Factors Caused Floods in Lahanam Village and Thakhamlieng Village, Savannakhet Province

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Abstract: ***To better understand the factors that cause flooding in Lahanam and Thakhamlien villages, Song Khone District, Savannakhet Province, the maximum daily rainfall at Lahanam Station (Song Khone District), Keng Kok Station (Champhone District) and Seno Station (Outhumphone District) Savannakhet Province was collected, followed by statistical analysis of data from 1999 to 2019. As a result of the analysis, the maximum daily rainfall of Lahanam station variesat104.65, 129.44, 144.97, 163.84, 177.46, 190.81, and 204.00 mm/day with the return period of 2, 5, 10, 25, 50, 100 and 200 years, respectively. Besides this, the maximum value of flood water was also calculated by using a formula and program analysis. The results of the calculation of Lahanam station vary at 300.3, 407.6, 496.9, 621.5, 741.7, and 879.5 cubic meters/second with the return period of 2, 5, 10, 25, 50, 100, and 200 years, respectively. In addition, the topography of the villages in the study area and nearby villages a total of 7 villages were investigated and it was found that the level of the area of Lahanam and Thakham Lien villages, which is a regular village affected by floods is 101 to 138 meters, the level of residential area is 121 to 130 meters and the level of the river bank is 119 to 126 meters compared to the average sea level. When there is a heavy rain event or a storm, the water flows over the bank and causes widespread flooding, especially in Lahanam village because it is a relatively flat area and their houses are located near the river bank and adjacent to 3 rivers (Se Bang Hieng, Se Sam soy, and Se Champhon).***

Keywords: rainfall, flood, storm, typhoon

1. Introduction

Lao People's Democratic Republic (Lao PDR) is a country located in a tropical climate zone, influenced by East Asia and India. Monsoons leading to high and frequent rainfall with an annual average rainfall of 1, 300 – 3, 000 mm (Department of Disaster and climate change management, Ministry of Natural Resource and Environment, 2016). In 2015 Lao PDR was severely affected by natural disasters, with seven major floods in seven northern and central provinces between June to September, flash flooding affected multiple people's lives and properties, social security, and major national socio–economic infrastructure loss.

Savannakhet Province is a province located in the central part of Lao PDR, on the east sharing a border with Vietnam which borders the South China Sea and the Gulf of Tongkeng. Every year, Savannakhet Province, as well as Lao PDR, is affected by storms influenced by the sea with different levels of strong/speed caused sudden rains and high water levels in major rivers such as Xebanghieng, Xechamphone, Xesamsoy, Xelanong, Xepon, Xebangnuan, and Xebangfai rivers, and widespread flooded to many areas (residential and agricultural areas…), and affected to people lives and properties. Based on statistics from the Department of Water Resources 2014 and a report from Songkhone District of Natural Resources and Environment 2018, serious floods in Savannakhet province occurred in 2004, 2005, 2011. The most flooding is from storms and heavy rains for several days such as 5 – 10 days, and 15 - 20 days in some areas. The continual heavy rain for several days caused the amount of water in the river to rise up than the normal level, water overflowed from the bank and flooded the area outside the original source of water causing damage to people's lives and property (Supitsa Thanalum, 2009; Suphavadee Peamchith, 2017; Chanya Boonson, 2017). Moreover, surface water occurs when the amount of rainfall or rainfall rate is higher than the soil absorption rate that allows water to flow through which depends on the characteristics of the soil, the initial moisture as well as blocking and storing capacity in various sources (vilaphon, 1988). In addition, another factor that caused the flood is the influence of storms. The Typhoon storm "Haima" hit the northern and central parts of Lao PDR, causing heavy rains, widespread flooding, and severe erosion in various provinces (The Government of the Lao PDR with support from the ADB, ADPC, FAO, GFDRR, Save the Children, UNDP, UNFPA, UNICEF, UNHABITAT, WFP, WHO, World Bank, World Vision, and WSP, 2011). Heavy rains from Tropical Storm "Son - Tinh" caused floods in many districts in 13 provinces across the northern, central, and southern parts of Lao PDR (2018 Lao PDR floods). Therefore, to explain the significant factors that influenced the floods in the study site, an analysis of the maximum daily rainfall in the lower Xebanghieng area was conducted to find the maximum rainfalls that may occur in the return periods of 2, 5, 10, 25, 50, 100and200 years.

2. Methods

2.1 Site descriptions

Lahanam and Thakhamlien villages, Songkhone District, Savannakhet Province were selected as the study sites. This area is located along Xebanghieng River bank, about 9 Km faraway from Songkhone district (Figure 1). In 2022, the population and number of households in these villages were 3, 522 and 570, respectively. The site is located between latitudes 1798660 N and longitudes 528620 E, with an average elevation of 138 m above sea level.

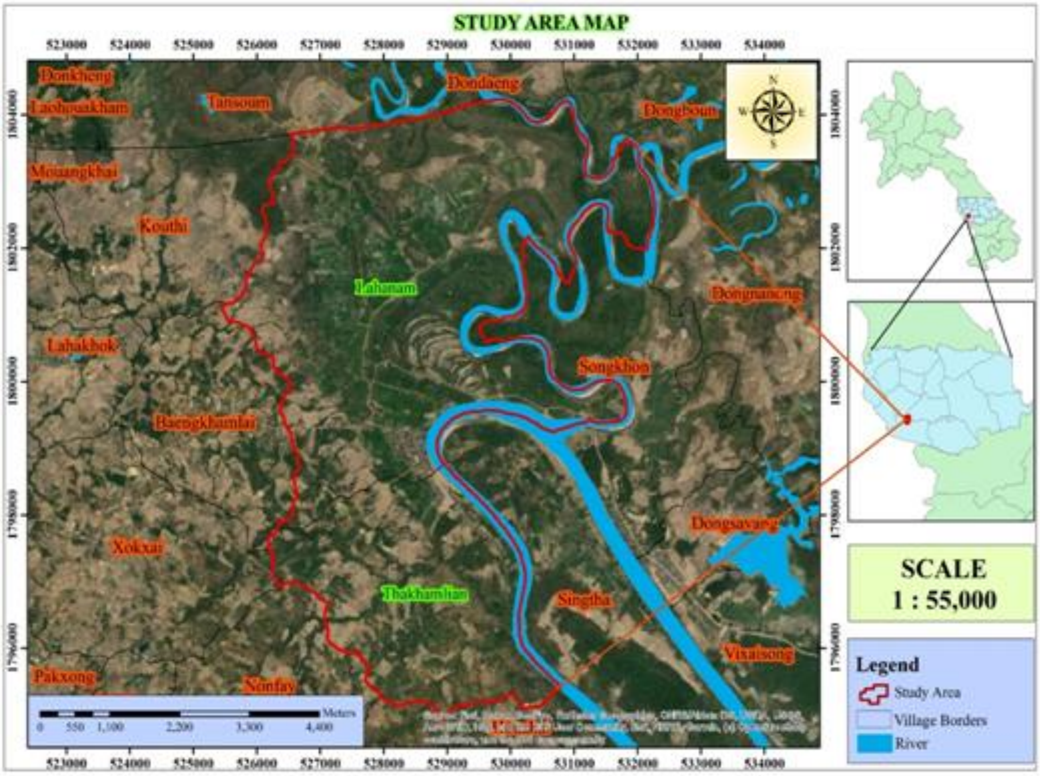

Figure 1: Location of the study area

Figure 2. shows the maximum/minimum air temperature and monthly precipitation recorded from 1999 to 2019 at Kaisone and Songkhone meteorological - hydrological stations which are located nearby Lahanam and Thakhamlien Villages where are the study site of this study particularly the Songkhone meteorological - hydrological station which is only 9 Km far away from the study site. Air temperature peaks in April and is the lowest in January. Precipitation is concentrated in a 5 – month rainy season occurring from May to September. Annual rainfall in the Songkhone, Xeno, and Kengkok Districtsis approximately1, 505 mm, 1, 387mm and 1, 258mm, respectively.57% more than they early average for Songkhone station.

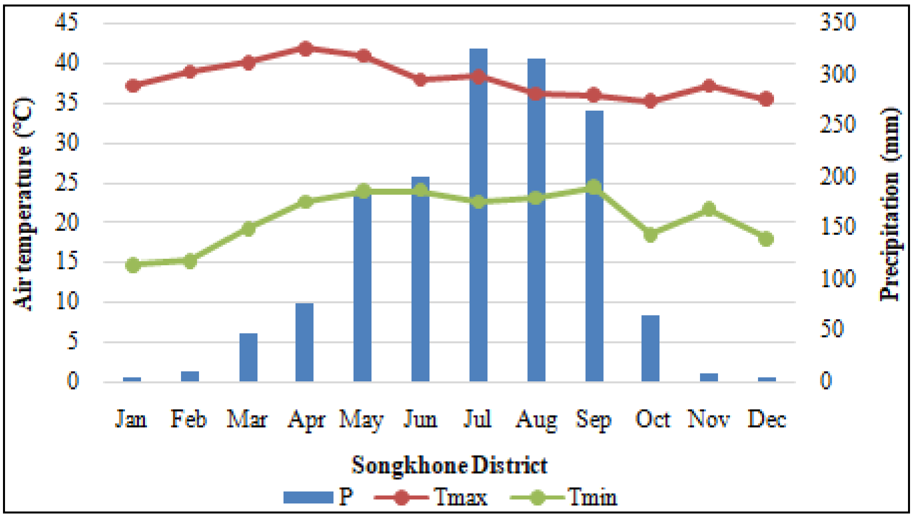

Figure 2: Maximum/minimum air temperature and monthly precipitation from 1999 to 2019 in Kaisone and Songkhone stations. (The figure was drawn based on data provided by the Kaisone and Songkhone District of Agriculture and Forest Office, Svannakhet Province).

Topographic survey of flood area and data collection

This topographic survey of the flood area was carried out in Lahanam and Thakhamlien Villages from 25 November to 9 December 2022. To study the topography of the study area as well as levels of the Xebanghieng River and surrounding rivers, a GIS and ArcGIS program was used.

The main data used in this study consists of map data and geographic data and meteorological–hydrological data. Map and topographic data are the national topography map (1:100.000), detailed DEM 10mx10m from the national geography department, land used maps ratio 1:100.000 of the national geography department 2010, and GIS. While, meteorological– hydrological data are: daily rainfall data of

3 stations that located nearby the study area, which include Xeno rainfall measurement station (Outhoumphone District), Kengkok Station (Champhone District), and Lahanam rainfall measurement station (Songkhone District);Water level data of Lahanam and Sopnam (Xebanghieng) stations and Xechamphone Station as well as data on floods and damages in 2004 – 2018;Flood impact report of the Songkhone District of Natural Resource and Environment, No. 753, dated 5 December 2018. For the maximum rainfall analysis, the maximum daily rainfall data of21 years (1999-2019)was used by applying the method of Log-Pearson Type III based on the return period of2, 5, 10, 25, 50, 100 ,and 200 years as shown in formula(1): $Logx = Log\bar{x} + (Krt \times S_{logx})$….(1) where x is maximum daily rainfall value of some specified probability, $Log\bar{x}$is the average of the Logx rainfall values K is frequency factor and S is the standard deviation of the $logx$ Values. While calculating the maximum of water discharge, the Rational method is used as shown in the equation (2): Q = CIA…(2), where Q- Peak rate of runoff (m^3/s); C - Runoff coefficient, an empirical coefficient representing a relationship between rainfall and runoff; I - Rainfall intensity(mm/h), A - The watershed area (m^2).

3. Results and Discussions

Maximum rainfall analysis

The analysis of maximum rainfall is using the maximum daily rainfall data of21years (1999 - 2019) from 3 rainfall measurement stations (Lahanam, Kengkok, and Xeno stations) by applying the method of Log - Pearson Type III with probability of return periods of 2, 5, 10, 25, 50, 100 and 200 years. The results of the analysis found that the maximum value of daily rainfall that may occur in the return periods of 2 to 200 years at the Xeno Station (Outhoumphone District) is from 79.42mm/day with a return period of 2 years to 159.33 mm/day ina return period of 200 years, the maximum daily rainfall value at the Lahanam Station (Songkhone District) is from 104.65 mm/day with a return period of 2 years to 204 mm/day in a return period of 200 years, and at the Kengkok Station (Champhone District) maximum daily rainfall is from 105.75 mm/day with a return period of 2 years to 330.76 mm/day in a return period of 200 years, as shown in Table 1 and Figure 3.

Table 1: Summary of maximum rainfall calculation for each return period

Return period (Year)	Maximum rainfall (mm/day)		
	Xeno Station	Lahanam Station	Kengkok Station
2	79.42	104.65	105.75
5	103.67	129.44	146.26
10	117.33	144.97	176.48
25	132.36	163.84	218.68
50	142.25	177.46	253.21
100	151.19	190.81	290.45
200	159.33	204.00	330.76

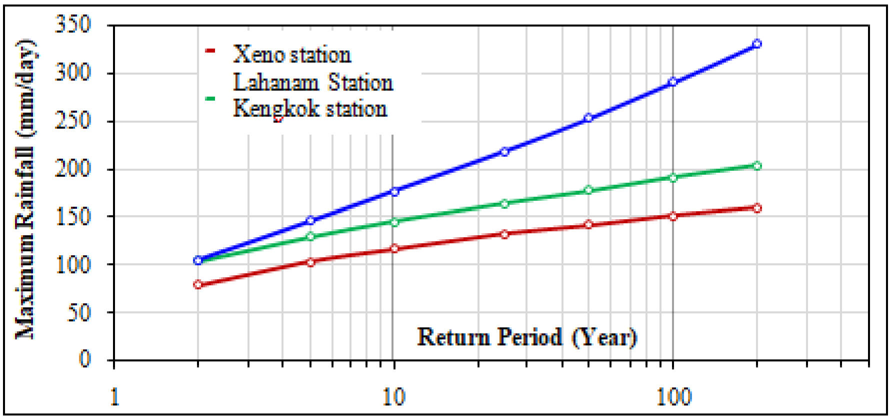

Figure 3: Relationship between rainfalls and each return period at three stations

Calculation of maximum surface runoff

The calculation of maximum surface runoff for each return period in this study was applied to the Rational method. The geography data of the study site is analyzed by the ArcGIS as shown in Table 2 and the runoff coefficient of each return period can be found in the table developed by Chow and team (1988) by using types of land use in the study site as shown in table 3.

Table 2: Geographical characteristics of the study site

No.	Geographical characteristics of the study site	Value	Unit
1	Watershed area	1, 450.8	km
2	Length of watershed edge	3.54	km
3	Highest elevation of study site	160	m
4	Lowest elevation of study area	124	m
5	Average slope of study site	1.02	%
6	Time of concentration (Tc)	61.57	minute

Table 3: Surface runoff coefficient of each return period

Type of land use	Area size (km^2)	(Runoff coefficient, C)					
		2 years	5 years	10 years	20 years	50 years	100 years
Forests	17.12	0.22	0.25	0.28	0.31	0.35	0.39
Agriculture	8.56	0.31	0.34	0.36	0.4	0.43	0.47
Residential areas	2.86	0.73	0.770	0.81	0.86	0.90	0.95
Net surface runoff coefficient		0.298	0.329	0.357	0.392	0.429	0.470

The rainfall intensity of each return period at each station (Lahanam, Xeno, Kengkok stations) is built from data of maximum daily rainfall in the 21 - year period (1999 - 2019) as shown in Figure 4 to Figure 6.

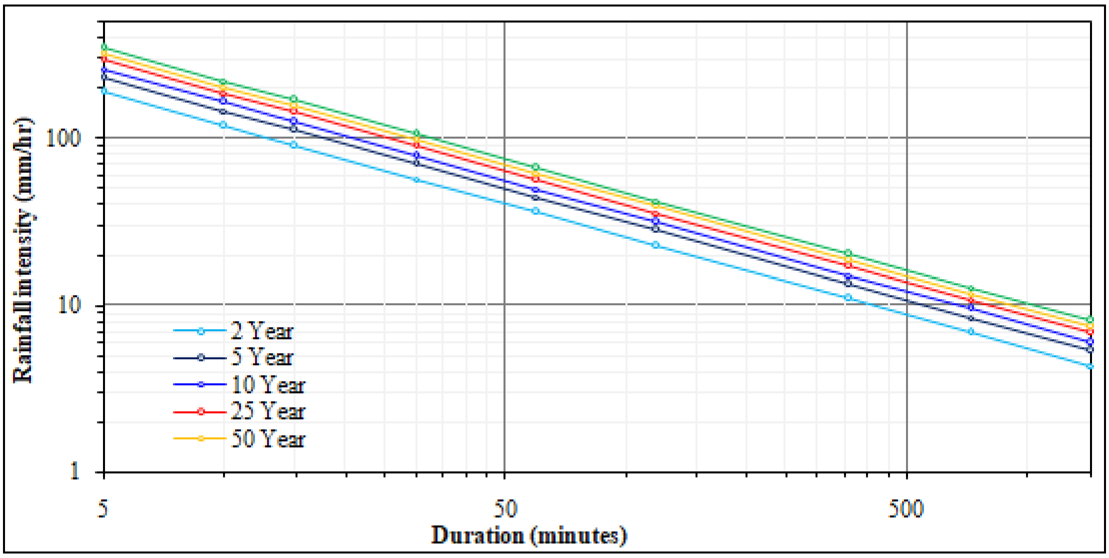

Figure 4: Graph of rainfall intensity and return period at Lahanam Station

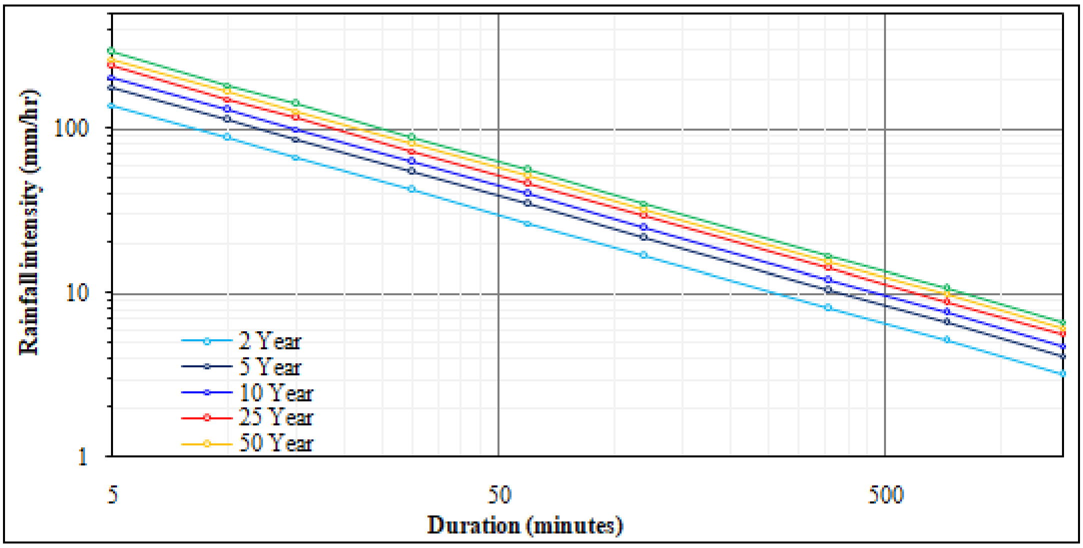

Figure 5: Graph of rainfall intensity and return period at Xeno Station

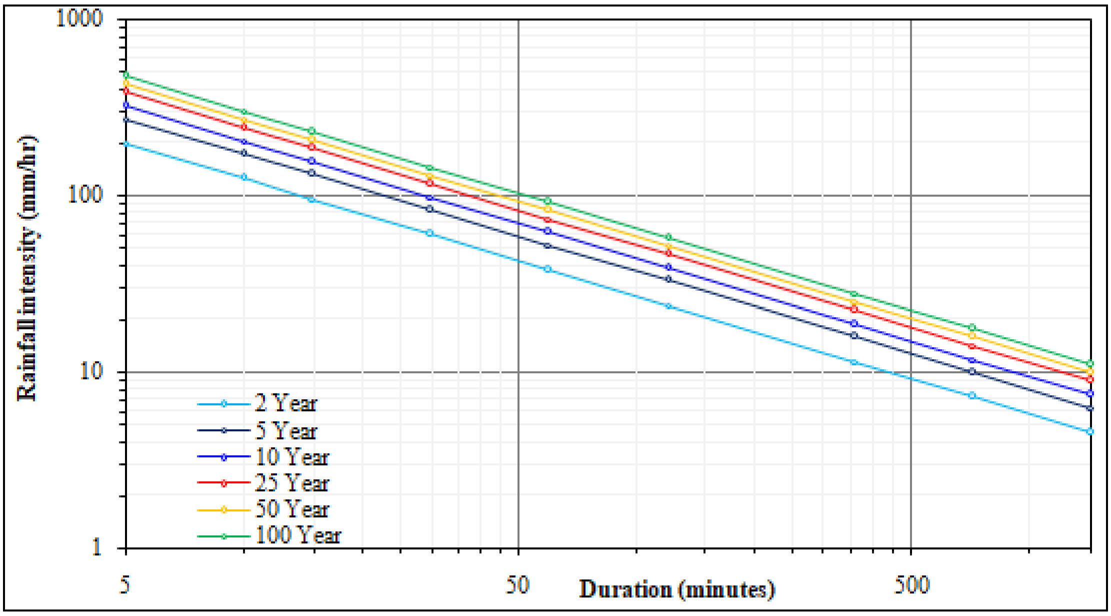

Figure 6: Graph of rainfall intensity and return period at Kengkok Station

The results of peak flood calculation based on a rational method found that the maximum of water discharge tends to increase which is consistent with the maximum rainfall analysis. Table 4and Figure 7 show thepeak flood values of return periods from 2 years to 200 years at Xeno Station is 223.3m^3/s to 737.9 m^3/s, respectively; peak flood values of Lahanam Station are300.3 m^3/s for return periods of 2 years and 879.5 m^3/s for return periods of 200 years; and peak flood values at Kengkok Station is315.0 m^3/s for return periods of 2 years and 1, 204.2m^3/s for return periods of 200 years.

Table 4: Result of maximum waterlogging calculation applied the rational method

Return Period (Year)	Surface runoff coefficient	Peak Flood (m^3/s)		
		Xeno Station	Lahanam Station	Kengkok Station
2	0.298	223.3	300.3	315.0
5	0.329	318.8	407.6	480.3
10	0.357	397.9	496.9	616.4
25	0.392	508.9	621.5	809.0
50	0.429	615.5	741.7	992.7
100	0.470	737.9	879.5	1204.2

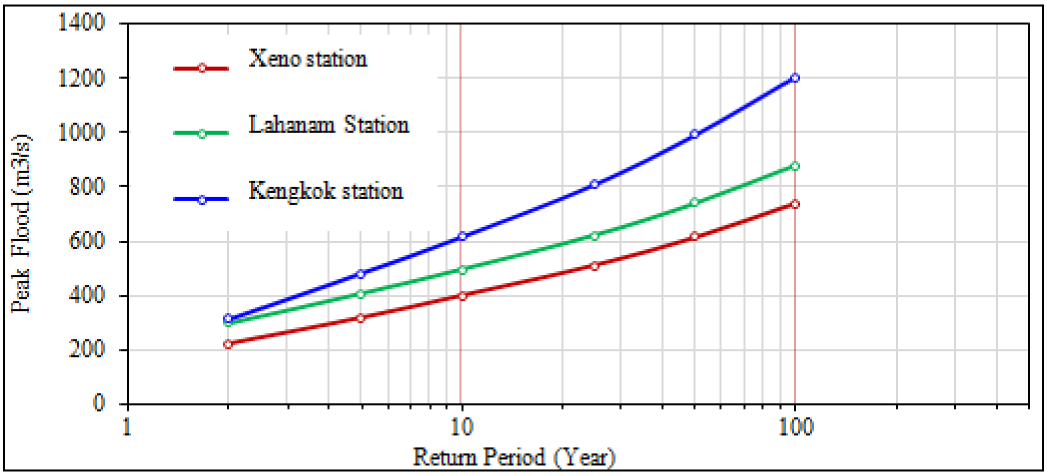

Figure 7: Graph of peak flood applied the rational method for each return period

The air temperature in the 21 - year period (1999 – 2019) of Kaysone Phomvihan District which is 35 Km far from the study site, shows the highest value at 42 ^{0}C in April and the lowest value at14^0 C in January. The topographic study covers seven villages namely Lahanam and Thakhamlien villages (study villages), Bengkhamlai, Nonfay, Xokxay, Singtha, and Houahat (nearby villages) in Songkhone District, Savannakhet Province. Based on the Digital Elevation Model (DEM) and data collected from the site survey, it found that Lahanam and Thakhamlien villages have similar topography with elevations from101 to 138 m compared to the sea level, residential area's elevation is between 121 to 130 m, the elevation of Xebanghieng river bank is between 119 to 126 m. However, most areas of these two villages have elevations of 113 to 119 m and 115 to 126 m for Lahanam Village and Thakhamlien Village, respectively. While the topography elevations of nearby villages have similar and different levels as shown in Table 5.

Table 5: Topography elevations of study site and nearby villages

Location	Overall area elevation * (m)	Most of the area elevation * (m)	Elevation of residential area* (m)	River bank elevation* (m)
Lahanam Village	101 - 138	113 - 119	121 - 130	119 - 126
Thakhamlien Village	101 - 138	115 - 126	121 - 130	119 - 126
Singha Village	106 - 167	120 - 132	118 - 124	114 - 128
Houahat Village	115 - 167	127 - 144	152 - 167	121 - 130
Bengkhamlai Village Xokxay Village Nonfay Village	118 - 167	139 - 152	134 - 167	No river borders

* Medium elevation compared to sea level

Figure 8 shows the Village boundary lines of the study area and nearby villages, elevations of areas, and water sources. As shown in the Figure, the village located nearest to the river is Lahanam Village, which is bordered by Xebanghieng, Xesamsoy, and Xechamphone rivers, and it is a village with a relatively flat landscape; The Thakhamlien village is bordered with Xebanghieng River and is a village with the relatively flat landscape as the same as a Lahanam village case; Houahat and Singtha villages is bordered with Xebanghieng River, both villages have a flat landscape and some hilly areas. While, Bengkhamlai, Xokxai. and Nonfay villages do not have any borders with rivers and most of the area is in the highlands.

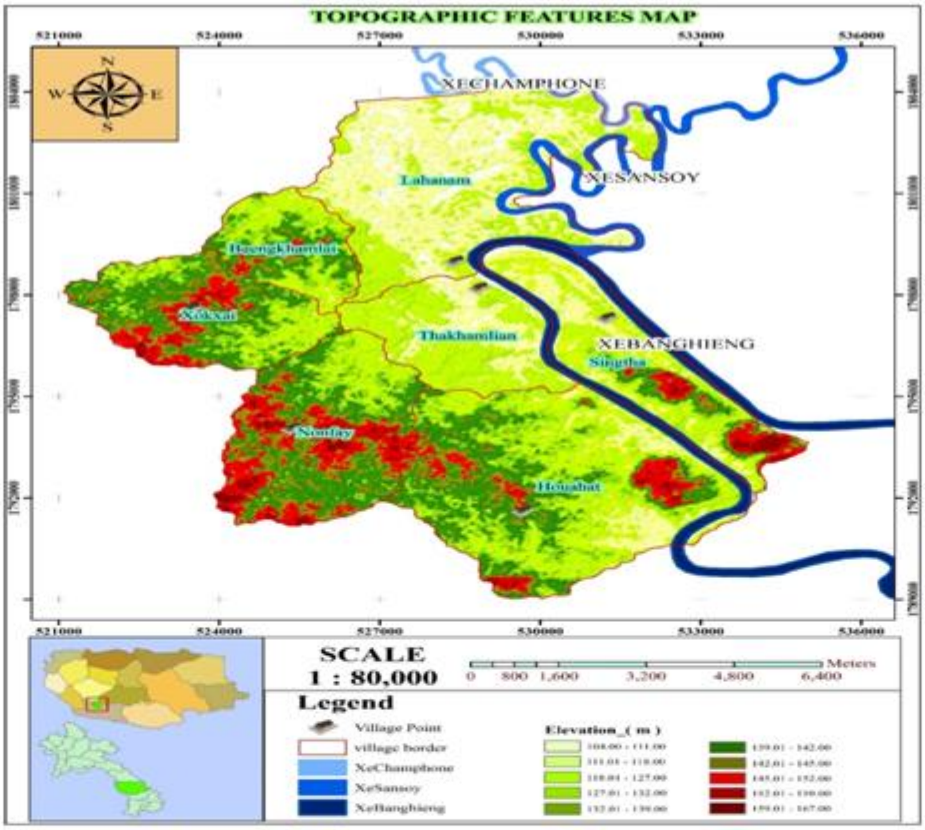

Figure 8: Borders and topographic elevation of study site villages and nearby villages

4. Discussions

In this study, there are many factors have been studied but the rainfall factor is the main factor after studied of 3 rainfall stations (Xeno, Lahanam, and Kengkok) located nearby the study site, it was found that the maximum daily rainfall for the return period of 2 to 200 years of Kengkok Station that located in Champhone District is higher than the other stations. However, when considering the annual rainfall in the21 - year period (1999 - 2019) it was found that Kengkok Station has an average rainfall of approximately 1, 258 mm and 52% is higher than the average annual rainfall. While, Lahanam Station located in Songkhone District which is the closest station to flooded areas, has the maximum daily rainfall for the return period lower than Kengkok Station but the average annual rainfall is around 1, 505 mm and 57%is higher than the average annual rainfall. From these results, it is not clear, and maybe because the value of the maximum daily rainfall at Lahanam Station is higher than the value of the maximum daily rainfall at Kengkok Station.

The results of peak flood calculation according to the return period found that there is a similar value as the analysis of the maximum daily rainfall, peak flood of the Kengkok Station is higher than the other stations, it is suggested that there are many factors used for this calculation such as surface runoff coefficient (C) which is considering to land used types and land used sizes and topographic features of the study site including the size of the basin, length of basin edge, elevation, the slope of the site, and time of concentration (Tc). Furthermore, the intensity of rainfall at each period of time, which is based on the maximum daily rainfall data, may also contribute to Kengkok Station having a higher or peak flood value than other stations.

On the other factor, Lahanam and Thakhamlien villages are villages with relatively flatland the area and there are residential buildings built near the rivers, particularly Lahanam Village which has an area close to three rivers (Xebanghieng, Xesamsoy, and Xechamphone rivers) which is the cause of more frequent floods than other villages as shown in Figure 9.

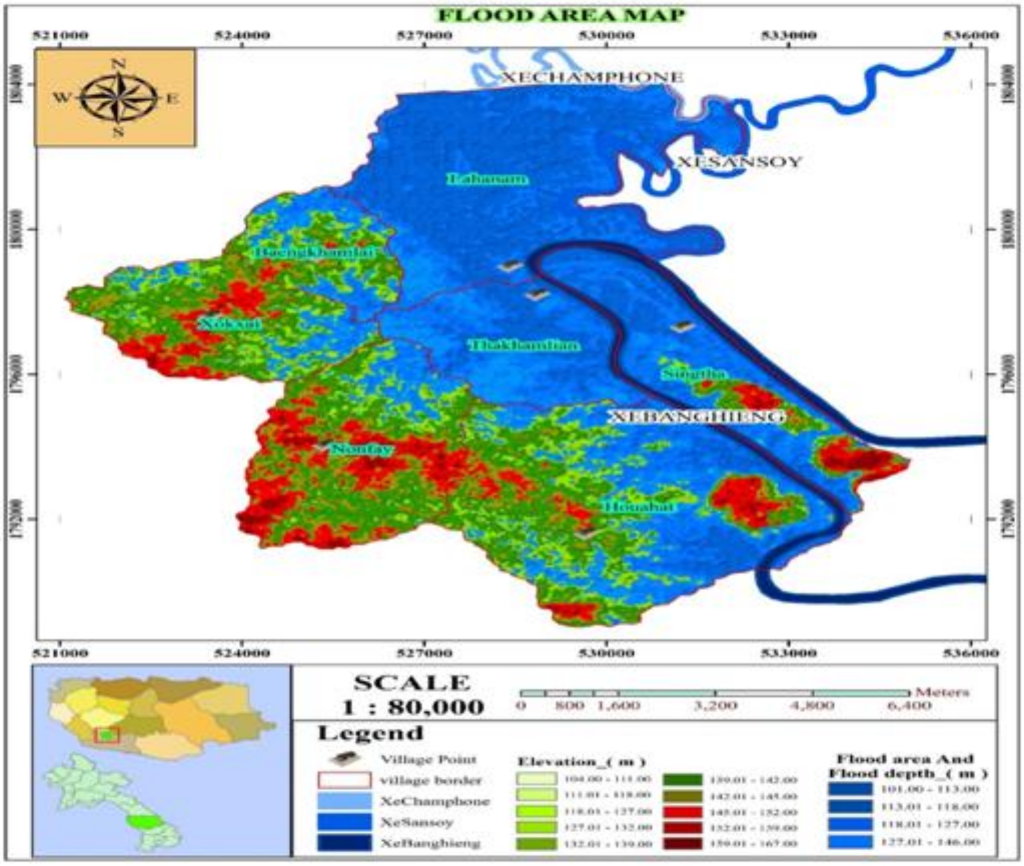

Figure 9: Flood areas in the study villages and nearby villages

5. Conclusion

To understand the factors that cause flooding in Lahanam and Thakhamlien villages, Songkhone District, Savannakhet Province, the amount of maximum daily rainfall, flood peak, temperature, and topography elevation of the study site and nearby villages are examined. The results of this study are as follows:

1) Maximum daily rainfall at Lahanam Village Station, Songkhone District (study site) for return periods of 2 years to 200 years is 104.65 to 204.00 mm/day, respectively.
2) Flood peak at Lahanam Village Station, Songkhone District (study site) for return periods of 2 years to 200 years is 300.3 to 879.5 mm/day, respectively.
3) Maximum air temperature of the 21 - year period (1999 - 2019) is at 42 ^{0}C in April and the lowest is at14.7^{0}Cin January.
4) The topography of the study site (Lahanam and Thakhamlien Villages) compared to the mean sea level is at101 to 138 m, most areas of villages are at the elevation of 113 to 126 m, the elevation of the residential area is at121 to 130 m, the elevation of the river bank is at119 to 126 m.

Statistics from the Department of Water Resources, Ministry of Natural Resource and Environment in 2014 and the flood impact report of the Songkhone District of Natural Resources and Environment in 2018 stated that serious floods in Savannakhet Province occurred in 2004, 2005, 2011, 2014, which these periods the maximum daily rainfall were between 83.4 and174.6 mm/day. Based on the maximum daily rainfalls analysis, Lahanam and Thakhamlien village areas might have flooded in the return period of 2, 5, 10, 25, 50, and 100 years with the maximum daily rainfall of 104, 129, 145, 164, 177, and 191 mm/day, respectively. In addition, due to the settlement along the river banks and some elevation of the residential area of two villages is lower than the elevation of river banks and when there are storms, heavy rain, and the amount of water overflowing the bank, then floods occur in some areas of two villages.

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