevention programs.

2 Literature Review

2.1 Fire Prevention Program in the Philippines

BFP is following a strategic plan to mitigate fire incidents from happening. Fire prevention is a proactive method to educate the public regarding the potential harm of fire and how to prevent them as well as reduce its damage. The bureau conducted annual efforts in response to the increasing number of fire incidences. In December 2019, the PSA released a 2017 report on Integrated Survey on Labor and Employment highlighting Occupational Safety and Health (OSH) Practices. In this 2017 report, 98.1% of the 32,288 establishments with 20 or more employees surveyed have implemented different preventive and control measures/activities to safeguard workers from avoidable danger and injury in the workplace. The most prevalent measure/activity

used by the establishments was the posting of safety signages and warnings, which accounted for 86.4% of the total. Other common measures/activities were smoke-free workplaces, earthquake, fire, and chemical spills; emergency planning and response activities, designation of safety/health officials and/or first-aiders and regular inspection and repair of equipment.

Fire prevention and control program tops the OSH policies/programs usually implemented by establishments with 82.6% of the total establishments surveyed. This shows the BFP's commitment to empowering establishments during fire occurrences. The bureau has conducted 45.1% of the recorded OSH-related training/seminars. Fire safety training was the most common among the training/seminars which accounted for 51.6% of the establishments (Philippine Statistics Authority, 2019).

2.1.1 Fire Cases in the Philippines

Across the country, fire has been a perennial problem due to weather and combustible materials often used in residential and industrial structures. The steady high fire records show that BFP still has to strictly implement its strategic programs in mitigating fire. On average per year, the Philippines has 15,733 fire incidents from 2013-2018 with 855 fire-related injuries and 253 fire-related deaths (Congressional Policy and Budget Research Department, 2020).

Similarly, researchers conducted few studies involving the Philippines' fire cases. Balahadia and Trillanes (2017) stated that spatiotemporal investigation of fire incidents might allow authorities to plan sustainable logistics in firefighting programs based on the place and timing of fire incidents. Fire suppression through temporal and geographic analysis requires precise fire mapping techniques that can provide models of fire incidents. The mapping of hazard-prone areas is a frequent method of tracing disaster patterns; thus, it generates fire-risk-specific whereabouts (Balahadia & Trillanes, 2017).

Results showed from a prior study that fire incidents that occurred in Manila, Tondo and Sampaloc areas from 4 pm to 8 pm have the highest fire incidents. This result doubles in the summer months when all cooling appliances are at working their maximum. Most fire incidents are caused by faulty electrical connections, unattended open flames and cigarette butts. These commonly happen in heavily-dense population areas. The encoded fire data are based on 2011 – 2015. Looking closely at the data, fire occurrences usually start in informal settlements where most citizens lack knowledge of fire prevention. In addition to this, most of the shelter materials are made from combustible materials. With these, the researchers recommended that additional areas should be subject to examination.

Urrutia et al. (2018) on the other hand, used multiple linear regression examined through EViews7 and MATLAB to analyze fire accidents within the range 2016-2020. Balahadia and Trillanes (2017) complemented the results obtained by Urrutia, et.al. having March with the greatest number of fire incidents in 2015 with 2,863 fire incidents (Urrutia et al., 2018). Aside from faulty electrical connections, spontaneous combustion (in March 2015) and unattended

cooking/stove (March 2015) is the top cause of fire incidences. It has also to be noted that open flame due to torch (April 2014) and unattended lighted candle or gas station (from 2005 to 2010) contribute to an increased number of figures in the data. Bringula and Balahadia (2019) further point out that the perception of unattended cigarette butts will not cause big fire incidents should be changed. The unattended cigarette butt in this study ranked second in this study (Bringula & Balahadia, 2019). Faulty electrical wiring is the primary cause of fire incidence, the government must have the political will to subject building owners to standard electrical wiring designs.

In another study that analyzed fire incidents from 2009-2013, the province of Batangas recorded those electrical connections were the main cause of fire incidents with a frequency of 25.54%, followed by overheating of electrical appliances (23.39%) and grassfire (22.9%) (Cabañas et al., 2017). Fire incidents seem to frequently happen in residential types with a frequency of 62.75%, followed by commercial/mercantile type of structures with a frequency of 7.25%. The researchers conducted the said study through a retrospective method where it found that fire incidents increased in 2013 due to the height of the barangay elections campaign period where arson cases were used as black propaganda by some election candidates. Not to mention the business establishments who want to claim fire insurance because of the low economic income experienced that year plus the increase in temperature in the country.

Data analytics have been a major contributing factor in the attempt to lower fire incidence, that is through predictive analytics (Qureshi, 2021). Analyzing tons of data with abundant values and attributes provides more significant fire information. Data analytics with spatiotemporal provides more insights to determine the likelihood that fire may occur at a period and specific area or region. Experts see these [2] approaches as a potential tool in fire prevention and damage control. Fostering a culture of fire prevention (Lacey & Valentine, n.d.) saves not only citizens and properties but also serves as a healthy indicator of protecting the firefighting personnel. Serious efforts that fire prevention culture has already been integrated into people's minds is when at the start of the construction of a structure/building/house, the shaping model of fire prevention and mitigation is already inculcated.

3 Research Objectives

This study's objective is to examine the fire incident data in the province of Pampanga and report its results through spatiotemporal analysis. Moreover, the study intends to

1) describe the incidents in terms of date, time, location, cause, alert level, establishment involved, and assessed damage value;

2) determine if the spatiotemporal attributes of fire incidents using the historical data from the BFP Pampanga; and

3) determine the possible value of the findings towards improving fire prevention programs implemented in Pampanga.

4 Materials and Methods

Reflected in Figure 1 is the process flow of the study, it indicates the study will start with data collection, then collected data will be subjected to data cleaning and pre-processing in order to prepare it for spatiotemporal analysis. The analysis will then be used for recommendations for fire prevention programs.

Figure 1: Process Flow of the Study

4.1 Data Collection

All official historical data of fire incidents in Pampanga was requested and collected from BFP Region 3 located in Sto. Tomas, Pampanga. The data coverage provided by the BFP was from January 2013 to December 2020.

Republic of the Philippines
Department of the Interior and Local Government
BUREAU OF FIRE PROTECTION
Regional Office 3
INVESTIGATION AND INTELLIGENCE BRANCH

MONTHLY FIRE INCIDENT MONITORING SHEET
CY 2013

No.	Date and Time	Location (complete address)	INVOLVE ESTABLISHMENT NAME of OWNER/s - OCCUPANT/s	ALARM STATUS	CAUSE of FIRE	NAME of FATALITY / INJURED	Status of Case/Amount of Damage
				JANUARY			
1	02 1950H Jan 2013	San Agustin, Candaba	Residential	1st Alarm	Unattended lighted lamp	Negative	50,000.00
2	03 0456H Jan 2013	Purok I, Sapang Maisac, Mexico	Mixed (Shanty and Junkshop)	1st Alarm	Unattended lighted cigarette butt	Negative	500,000.00
3	03 1043H Jan 2013	Cangatba, Porac	Vehicular	1st Alarm	Electrical short circuit	Negative	5,000.00
4	04 0830H Jan 2013	#443 Gen. Hizon Ave., Del Pilar, City of San Fernando	Residential	1st Alarm	Electrical appliances (overheated electric fan)	Negative	8,000.00
5	04 1148H Jan 2013	Sampaloc, Apalit	Residential	1st Alarm	Unattended cooking	Negative	60,000.00
6	05 1637H Jan 2013	Sta. Lucia Anac, Masantol	Residential	1st Alarm	Electrical appliances (overheated rechargeable flash light)	Negative	7,000.00
7	10 1150H Jan 2013	60-88 and 6094 Igante St., Lourdes Northwest, Angeles City	Residential	1st Alarm	Unattended lighted candle		120,000.00
8	13 0900H Jan 2013	1168 Jupiter St., San Fernando Subd., Sto. Niño, City of San Fernando	Residential	1st Alarm	Unattended lighter	Negative	100,000.00
9	18 0245H Jan 2103	Purok 03, San Isidro, City of San Fernando	Vehicular	No operation	Electrical short circuit	Negative	20,000.00
10	19 1309H Jan 2013	Blk 29 Lot 1 Pandacaqui, NHA, Mexico	Residential	2nd Alarm	Electrical short circuit	Negative	300,000.00
11	22 1425H Jan 2013	San Nicolas, Sitio Suluk, Masantol	Residential	2nd Alarm	Electrical short circuit	Negative	200,000.00
12	23 1425H Jan 2013	No. 16 Margarita St., Pilar Village, San Isidro, City of San Fernando	Residential	1st Alarm	Unattended lighted matches	Negative	8,000.00

Figure 2: Partial capture of the dataset in spreadsheet format.

Table 1: Fire attributes and their description.

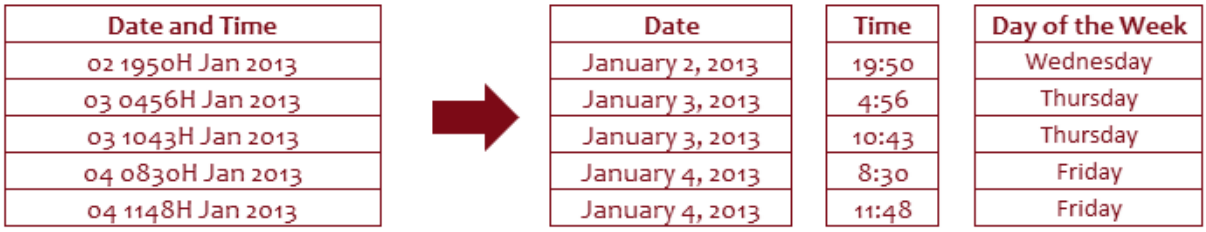
Attribute	Description
No.	The record number for each fire incident within a year
Date and Time	The date and time of the fire incident
Location	The location of the fire incident
Cause of Fire	They involve the establishment and name of the owner or occupants
Name of Fatality / Injured	The fire alarm level
Status of Case/ Amount of Damage	The detailed cause of the fire

Figure 2 provides a partial capture of the dataset in spreadsheet format. Table 1 shows that 8 main attributes can be found from the raw data provided by the BFP. The data consisted of the

following attributes: no. date and time, location, involved establishment/occupancy, alarm status, causes of fire, name of fatality/ injured, and status of care/amount of damage.

4.2 Data Cleaning and Preprocessing

On the data cleaning and pre-processing, several steps were followed. The "No." attribute was removed as it does not contain any information other than serving as a record count per year. The fatality/ injured was also removed from the dataset as this is not part of the scope of the study.



Date and Time
02 1950H Jan 2013
03 0456H Jan 2013
03 1043H Jan 2013
04 0830H Jan 2013
04 1148H Jan 2013

Date	Time	Day of the Week
January 2, 2013	19:50	Wednesday
January 3, 2013	4:56	Thursday
January 3, 2013	10:43	Thursday
January 4, 2013	8:30	Friday
January 4, 2013	11:48	Friday

Figure 3: Extraction of the new date, and time attributes from the Date and Time attribute

As seen in Figure 3, the date and time within the raw data are in text format, therefore it cannot be processed the way it is. To solve this, a new attribute was created (i.e., date, time) which was extracted from the Date and Time attribute from the raw data. The day of the week attribute was also extracted from the date.

Location (complete address)
60-88 and 6094 Igante St., Lourdes Northwest, Angeles City
1168 Jupiter St., San Fernando Subd., Sto. Niño, City of San Fernando
Purok 03, San Isidro, City of San Fernando

Barangay	Municipality
Lourdes Northwest	Angeles City
Sto. Niño	City of San Fernando
San Isidro	City of San Fernando

PSA_Barangay	PSA_Municipality
Lourdes Northwest	Angeles City
Sto. Niño	City of San Fernando
San Isidro	City of San Fernando

Figure 4: Extraction of Barangay and Municipality from the Location attribute.

From Figure 4, the data for the location of the fire incidents are not in a unified format, some contain the exact location (i.e., house number and street address) of the fire incidents while others do not. The only common within the location attribute is the presence of the barangay and the municipality. In order to make the data uniform, an additional two (2) new attributes were created (Figure 4) (i.e., barangay and municipality attributes). The two new attributes were further pre-processed and subjected to counter-checking as the record used multiple names for one barangay or municipality. The study used the official names from the Philippine Statistical Authority for the final names to be used for the barangay and municipality. This is process is crucial to make the data usable for spatiotemporal analysis. For the involved establishment attribute, the name of the establishment and any name that can identify a person within this attribute were removed. For the causes of fire, the data from this attribute was reclassified into 20 main causes (Table 2).

Table 2: Causes of Fire.

Code	Main Cause of Fire
1	Faulty electrical connection
2	Neglected cooking stove
3	Open rubbish
4	Cigarette butt
5	Torch
6	Candle
7	Matchstick and lighter
8	Direct flame contact
9	LPG related
10	Neglected electrical appliances and devices
11	Overheated industrial machinery
12	Electrical machinery
13	Chemicals
14	Incendiary devices and flammable liquid
15	Spontaneous combustion
16	Pyrotechnic
17	Bomb explosion
18	Lightning
19	Under investigation/unknown
20	Other causes of fire

4.3 Spatiotemporal Analysis

Table 3: Number of Barangay, population, and income class of 19 towns and 2 cities in Pampanga including Angeles City (Philippine Statistics Authority, 2017b, 2017a).

Cities/ Municipalities	No. of Barangay	Population Density (per km2)	Total Population	Household Population	Number of Households	Income Class
Angeles City	33	6,830	411,634	408,885	96,219	1st
Mabalacat City	27	3,015	250,799	250,659	56,650	3rd
City of San Fernando	35	4,527	306,659	304,211	68,272	1st
Apalit	12	1,756	107,965	107,740	23,779	1st
Arayat	30	993	133,492	133,480	28,144	1st
Bacolor	21	550	39,460	39,393	9,593	3rd
Candaba	33	633	111,586	111,586	22,664	1st
Floridablanca	33	713	125,163	125,014	28,915	1st
Guagua	31	2,413	117,430	116,807	26,336	1st
Lubao	44	1,033	160,838	160,838	34,492	1st
Macabebe	25	721	75,850	75,840	16,321	1st
Magalang	27	1,163	113,147	112,390	24,484	1st
Masantol	26	1,183	57,063	57,061	11,946	2nd
Mexico	43	1,317	154,624	154,481	32,518	1st
Minalin	15	988	47,713	47,713	9,931	4th
Porac	29	396	124,383	124,326	27,474	1st
San Luis	17	952	54,106	54,106	10,945	3rd
San Simon	14	927	53,198	53,194	11,420	3rd
Santa Ana	14	1,385	55,178	55,178	11,115	3rd
Santa Rita	10	1,377	40,979	40,926	9,064	4th
Santo Tomas	7	1,900	40,475	40,447	9,214	4th
Sasmuan	12	305	28,004	28,004	5,805	4th
TOTAL	538	1,265	2, 609,744	2,602,279	479,082	-

For the analysis of the data, Python programming and Tableau software was both used. For mapping the location of the fire, Python programming was used while for the graphical representation of the fire and further analysis in terms of time and location and other attributes,

Tableau software was used. Basic statistical reports such as frequency and percentage were also reported. From Table 3, the number of barangays in Pampanga, its population and their income classes which include Angeles City. This table along with the results from the analysis was used to determine what are the possible implication of the results of the study for improving the fire prevention programs of the BFP.

5 Results and Discussion

5.1 Fire Incidents in Pampanga

Presently, there are 3,048 fire incidents recorded by the Regional Office of the Bureau of Fire Protection (BFP) in Pampanga, Philippines from 2013 to 2020. As seen in Table 4, most incidents (n = 1,907) are recorded in the afternoon between 8:00 AM to 4:59 PM and peaks from between 2:00 to 2:59 PM (n = 266) while lowest number of instances is between 6:00 to 6:59 AM (n = 32) (Figure 10).

Table 4: Fire incidents in Pampanga grouped by daytime.

TIME	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
Morning (12:00 AM to 7:59 AM)	45	52	33	36	42	38	46	42	334
Afternoon (8:00 AM to 4:59 PM)	140	357	250	149	134	176	433	270	1909
Evening (17:00 to 11:59 PM)	80	151	112	85	48	65	146	118	805
TOTAL	264	560	395	270	224	279	625	430	3,048

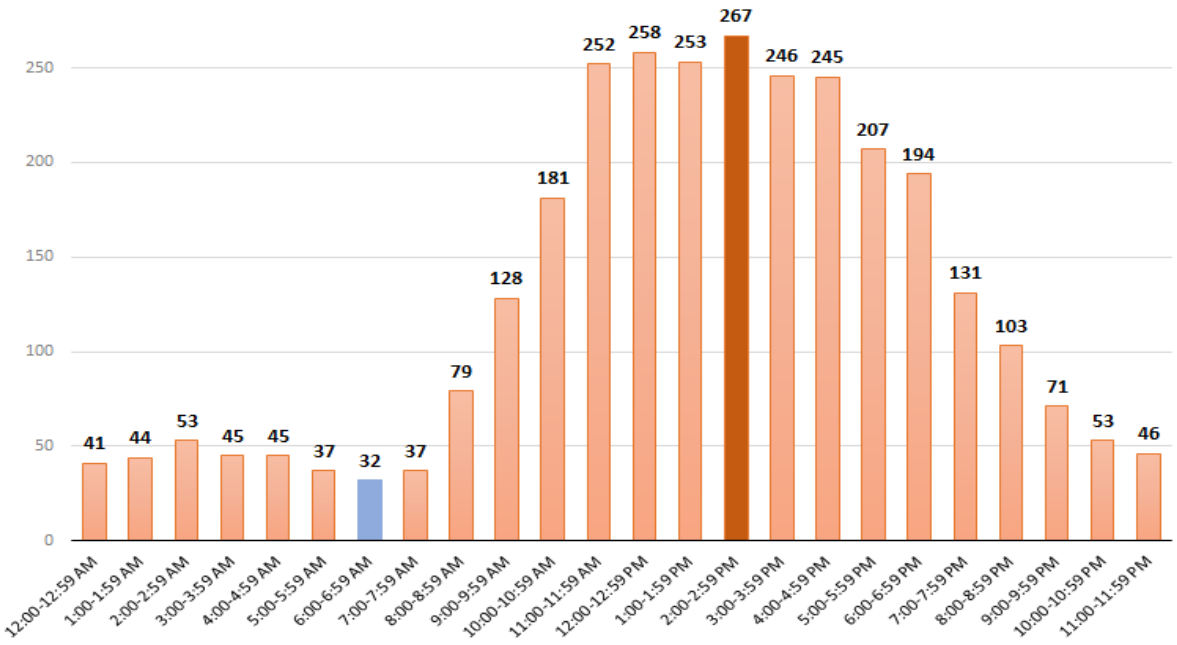


Figure 5: Hourly fire incidents in Pampanga

Figure 5 showed that the number of fire incidents started to rise from its lowest point at 6 AM to its peak at 2:00 to 2:59 PM and continued to go down. Similar findings were found in the study conducted in Manila by Bringula and Balahadia (2019), which showed that fire incidents increase during the daytime when people become active.

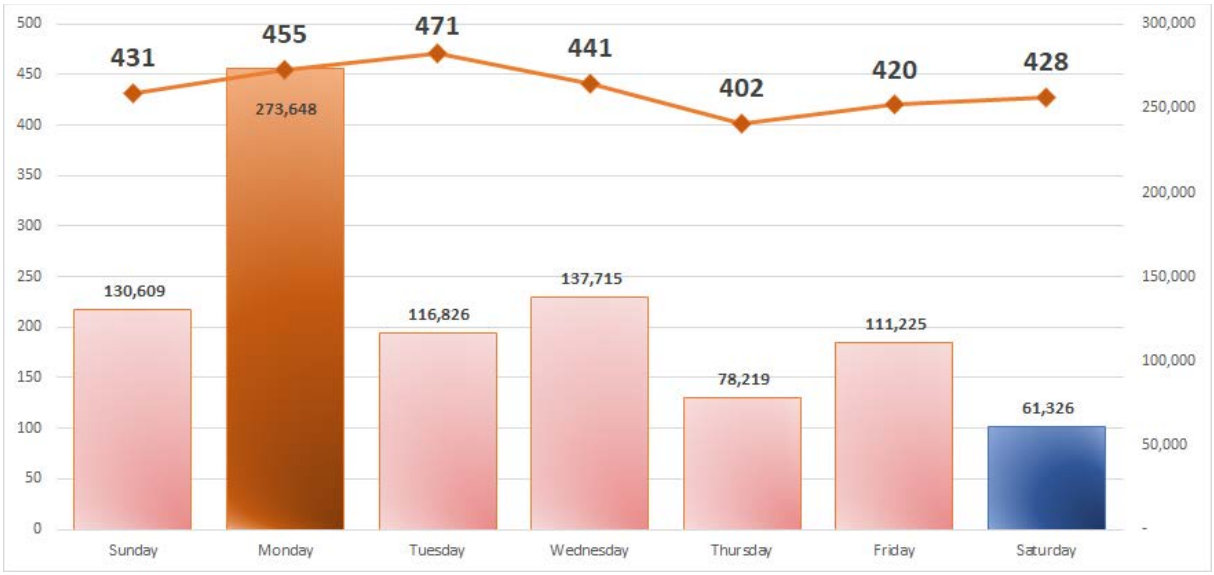


Figure 6: Daily fire incidents in Pampanga and their cumulative estimated damages (in thousands)

Figure 6 illustrates that in terms of estimated damages due to fire, cumulatively, Monday has a total of 273, 648 (in thousand), while Saturday has the least amount of total damages. On average, fire incidents are likely to occur on Monday and Tuesday (Table 5). Furthermore, fire incidents are at their highest on Tuesday (n = 59) but overall, the daily average of fires that happened from 2013 to 2020 is 54 (SD = 2.66).

Table 5: Annual average of fire incidents, estimated damage to property, fatalities and injuries in Pampanga by day of the week.

Day	Fires		Estimated Damage to Property (in Thousands)	
Sunday	54	14%	304	15%
Monday	57	15%	506	25%
Tuesday	59	15%	254	12%
Wednesday	55	14%	354	17%
Thursday	50	13%	150	7%
Friday	53	14%	310	15%
Saturday	54	14%	165	8%
TOTAL	381	100%	2043	100%

Figure 7: Monthly fire incidents in Pampanga and their average estimated (in thousands) damages

Figure 7 illustrates that in terms of monthly fire incidents, within the dataset, the month of March recorded the highest (n = 549). The incidents started to descend after their peak in March and started to rise again after September. Figure 16 also showed that incidents during the rainy season are low as compared to the incidents recorded during the dry season in the Philippines. Figure 3 also showed that the monthly average estimated damage is at its highest during December (i.e., 26,686 (in thousand))

5.2 Fire Cases Per Location in Pampanga

Table 6 showed that more than one-third or approximately 38% of the recorded fire incidents in Pampanga are attributed to cities (i.e., Angeles City, City of San Fernando, and Mabalacat City). It further showed that the City of San Fernando recorded the highest number of fire incidents (n = 491) while the municipality of Sasmuan has the least number of fire incidents recorded (n = 141).

Table 6: Fire incidents recorded in Pampanga are grouped by cities, municipalities, and year.

Cities/ Municipalities	2013	2014	2015	2016	2017	2018	2019	2020	%
City of San Fernando	54	95	49	46	23	54	102	67	16.11
Macabebe	32	86	37	29	22	23	87	65	2.43
Angeles City	52	95	28	15	19	18	61	30	10.43
Bacolor	16	31	23	20	11	24	66	50	7.48
Lubao	13	25	40	27	18	31	46	28	2.92
Minalin	15	11	49	10	33	17	25	16	3.31
Sasmuan	6	25	13	4	27	12	33	21	0.49
Apalit	8	28	14	23	13	15	12	7	4.30
San Luis	7	16	9	10	3	9	34	24	0.95
Santa Ana	6	14	14	10	13	21	18	15	2.95
Guagua	9	11	2	5	1	7	40	30	7.81
Porac	4	28	28	12	4	1	12	6	3.84
Mabalacat City	7	15	30	8	5	5	12	11	11.35
Santa Rita	2	8	12	9	6	15	16	12	2.66
Magalang	1	22	16	13	2	8	8	3	2.26
Masantol	5	20	10	8	3	5	11	10	0.69
Santo Tomas	4	4	2	11	8	8	15	10	5.09
Arayat	6	9	4	2	1	4	13	9	1.57
Candaba	8	4	3	1	1	1	6	4	0.95
San Simon	2	6	5	2	8	0	2	2	3.41
Mexico	3	4	4	3	2	1	2	0	5.68
Clark Freeport Zone	2	3	3	2	0	0	3	2	0.16
Floridablanca	3	0	0	0	1	0	1	0	3.15

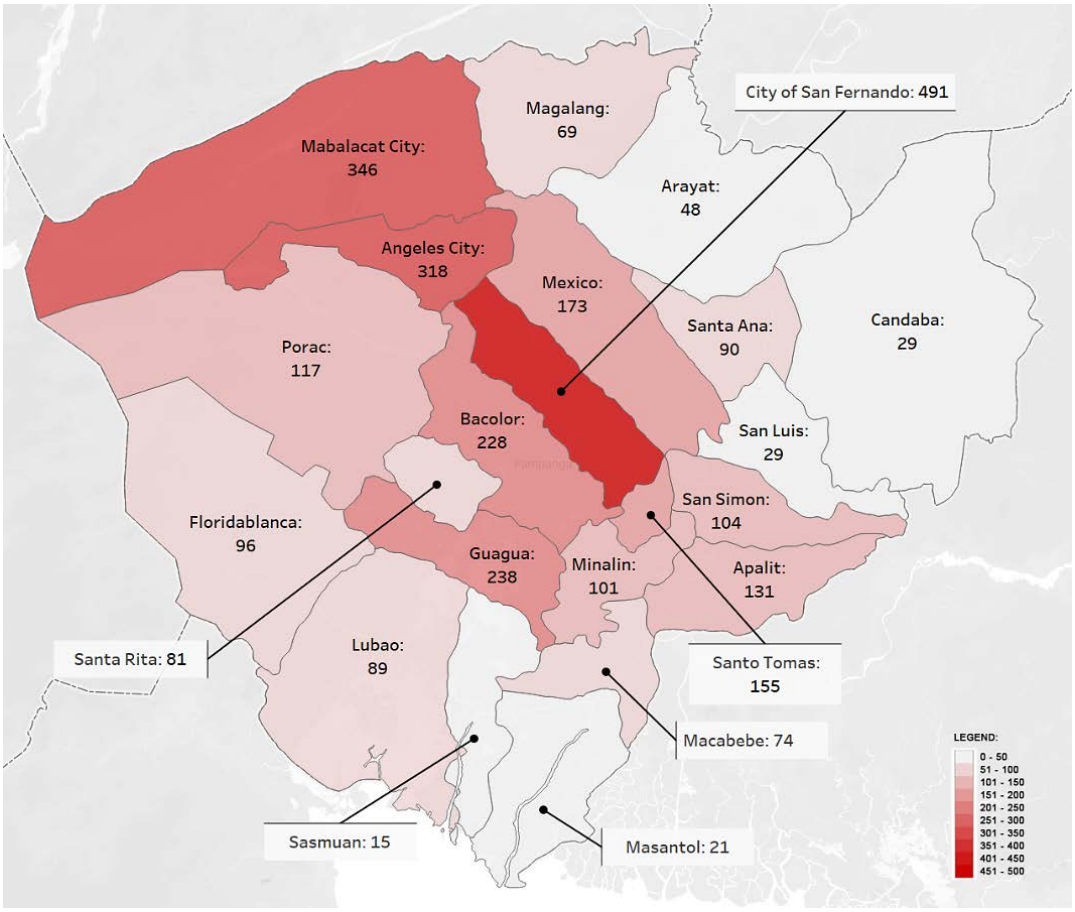


Figure 8: Fire incidents in Pampanga per municipality excluding Clark Freeport Zone

Figure 8 illustrates that towns with the highest number of recorded fire incidents are close to each other. In particular, fire incidents among towns around the 3 urbanized cities (i.e., City of San Fernando, Angeles City, and Mabalacat) of Pampanga are relatively high as compared to those far areas such as Sasmuan, Masantol, and Candaba. One possible reason why fire incidents in these 3 towns are relatively low is due to their low population density (Philippine Statistics Authority, 2017b). Additionally, the top 10 towns as seen in Table 7 comprised 2301 or 75.49 percent of all fire incidents recorded in Pampanga excluding Clark and the expressways.

Table 7: Top 10 cities and municipalities with their highest and lowest fire incidents recorded in a barangay excluding NLEX, SCTEX, and Clark.

City/ Municipality	Barangay with Highest Incidents	#	%	Barangay with Lowest or No Incidents	#	%
Angeles City	Balibago	35	11.08	Lourdes Sur East and Salapungan	0	0
Apalit	San Vicente	42	32.56	Calantipe and Cansinala	0	0
Bacolor	Cabalantian	45	19.74	Balas and Concepcion	0	0
City of San Fernando	Dolores	59	12.19	Dela Paz Sur	1	0.21
Guagua	San Matias	29	12.24	Rizal	0	0
Mabalacat City	Dau	65	19.64	Macapagal Village and Santo Rosario	0	0
Mexico	Lagundi	27	16.36	Buenavista, Cawayan, Concepcion, Culubasa, San Lorenzo, San Nicolas, and San Patricio	0	0
Porac	Manibaug Pasig	15	13.04	Calzadang Bayu, Camias, Diaz, Inararo, Pias, Sapang Uwak, and Villa Maria	0	0
San Simon	Santa Monica	31	32.29	Santa Cruz	0	0
Santo Tomas	San Matias	43	27.74	San Bartolome	6	3.87

Table 7 showed that Balibago, Angeles City recorded the highest number of fire incidents. In the 2015 census, Barangay Balibago is ranked as the most populous barangay in Angeles City (Philippine Statistics Authority, 2017a). This is the same for the town of Apalit, Mabalacat City, and San Matias (Philippine Statistics Authority, 2017b). Sasmuan, Masantol, San Luis, Candaba, and Arayat have the least number of recorded fire incidents. In 2020, these 5 municipalities are considered low-lying and flood-prone areas by the Pampanga LGU (Regala, 2020).

Figure 9: Fire incidents in a Barangay with an average of more than 3 annually excluding Clark, NLEX, and SCTEX

Figure 9 illustrates the barangay with at least 3 annual average fire incidents from 2013 – 2020. Figure 14 showed that Dolores in the City of San Fernando, Tabun and Dau in Mabalacat City has the highest annual average of fire incidents recorded. Moreover, Figure 14 displays those barangays with a high annual average of fire incidents are also relatively close to one another.

5.3 Fire Alarm Levels Recorded in Pampanga

In terms of fire alarm, Table 8 showed that the highest recorded fire alarm in Pampanga from 2013 to 2020 is Task Force Alpha which occurred only twice, both occurred in 2015. Fire alarm levels of recorded fire incidents in Pampanga are mostly in the first alarm (n = 2901). The main reason for this is that most fires involved rubbish as the main cause (Table 9) and grass fields as the establishment (Table 10).

Table 8: Fires in Pampanga grouped by alarm levels.

Alarm level	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
No operation	3	4	4	3	6	6	4	6	36
First alarm	242	537	364	250	210	268	612	418	2901
Second alarm	16	16	21	12	5	5	6	4	85
Third alarm	3	3	4	4	2	0	3	2	21
Fourth alarm	0	0	0	1	0	0	0	0	1
Fourth alarm	0	0	0	1	0	0	0	0	1
Task force alpha	0	0	2	0	0	0	0	0	2

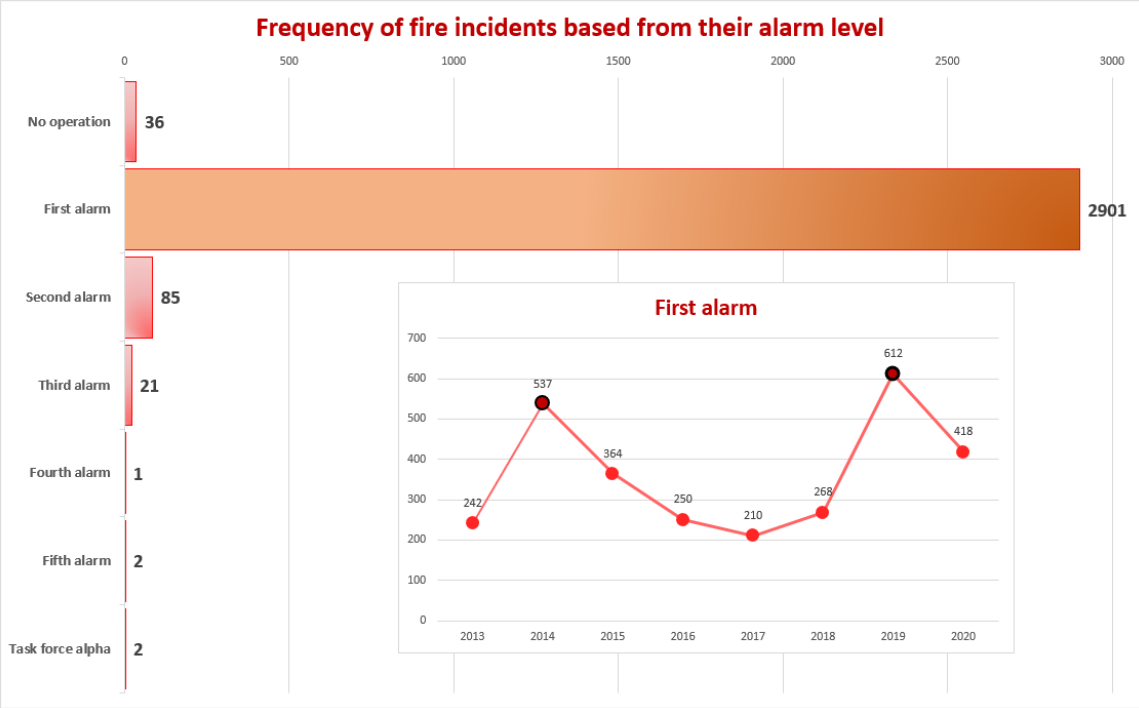


Figure 10: Recorded alarm levels

Figure 10 showed that in terms of fire incidents recorded as first alarms, the incidents annually have an upward trend from 2013 to the present with an annual average is 363 and ranging from 210 to 612.

5.4 Causes of Fires in Pampanga

The main cause of fire in Pampanga is rubbish or garbage (Table 9). Rubbish due to fire (n = 1860) accounted for 61% of all fires recorded. Table 8 further showed that fire incidents can are attributed to faulty and neglected electrical connections and devices as well as due to open flames such as candles, lamps, and cooking stoves.

Table 9: Top 5 causes of fire in Pampanga from 2013 to 2020.

Causes of fire	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
Rubbish	80	416	274	139	98	128	455	270	1860
Faulty electrical connection	92	75	40	68	66	91	76	64	572
Neglected appliances and devices	27	13	6	8	15	13	20	18	120
Candle and lamp	11	14	12	16	14	10	12	12	101
Neglected cooking stove	6	5	9	9	9	7	12	15	72

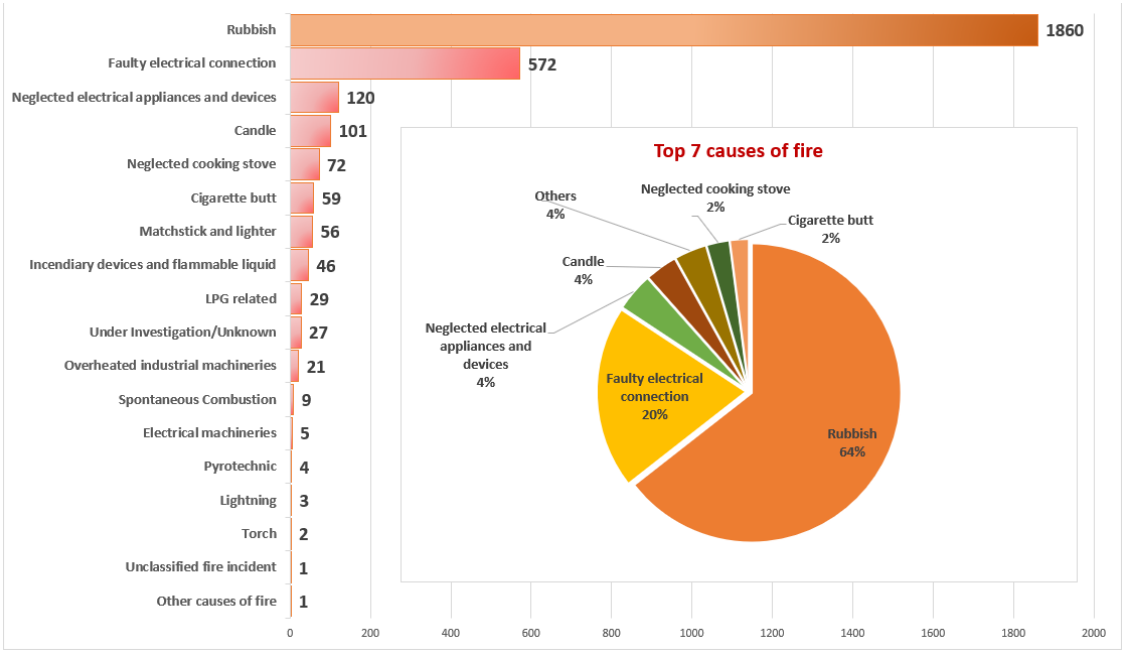


Figure 11: Causes of Fire in Pampanga

Figure 11 showed that more than half or 64% of the top 7 fire causes came from rubbish followed by faculty electrical connection (20%), neglected electrical devices (4%), open flame (e.g., 4% from the candle, 2% from the neglected cooking stove) and cigarette butt (2%).

5.5 Establishment Involved in Fires in Pampanga

Most fires involved grass field (n = 1708) and residential (n = 720) establishment as shown in Table 10. This is consistent with recorded causes of fire which are rubbish, faulty and neglected electrical connections, open flame and a cigarette butt.

Table 10: Top 5 establishment types involved in fire incidents from 2013 to 2020.

Establishment	2013	2014	2015	2016	2017	2018	2019	2020	TOTAL
Grass	65	391	251	124	89	111	424	253	1708
Residential	106	87	75	92	73	92	99	96	720
Vehicular	28	16	11	12	21	23	36	28	175
Garbage	10	22	18	9	1	7	14	9	90
Storage	9	4	5	8	12	9	15	12	74

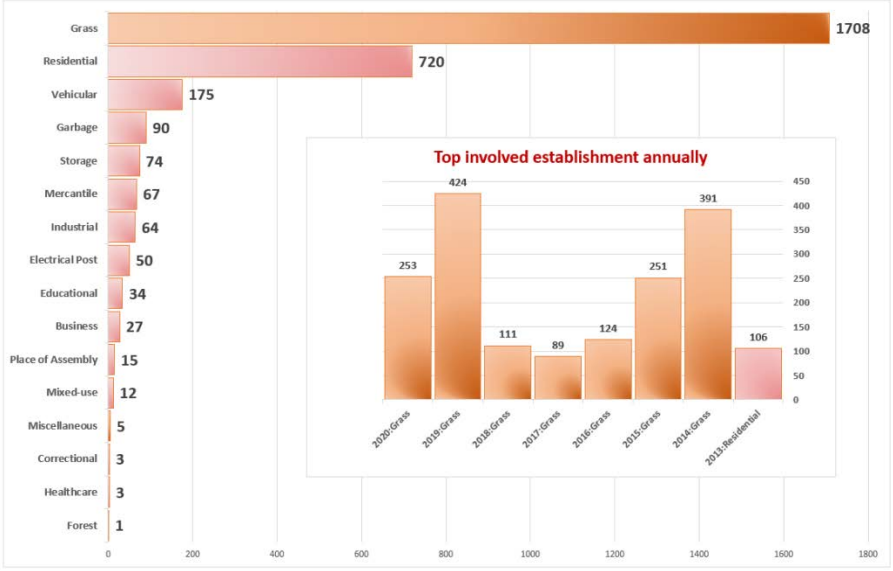


Figure 11: Involved establishments and the highest establishment involved per year in Pampanga

Figure 12 showed that fires from grass fields and residential top the list in involved establishments in Pampanga. From 2013 to 2020, fires from grass fields were attributed to more than half or 56% of all involved establishments. Fire coming from grass fields dominated the list from the year 2014 to 2020 with an average of 235 fires per year.

This study recommends further work to:

a. Decentralize and empower the local barangays to respond to fire prevention programs of the bureau by designing their strategic plan that is appropriate according to the geographic and demographic risks of their barangay.

b. Identify the most effective and accessible medium to educate the households concerning fire prevention programs by activating the local barangay's fire brigade. Regular periodic conduct of fire prevention seminars (webinars) and training will help inculcate a culture of the highly-aware fire-sensitive community.

c. The process of spatiotemporal identified lapses of BFP in terms of consistency in record entry of fire incidents. The designing of a web application for record-entry, and generating hotspots, will help normalize data inputs.

d. Perform intensive fire prevention campaigns, especially on fire hotspots, to consistently reduce the number of fire incidents. The process of spatiotemporal is better to be replicated in region 3 provinces to collectively ease fire incidence occurrences.

e. The common causes of fire and the profile of victims should comprehensively be examined to determine customized fire prevention programs according to the geographic characteristics of the municipality. Highly-urbanized cities and component cities, according to the study, have the most number of fire incidents. The results of the study should be utilized in the conduct of urban planning. Therefore, a close collaboration with the Department of Environmental and Natural Resources and other environment-related government agencies should help design fire prevention promotional materials.

f. The bureau must also intensify, whether household or business establishment inspection, to strictly uphold training or seminar on fire prevention measures and fire safety equipment on a regular periodic basis. Training on how to develop fire safety and implementation plan should be elaborated at the barangay level.

g. Develop an expert system that can help the bureau to assess the fire hazard based on their existing data as well as to assists them to maximize their resources.

6 Conclusion

The application of spatiotemporal achieved to reveal the underlying phenomenon of fire incidents in the municipalities of Pampanga based on space and time. The results are essential inputs during the decision-making in determining what areas fire incidents are likely to happen. The results (such as geographically proven, time (and day)-bound, type of establishment) will help the Bureau of Fire Protection (BFP) in re-designing their campaign strategies in educating the households of Pampanga about fire prevention, as well fire services of the said agency.

7 Availability of Data and Material

Data can be made available by contacting the corresponding author.

8 Acknowledgement

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